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Species-Site Interactions in a Managed
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Mark A. Hare

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SPECIES-SITE INTERACTIONS IN A MANAGED SUBTROPICAL DRY FOREST OF THE DOMINICAN REPUBLIC

By

Mark A. Hare

A THESIS

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ABSTRACT

SPECIES-SITE INTERACTIONS IN A MANAGED SUBTROPICAL DRY FOREST OF THE DOMINICAN REPUBLIC

By

Mark A. Hare

In 1986, a thinning study was initiated in a subtropical dry forest of the Dominican Republic. After six years of inventories, no effects attributable to thinning were observed. Classification and ordination techniques were subsequently applied to the inventory data collected prior to thinning. Data consisted of basal area contributions of sixteen dry forest species on 120 100 m^2 sites. Using clustering techniques, the sites were partitioned into six groups, each representing a characteristic species composition. Group One was dominated by *Bursera simaruba*, Group Three by *Acacia scleroxyla*, Group Four by *Phyllostylon brasiliensis*, Group Five by *Caesalpinia coriaria*, Group Six by *A. farnesiana* and Group Seven by *P. brasiliensis* and *Pithecellobium circinale*. The relative positions of the groups in correspondence analyses and canonical discriminant analyses suggested a gradient moving from Group Three to Group Four. Additional analyses using overstory structures and growth and mortality parameters indicated this apparent gradient was related to relative productivity.

This study is dedicated to Humberto Checo and to the other individuals past and present who have given their time and sweat in the work of the ISA-Mao Forestry Experimental Station. May their work bring sense to the chaos, and better lives to the communities everywhere entwined in a life or death dance with dry forests.

ACKNOWLEDGEMENTS

I have waited a very long time to write this section. Sometimes, when the end of this journey was lost in the mists of the farthest horizon, I would imagine what I would say here. It helped a little.

The first people I want to acknowledge are my parents, and not just because I know I should. My parents are incredible people. After some thirty-two years of wanderings, I have met only a handful of individuals whose level of integrity, compassion and dedication can match theirs. They have shown me again and again the literal significance of Christ's command to serve. I depend on their presence and support, and on their witness for how life is to be lived.

Next, I need to recognize my brothers and sisters and their respective families. Their love has been indispensable. It is beyond counting the number of times I have ended up on one of their doorsteps with little or no warning. Crazy as larks all of them, but somehow they manage to make it day by day in the "normal" workaday world, and still keep their senses of humor. I depend on their support, which they freely give.

I also want to acknowledge Dr. Douglas Lantagne. This study and my degree would not have happened without him. Doug has always been willing to share his professional silvicultural experiences and our conversations have been invaluable in my personal education. Pieces of those conversations are interwoven throughout this study. Doug has also shown incredible patience with my internal time table, and he succeeded again and again in finding financial support when I most needed it. I could not have found a better advisor and friend. I owe him a great deal. In all likelihood, he will remind me of that.

I also need to express my appreciation to my other committee members, Dr. Peter Murphy and Dr. Carl Ramm. Dr. Murphy was extremely helpful in directing my literature search, as well as in bouncing ideas around when I was still unsure of the direction for my research. Dr. Ramm is almost entirely responsible for my interest in multivariate methods. His MVA class was well-organized and very effective in providing a hands on approach to using the statistical procedures. Dr. Ramm also did an incredibly thorough editing job on my thesis. I don't know whether or not to thank him for that, but the final product is better for his work.

I was exceptionally lucky to have Humberto Checo at my disposal for a year and a half. Checo has an intuitive understanding of the dynamics of the dry forest in general, and the ISA-Mao silvicultural thinning study in particular. Checo is the person who will ultimately determine if any of my observations are valid and/or useful for developing long term sustainable management practices of subtropical dry forest.

The graduate students in the Department of Forestry are an incredible support group. I cannot count the times I have left the lunch room laughing. In particular, I would like to thank Michael Powers, Jill Fisher, Peg Payne and Andy David for giving me rides, making me laugh and just generally for being "bitchin' dudes".

I owe a lot to any number of other people. Friends who have helped me out, or bought me a beer, or just told me something good about life- these are the things which have made life worthwhile these last four years. I especially want to recognize my current roommate, Chekole Kassa and his "brothers", Yonas, Nathnael and Berhan. In the last two years, I have frequently depended on them to keep me sane. Again and again, with beer, music and Ethiopian food they have set me back on the path and kept me going.

I also want to acknowledge the professors and fellow students from my undergraduate work at Warren Wilson College in Swannanoa, North Carolina. After four years in a Big Ten institution, I am keenly aware of both the strengths and weaknesses of a small liberal arts institution such as WWC and I find that the strengths far outweigh the limitations. The institutional opportunities available at a large university are no match for the intellectual, moral and spiritual resources

available at WWC. Warren Wilson is blessed by a faculty and staff which are dedicated both to the students and to the college community as a whole. My experience there was invaluable to my development as a wholly educated person.

Finally, I want to acknowledge friends met and made in the Dominican Republic. The human and cultural resources available on Hispaniola are truly awesome and I have had enormous fun in all my visits there. Without hesitation, I commit my time and strength to the future of that island.

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Introduction

Deforestation is recognized as one of the most serious environmental and economic problems for many countries in the tropical and subtropical regions of the world. In many of these countries, dry forests are the areas most heavily impacted. Often large portions of the population depend on them for fuel, lumber, animal forage, food and medicine (Fries 1992, García and Alba 1989, Cuevas and Hernandez 1987, Murphy and Lugo 1986a). Where communities depend on the dry forest for their daily existence, the quality of life degrades as the quality of the forests erodes due to inefficient and excessive exploitation (Fries 1992, García and Alba 1989, Cuevas and Hernandez 1987).

In the Dominican Republic, the dry forest life zone occupies around 21 percent of the country and accounts for about 29 percent of the total estimated forest cover (Knudson et al. 1988, Laureano 1991). Fifty percent or more of the fuelwood harvested each year comes from the dry forest and nearly two-thirds of the population still depends on firewood and/or charcoal for cooking and heating (Laureano 1991). Many communities are established within or adjacent to the forest, depending on its resources for building materials, animal forage, honey production and medicines (Cuevas and Hernandez 1987). Based on current rates of exploitation, mature dry forest timber is expected to be exhausted by the year 2002 (Laureano 1991).

One goal of forest management is to increase forest productivity while assuring maximum efficiency in the use of the forest. In temperate forests, management practices include biological and ecological interactions in establishing effective silvicultural practices (Coile 1952, Ralston 1964, Carmean 1975, Barnes 1984). Silvicultural treatments are based on species composition and the specific environmental characteristics of a given site, to assure the maximum sustainable yield of the desired products (Cajander 1926, Barnes 1984). Scientific forest management has a much more limited history in the tropics and subtropics (Fries 1992, Lamprecht 1989), although plantation forestry has received a great deal of attention in recent years. In the semiarid regions, there is evidence that the productivity of non-degraded native forests are as high as plantations of introduced species (Hardcastle 1992, von Maydell 1992, Montero et al. 1984). More over, native forests preserve the diversity of species essential to providing the variety of products upon which rural populations depend (Hardcastle 1992, von Maydell 1992). Proper management of tropical dry forests has the potential - as in the temperate zone forests- to increase productivity and assure better efficiencies and sustainable yields of desired products. Understanding the ecological relationships in these forests is essential to developing appropriate management techniques (Fries 1992).

While limited in extent, there are projects in semiarid Africa that are successfully integrating improved management techniques into the structure of daily life in rural communities (Heermans 1992, Christensen 1992, Lungren 1992). Literature relating to the management of native dry forest in South America, including the Caribbean, is difficult to find. One exception is in the Dominican Republic where the Instituto Superior de Agricultura (ISA) established the ISA-Mao Experimental Forestry Station (EEF ISA-Mao) in a subtropical dry forest located near the city of Mao. The station's goal is to integrate ecological, silvicultural and economic information to develop management models for the enhancement of growth and yield of fuelwood and charcoal from the native dry forest (Knudson et al. 1988). Since its initial inception, the station's work has broadened to include research on the use of the forest for forage and honey production (Checo, personal communication).

After initial studies examining variations in species composition and structure across the landscape (Powell and Mercedes 1986), a silvicultural study was established in 1986 to determine the effects of thinning in a forest where fifty percent of the stems were less than five cm diameter at breast height (DBH). Treatments were initiated in 100 m^2 plots at one of five target levels of thinning, including undisturbed control plots. The initial experimental design assumed variations in species composition and site conditions would be controlled using a randomized complete block layout with subsampling. In 1988, analyses of diameter and height growth suggested that a positive response was occurring at the highest level of thinning (Knudson et al. 1988). In 1992, however, analyses revealed high rates of mortality and inconsistent growth results within treatments. Standard univariate statistical analyses were not able to account for the variation in growth and mortality (Checo, personal communication). Therefore, multivariate analyses were initiated to examine the relationships of species composition to site productivity. Multivariate statistical analyses (MVA) can jointly examine many interrelated variables. Using MVA techniques of classification and ordination, species distributions before thinning were examined in relationship to site quality and disturbance history. This approach was expected to provide insight into the dynamics of the dry forest ecosystem and explain some of the effects of controlled thinning.

The goals of this study are to (1) determine whether patterns of species composition existed among the sampled sites in the unthinned forest, (2) examine the implications of species distribution with respect to disturbance history and underlying environmental gradients, and (3) explore the relationship of growth and mortality with respect to species composition.

The objectives are:

1) Examine a subset of sites for natural groupings of sites with similar species compositions.
2) Inspect the entire data set to determine if similar groupings can be detected.
3) Using data ordinations, examine site groupings for implications in terms of underlying environmental gradients.

4) Based on the results of these pattern analyses, use information about dominant species, site conditions and overstory structure to assess implications with respect to disturbance histories and underlying environmental gradients.

5) Based on the results of the pattern analyses, examine groupings of sites for differences in growth and mortality.

Literature Review

Site Classification

Determining the potential productivity of a forest is essential for applying the appropriate treatment and managing for the optimum species. In his publication, *The Theory of Forest Types*, Cajander (1926) proposed a series of quality classes that identified forest units with similar growth potential based on characteristic understory species associations. Arranging units in the several quality classes from most to least productive, Cajander (1926) found that variations in growth, dominant tree height, structural characteristics, and soil conditions all followed recognizable patterns.

In the ensuing years, many other systems of site classification have been developed, each with its own emphasis and vocabulary (Rowe 1984). Holdridge (1967) developed a classification system to explain global variations of vegetation and productivity. Using average annual temperature, precipitation, and potential evapotranspiration (PET), Holdridge divided the globe into a series of Life Zones, each with characteristic climatic conditions, and consequently, characteristic vegetation. Holdridge found that, while species varied within a Life Zone from region to region, the form and structure of the climax vegetation were remarkably similar even among sites from different continents. Walter (1985) also emphasizes moisture and temperature relationships in his Climatic Diagrams. Unlike Holdridge, however, Walter's system illustrates seasonal variations, rather than annual means. Sites with similar seasonal patterns of rainfall and temperature would be more alike in their vegetation and potential productivity than all the sites with the same average annual climatic conditions (Walter 1985).

Macroclimatic conditions set the absolute limits on vegetative development (Holdridge 1967), but the direct effects of temperature and moisture conditions on vegetation are modified by topography, soils, and the vegetation itself (Walter 1985, Thomas and Squires 1991). Within a region of similar climatic conditions, there are variations in the landscape which must be understood to apply effective resource management techniques. In Germany, a comprehensive, integrated approach has been developed called ecosystem classification. In this system, classification begins by defining relatively homogeneous units based on macroclimatic conditions. Within these units, forestland is further divided by simultaneously using vegetation, soils and topography. Initially, each of these attributes was studied individually. Then, using interdisciplinary teams of specialists, the interrelationships between the factors were examined and criteria developed for determining site classes with homogeneous conditions for growth (Barnes 1984). A similar system has been developed and tested in Michigan. The key to this system is understanding the relationships between: (1) vegetation (overstory, understory, groundcover) and topography, (2) between vegetation and soils, and (3) between topography and soils (Barnes, et al. 1982).

In tropical America, Beard (1944) developed a classification of climax vegetation based on physiognomic characteristics. Just as Holdridge (1967) observed that under similar climatic conditions, forests will assume a similar structure regardless of species composition, Beard found that forests with different species components but with characteristic physiognomy are found repeated throughout tropical America. Beard suggested that these physiognomic groups can be organized along gradients, corresponding to decreasing availability of moisture. Beard (1944, 1953) observed that, while moisture is the primary factor affecting the vegetation, available moisture is determined by the mutual interactions of climate, topography and soils. Beard's system is primarily descriptive and was not developed for use as a management tool. More over, the system is based on undisturbed vegetation and is therefore not easily applied to the vast areas of forest affected by human intervention (Beard 1944, Holdridge 1967). Nevertheless, Beard's system does classify forest sites along gradients which can be interpreted in terms of productivity. The relationships he describes between separate physiognomic groups may have implications in understanding successional processes (Beard 1944).

To determine the production potential of a forest in the semiarid tropics, both Holdridge and Walter's systems are helpful in establishing limits of productivity within a relatively broad geographic region. Beard's classification system offers insights into patterns of forest structure and composition across a landscape, and suggests implications with respect to moisture availability and disturbance history.

Finally, however, within the context of site potential, the total complement of vegetation-soil-topographic interactions must be described and understood if an optimum management program is to be developed.

Site Factors

Many studies have examined the interrelationships between species distributions, site productivity, climate, topography and soil in temperate America (Coile 1952, Ralston 1964, Carmean 1965, 1975, Kercher and Goldstein 1977, Pregitzer, et al. 1983, Padley 1989, Fisher 1994). While their relative importance differs from site to site, the total complement of factors found to be important remain constant among most of the studies. Climate determines the total moisture available. Aspect, slope length, slope steepness and slope position affect soil development and soil moisture relationships. They also control angle of light entry and total irradiation. Soil texture, depth and rockiness are influenced by topography and in turn affect the development of vegetation. Plants are ultimately indispensable for soil accumulation, keeping fine particles in place against the force of gravity, adding organic matter and cycling nutrients up from the subsurface horizons. Disturbance, particularly human intervention, may affect species distributions in random ways (Barnes et al. 1982) and change potential site productivity through erosion and soil compaction. In the tropics and subtropics, excessive exploitation of dry forest trees usually leads to a reduction in species diversity and increasing dominance by more xerophytic species such as cacti and thorny legumes (Holdridge 1945, 1967, Tamayo 1963, Powell and Mercedes 1986). Nevertheless, post disturbance vegetation often shows characteristic patterns which can be related to underlying physical conditions (Cajander 1926, Grigal and Goldstein 1971, Kercher and Goldstein 1977, Whitney 1991).

Many factors which influence soil development, species distributions and site productivity in the temperate zone appear to be of equal importance in the tropics (Beard 1944, 1953, Asprey and Robbins 1953, Loveless and Asprey 1956, Markham and Babbedge 1979, Furley and Newey 1979, Powell and Mercedes 1986, Yair and Shachak 1987, Thomas and Squires 1991). However, the relative intensities of each factor and the interactions between factors differ in the semiarid areas (Arnon 1992). Parent material is usually more important in determining soil characteristics due to less leaching (Arnon 1992), although run-off from slopes may greatly increase productivity and soil development at the slope's base (Walter 1985, Yair and Shachak 1987, Arnon 1992). Also, near the equator, east and west slopes are the driest, versus the south and southwestern slopes in the temperate zone. In the arid zones, on flat ground, water will sink to greater depths on sandy soils than on clay soils, and therefore remain available for plant growth for a longer period after a single rain event. Rocky soils may permit even deeper saturation and may therefore present the least drought like conditions in some situations (Walter 1985, Lamprecht 1989).

Although site factor studies in the tropics which describe changes in species composition in relation to soil conditions and topographic position tend to be more descriptive than quantitative, they illustrate general trends. In applying Beard's system to the vegetation of Jamaica, Loveless and Asprey (1956) noted that two related formations found on limestone derived soils were associated with different degrees of slope steepness and soil depth. A third, more complex formation occurred on the adjacent lowlands where alluvium material overlies marine clays. In Ghana, Markham and Babbedge (1979) studied the transitions between forest and savanna along transects laid across slopes representing nine meters change in elevation. They found that the changes in vegetation were associated with slope position, soil depth, nutrient status and moisture availability. In Belize, Furley and Newey (1979) also found distinct species associations corresponding to slope position. They found soils to be deepest and biomass greatest on foot slopes. Mid-slope sites had more shallow soils and the vegetation was shorter and forest structure less complex. Summit forest sites had species described as typical of more mature forest, although the vegetation was generally more open and included cactus species. Overall, they found that soil depth and moisture content tended to decrease from foot slope to summit, while pH, exchangeable Ca and the percent sand fraction tended to decrease from summit to foot slope. At the ISA-Mao station in the Dominican Republic, Powell and Mercedes (1986) found that species and structure changed rapidly when the topography became more rolling. Ridges were noted to have structure and complexity similar to highly disturbed areas in more level terrain.

Detailed models of ecosystem interactions for semiarid tropical forests are not available in the literature. However, the studies available show that vegetation, topography and soil relationships found to be important in the temperate zone are also important in the tropics, perhaps even more so in the dry regions. Topography affects soil development, moisture relationships, and total irradiation which in turn affect the species distributions and the potential productivity of a given site.

Site Disturbance

The effects of cutting on species distributions in the subtropical dry forest has not been studied extensively. In their study of forest formations in Jamaica, Loveless and Asprey (1956) noted that an area representing evergreen bushland (Beard 1944) had been affected by extraction of firewood and fence posts. The authors suggested that composition of the forest was essentially unchanged from a climax formation because harvested trees coppice extensively and can therefore reform the original canopy rapidly. In Venezuela, Tamayo (1963) noted that the most heavily disturbed areas of dry forest were nearest to population centers. These forests consisted of small shrubby legumes such as *Prosopis juliflora* and columnar cacti, with scattered clumps of ground cacti in the *Opuntia* genus the only remaining ground vegetation. In a general review of the dry forests of the Dominican Republic, Holdridge (1945) noted that local dominance of the subtropical dry forest by *Lemaireocereus hystrix* was probably due to heavy cutting. In their study of species composition and structure in the Mao forest, Powell and

Mercedes (1986) observed that areas along the forest edge and adjacent to major foot paths appeared to be the most highly disturbed. The authors associated the cacti, *Lemaireocereus hystrix* and *Consolea moniliformis* and the trees, *Prosopis juliflora* and *Phyllostylon brasiliensis* with highly intervened areas. Maxwell (1985) includes *Acacia tortuosa* in the list of species dominating disturbed sites. In an area previously cut and cultivated, Powell and Mercedes (1986) found that the species *Exostema caribaeum* dominated the canopy.

Overall disturbance tends to reduce forest diversity, increase the dominance of cacti and thorny legume species and creates a low open structure of small trees (Holdridge 1945, 1967, Tamayo 1963, Powell and Mercedes 1986). However, since cutting for charcoal and construction is selective, large trees in a given area are not by themselves an indication that the site has not been extensively disturbed (Maxwell 1985). On the other hand, an area of forest with large specimens of species known to be favored for charcoal and/or construction would suggest that the area has been relatively free of significant human disturbance (Powell and Mercedes 1986).

Multivariate Analyses

Multivariate methods are statistical techniques used to examine the variance expressed in a data set, particularly the covariance observed among many interrelated variables. Normally, researchers use multivariate analysis (MVA) when they are interested in the patterns expressed in a data set rather than in quantifying a treatment effect. In many ecological studies, unlike most designed experiments, the levels of the pertinent parameters are uncontrolled, their distributions are usually not statistically normal, and the relationships between parameters are often unknown or not well understood. Standard statistical procedures are therefore not appropriate, nor can they elucidate the relationships which are of interest (Digby and Kempton 1987).

Two broad categories of MVA techniques in studies of species distributions are those used for classification and those used for ordination. Classification assumes that sites can be numerically partitioned into discrete units while ordination perceives community variation as continuous along one or more gradients (Pielou 1969, Grigal and Goldstein 1971, Digby and Kempton 1987). Although communities may be continuous rather than discrete, recognizing discrete points along the continuum is still useful for understanding the interactions between species and their environment (Pielou 1969, Grigal and Goldstein 1971, Kercher and Goldstein 1977, Pregitzer and Barnes 1984, Digby and Kempton 1987). Digby and Kempton (1987) recommend classification techniques along with ordinations of the data to examine the relationships between groups.

Pregitzer and Barnes (1984) used a combination of classification and ordination techniques to examine differences in soil and topographic characteristics between site units previously delineated using an Ecological Classification System (ECS). They found that the field based ECS had identified classification units which differed in topographic and soil factors known to strongly influence tree growth (Pregitzer and Barnes 1984). Padley (1989) also found that separate ordinations using environmental and vegetation data sets were highly correlated with each other and with previous ECS designations.

In their study of an oak hickory watershed in the Smoky Mountains of eastern Tennessee, Grigal and Goldstein (1971) used four hierarchical clustering techniques to classify 290 sites. Clustering techniques are numerical analyses designed to separate units into distinct groups based on some type of distance matrix. Many different methods exist for cluster classification, each of which may result in a different grouping of the data. Using several different methods and comparing classifications across methods removes some of the potential for subjective interpretation of the data based on a single, well-chosen procedure that supports the investigator's preconceptions (Pielou 1969, Digby and Kempton 1987, James and McCulloch 1990). Grigal and Goldstein observed that within each of the four cluster techniques, at a level of classification which divided the data into four large distinct groups, each group had a distinctive species composition which appeared to characterize that cluster group. "Characteristic species" were determined by comparing the average relative basal area contribution of each species within cluster groups relative to the average contribution across the entire watershed. Species which on average contributed more basal area to a particular group than to the watershed as a whole were defined as characteristic of that group. Within each cluster technique, the characteristic species composition of a given group corresponded to the characteristic composition of one of the groups in each of the other three techniques.

Grigal and Goldstein also found that in each of the four major groupings, some of the sites remained consistent across all techniques, while other sites changed group membership depending on the technique used. Of the 290 sites, 131 grouped consistently in all four methods. The authors termed these "core" sites and interpreted them as representing discrete points along the species distribution continuum. Sites that were inconsistent in their group membership were noted to have species compositions intermediate between the characteristic compositions of the major groups. It was assumed that these intermediate sites changed membership according to the bias of a particular cluster technique (Grigal and Goldstein 1971, Kercher and Goldstein 1977).

To examine the relationships between clusters, Grigal and Goldstein (1971) used an ordination technique referred to as canonical variate analysis. Based on the values of a particular set of variables, canonical variate analysis (CVA) maximizes the ratio of between group variance to within group variance to give the best separation of the groups (Digby and Kempton 1987). Whereas other ordination techniques such as principal components analysis (PCA) give equal weight to all the variables, CVA develops a function which gives the greatest weight to the variables which are the most consistent within each group (Digby and Kempton 1987). Because of this property, groups formed based on cluster analyses will tend to separate in canonical space bases on the species which are common to sites within a cluster group, but uncommon to sites in other cluster groups. Species which are erratic within a group, or consistently present across all groups, will have less impact on the overall ordination relative to analyses which do not account for any structure within the data set. Grigal and Goldstein (1971) found that the four major groups of sites identified using cluster analyses and CVA in combination could not be identified using principal components analysis.

Plotting clusters from each of the techniques along the first two canonical axes of four respective canonical variate analyses, Grigal and Goldstein (1971) found that the four major groupings clearly separated from each other. Minor groups formed from the results of one classification plotted in close association with one the major groups, suggesting a relationship based on similar species compositions, as indicated by the average composition of sites within the respective groups. Grigal and Goldstein interpreted the clear separation of the groups in canonical space as a strong indication that the cluster techniques had recovered natural groupings within the data set.

As in most ordination methods, CVA includes a centering of the data, such that the origin or centroid, represents the grand mean of the data set, across all variables. The position of a site or a cluster with respect to the centroid therefore represents the site's degree of variation from the overall mean. Generally, both distance and direction are significant (Digby and Kempton 1987, Greenacre 1993).

In the CVA's applied to the results of each of four cluster techniques, Grigal and Goldstein (1971) found that the major groups had the same relative positions in two dimensions for each CVA procedure. More over, when CVA was applied to the subset of sties which clustered consistently across all techniques, Grigal and Goldstein found that each of the four main clusters plotted in one of the four quadrants formed by the juxtaposition of the first two canonical axes. The position of each group with respect to the centroid was in a different direction from the rest, suggesting that the groups represented different extremes of one or more underlying environmental gradients.

Using the vegetation groups defined by Grigal and Goldstein (1971), Kercher and Goldstein (1977) supplemented the data with measurements of environmental parameters at each site, including slope position, insolation, slope angle and age. Following a series of procedures developed from their previous use of CVA, the authors found a high association with the groups as described by the site factors and those described by the vegetation. In the process, Kercher and Goldstein (1977) determined that age and slope position were the two variables most significant in the separation of the four groups. They extrapolated this to suggest that, given the time since disturbance and the position in the watershed landscape, they could predict the vegetation most likely to dominate a given site.

Fisher (1994) used another ordination method, referred to as correspondence analysis, to study the species composition of pre-settlement forests in northern lower Michigan. Correspondence analysis (CA) is an ordination technique operating on a two-way contingency table of counts of objects (James and McCulloch 1990). It is primarily a graphical technique used to illustrate the relationship between data points in as few dimensions as possible. CA assumes chi-square distances for the interpretation of graph plots. If scores calculated for two or more sites are similar, the sites can be assumed to be geometrically close, if the data meets chi-square assumptions. As with CVA, the procedure begins by centering the data set, so that zero represents the grand mean across all variables. Therefore, direction, as well as distance may be used in interpreting the positions of the individual sites. Unlike CVA, correspondence analysis does not assume any *a priori* grouping of the data. Fisher (1994) found that CA was able to capture most of the species and site variance in the first two axes. Plotted with these two axes, the species followed an ordination along the primary axis according to moisture stress tolerance, with species near the centroid representing those with intermediate tolerance. Ordination of the sites suggested a similar pattern, with sites associated with particular landforms and soils following a gradient of relative soil moisture availability.

It can generally be concluded that patterns inherent in the species distributions across a landscape can be recovered using a combination of classification and ordination techniques. These patterns frequently reflect growth related gradients associated with specific topographic and soil characteristics. While no studies are available which describe the use of these methods in the dry forests of tropical or

subtropical America, the literature does suggest that vegetation-soil-topography relationships exist and that they are similar to relationships which have been described for temperate zone forests. Although disturbance has commonly altered the original species distributions in tropical and subtropical dry forests (Murphy and Lugo 1986a), distinct patterns may still exist, influenced by a combination of environmental and disturbance factors. In as much as they are not random, MVA techniques should be capable of capturing such patterns.

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Materials and Methods

Site Description

The ISA-Mao Experimental Forestry Station is located in the western part of the Cibao Valley in the Dominican Republic (19°35' N and 71°4' W). Occupying about 1000 ha in a semiarid region of the country, the station experiences two rainy seasons. One is from March to June, the other is from September to December (Knudson et al. 1988). Average annual precipitation is 647 mm, but is irregular from year to year (Figure 1) and the average annual temperature is 27.1°C (Checo and Ramm, unpublished). The ratio of potential evapotranspiration (PET) to precipitation is between 2.0 and 4.0 (Knudson et al. 1988). Based on average annual rainfall, temperature and PET, the Mao forest is classified as subtropical dry forest, according to Holdridge (1967).

Located between the Mao river floodplain to the northeast and the Cordillera Central mountains to the southwest, the station is characterized by rolling hills with elevations ranging from 78 to 175 meters above sea level. The site ranges from level terrain with deep soil to steep slopes with shallow soils. Soils are derived from limestone parent material with pH varying from 7.8 to 8.4 (Knudson et al. 1988). Soils in the area have been classified in the subgroup Ustalfic Haplargids, which are arid soils with higher than normal clay content (CRIES 1977), but Aridic Haplustalfs may be a more appropriate classification because

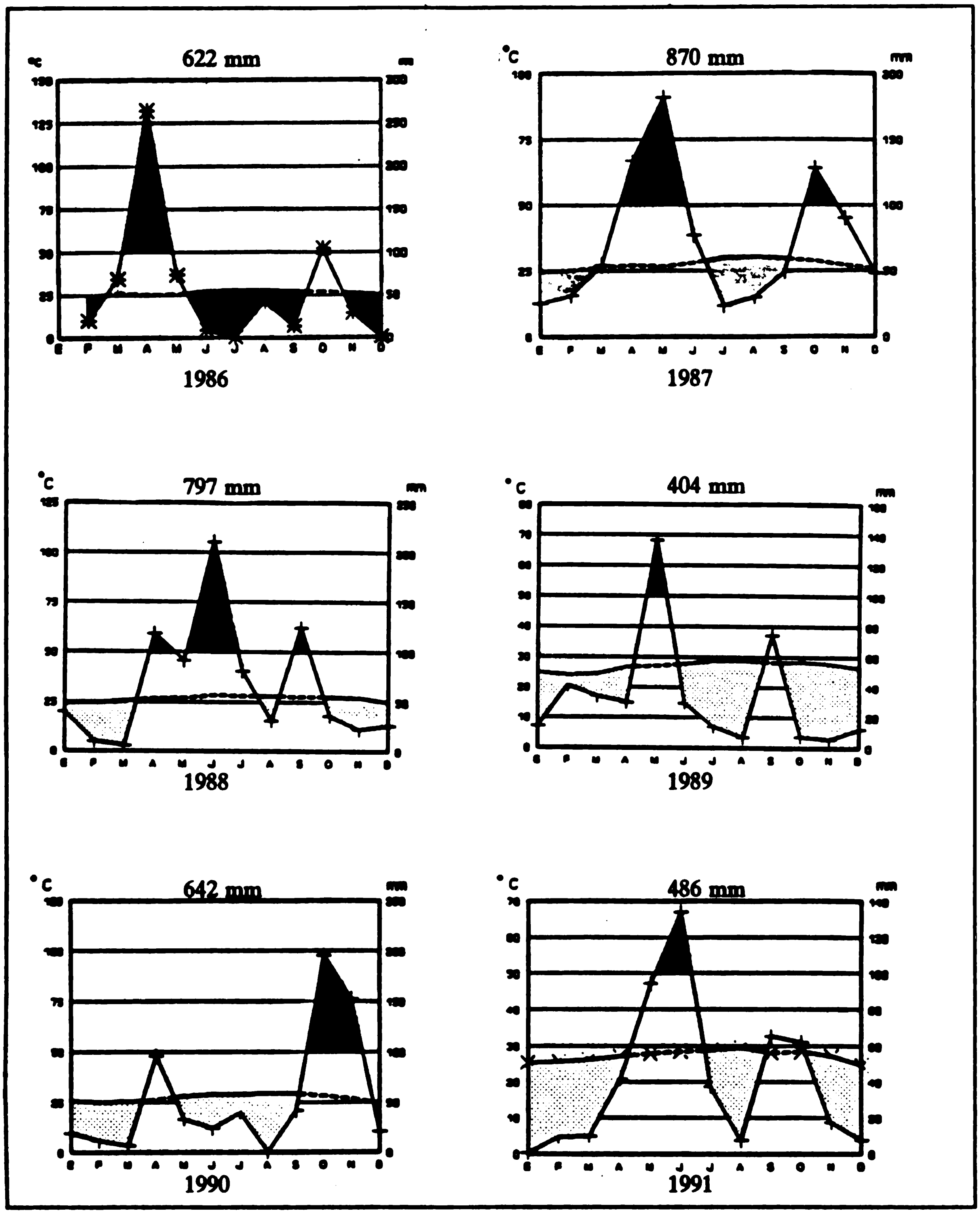

Figure 1 Rainfall and temperature patterns for six years during which the data of the current study was collected. The diagrams follow the criteria established by Walter (1983). The dotted line represents temperature. The points represent monthly precipitation. The upper shaded areas represent moisture in excess of potential evapotranspiration. The lower shaded areas represent moisture deficiencies. (Source: Checo and Ramm, unpublished).

soils with an aridic moisture regime are not normally associated with well developed forest vegetation (Mokma, personal communication). A high bulk density soil layer is present at depths between 35 and 50 cm in many parts of the forest (Checo, personal communication). This may represent a phenomenon common in semiarid regions where rapid evaporation of moisture limits the depth of rainfall penetration, resulting in the accumulation of eluviated calcareous material at shallow depths, forming a hardpan, or caliche (Arnon 1992).

The species composition and structure of the forest are complex. Like most of the subtropical dry forest in the Dominican Republic, the ISA-Mao forest has been subjected to both long term as well as relatively recent cutting, clearing and burning. Clearing for charcoal production was originally the principal source of disturbance, with evidence of old charcoal piles still present in many areas. Clearing for cultivation also occurred as well as considerable animal grazing (Powell and Mercedes 1986). Since 1978, such disturbances have been controlled, but incursions still occur by individuals from adjacent communities. These incursion involve removing individual trees for fence posts and house construction (Checo, personal communication).

The history of selective cutting in the ISA-Mao forest has resulted in a mosaic of site histories. Some areas were completely cut over, others had only a few trees extracted and a few areas have remained relatively undisturbed. The exact history of any given site is not well known. Most dry forest species sprout vigorously when cut, suggesting that trees with numerous stems may have been subjected to cutting at some point. Observations by Murphy (personal communication) in the Guanica dry forest of Puerto Rico suggest, however, that some trees may have multiple stems for reasons other than cutting. Exceptional moisture stress due to natural conditions may also be responsible for a higher incidence of multiple stems. Study plots in the Mao forest with the highest proportion of multiple stems may either represent the greatest level of intervention or the most severe environmental conditions. Exploitation of the forest also generally results in a shorter overall height and a greater dominance by smaller boles (Tamayo 1963, Powell and Mercedes 1986). A reduction in relative moisture availability can result in similar conditions (Beard 1944).

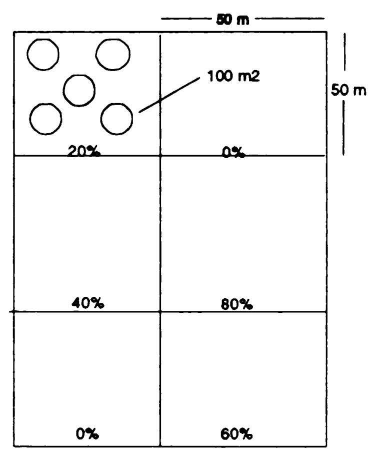

Figure 2 Plot layout for study of response of native dry forest to thinning. Sample of 1 of 4 blocks.

Original Study Design

Within this diverse landscape, a silvicultural thinning study was established in 1985-1986 (Knudson et al. 1988). Patterned after a randomized complete block design, four blocks, each with six 50 X 50 m plots, were located in sections of the forest representing different structure, topography and species dominance. Target thinning levels of 20, 40, 60 and 80% were randomly assigned to four of the 50 X 50 m areas. The two remaining sections were designated as controls. Within each of the 50 X 50 m areas, five permanent circular subplots were systematically located, each 100 m^2 (Figure 2). Each set of subplots was originally designed to represent a subsample of their respective treatment plot. Due to restrictions of time and resources, thinning treatments were applied only within each of the circular subplots (Checo, personal communication). Each subplot became its own experimental unit, rather than a representative of the larger 50 X 50 m area.

Because the subplots are not effective subsamples for 50 X 50 m plots, they have been considered independent samples of the area of forest corresponding to the silvicultural study. Statistically, the subplots are not independent since each set of five was systematically located within their respective 50 X 50 m area. Even if each set of subplots had been randomly distributed within their treatment plots, their independence would be ecologically questionable. In a plant ecosystem, a random distribution might actually consist of randomly distributed clumps of individuals rather than a random mix of the individuals themselves (Pielou 1969). Because of growth and reproductive patterns, two trees next to each other may be more likely to be of the same species simply because of their proximity, rather than due to some environmental characteristic. Closely situated sample plots might show similar species compositions because they all happen to fall within a random clump of species, rather than because the data points reflect some common underlying environmental characteristic (Pielou 1969). As more plots are included in the sample and when plots are distributed over a large geographic area, random associations tend to cancel each other out. Pielou (1969) also observes that the finer the species composition mosaic, the less likely proximate sites are to show spurious associations. In this study, subplots within a single 50 X 50 m plot may be more likely to have had the same species composition because of their proximity, not necessarily because of similar environmental attributes. It is assumed, however, that the study has enough sample points over a large enough geographic area to represent a diversity of site conditions. This should help minimize the probability of contriving arbitrary site relationships.

Before thinning (1986), all trees within each subplot with at least one stem greater or equal to 2.5 cm at breast height were identified by common species name, measured for height, diameter at breast height (DBH) and diameter at knee height (DKH). One height measurement was recorded for each tree. Stems were then removed based on the target thinning level. Residual trees were remeasured post-thinning and again each year through 1992. The goal of stem removal was to reach targeted treatment levels while maintaining a one to one relationship between the percentage of stem and basal area removed. In practice, due to the complex structure of the forest, the result was not as precise as desired. Comparing actual removal of stems and basal area with the target thinning rate, clearly shows that cutting was not consistent within treatment plots, nor within treatments across blocks (Table 1). This was discovered while preparing the data for multivariate analyses.

Table 1 A subsample of sites from the thinning study in a subtropical dry forest of the Dominican Republic demonstrating reassignment of the sites to new treatment designations based on the percent of initial basal area actually removed in the cutting. The first digit in Site ID indicates the block number (1 through 4). The second and third digit represent the site number (1 through 30) within each block. The original treatments are listed in the "Target thinning level" column. The actual percentages of stems and basal area removed are listed in the last two columns. The assigned cutting levels are the treatment designations used for analyses in this study.

ID	Target thinning level (%)	Assigned cutting level[1]	Actual basal area removed (%)	Actual stems removed (%)
212	20	C	0.0	0.0
213	20	C	0.0	0.0
214	20	C	0.0	0.0
215	20	C	0.0	0.0
111	20	1	1.6	7.4
112	20	1	3.1	8.7
211	20	1	3.9	3.3
114	20	1	10.7	21.1
415	20	1	12.3	13.0
313	20	2	15.9	44.4
115	20	2	16.5	12.5
113	20	2	18.3	21.4
411	20	2	23.7	27.1
311	20	2	24.2	18.5
314	20	2	26.3	39.3
312	20	2	27.3	28.9
413	20	2	31.3	41.1
412	20	2	35.2	37.8
414	20	3	46.8	42.9
315	20	3	54.8	45.9

[1]Assigned cutting level "C": < 1.0% basal area removed. "1": ≥ 1.0% and ≤ 15.0% removal. "2": >15.0% and ≤ 36.0% removal. "3": >36.0% and ≤ 55.0% removal. "4": >55.0% and ≤ 72.0% removal. "5": >72.0% basal area removed.

Because thinning was not consistent within targeted treatment levels, subplots were assigned a new treatment designation according to the actual basal area removed (Table 1). Basal area was used as the sole criteria for reassignment. Levels for reassignment were

Controls	< 1.0% basal area removed
Cutlevel 1	≥ 1.0% and ≤ 15.0% basal area removed
Cutlevel 2	> 15.0% and ≤ 36.0% basal area removed
Cutlevel 3	> 36.0% and ≤ 55.0% basal area removed
Cutlevel 4	> 55.0% and ≤ 72.0% basal area removed
Cutlevel 5	> 72.0% basal area removed.

Because the areas where the data was collected were not actually subsamples of the 50 X 50 m plots, they will be referred to as "sites" rather than "subplots". See Appendix A for the complete list of cutting level designations based on basal area removal.

Numerical Methods

Variable Selection

Forty-four species were identified in the initial pre-harvest inventory within the silvicultural study area. For analyses of species-site relationships, sixteen species were selected which were found to be the most dominant across the entire study area. To select these species, relative importance values were calculated using stem density, tree density, basal area density and frequencies as follows:

$$IV_x = RDS_x + RDN_x + RDM_x + RFR_x$$

Where:

IV_x = relative importance of species *x*.

RDS_x = [$\sum$ stems of species *x* / $\sum$ all stems] X 100

RDN_x = [$\sum$ trees of species *x* / $\sum$ all trees] X 100

RDM_x = [$\sum$ basal areas(DKH) of species *x* / $\sum$ all basal areas(DKH)] X 100

RFR_x = [frequency of species *x* / $\sum$ frequencies of all spp] X 100

The decision to select sixteen species was not arbitrary. Several versions of the importance values were calculated and it was noted that while each version ordered the species differently, the top sixteen species were always the same. For the species selected, each comprised at least 1.4% of the total basal area (Table 2).

To represent species dominance, stem counts, tree counts, and basal area summations were all possibilities based on the data collected in the silvicultural study. Each of these measures weights species differently according to the species' particular structural form. Stem counts give greater relative weight to species with multiple stems versus those species which tend to have single stems. Cinazo (*Pithecellobium circinale*- #2, Table 2), for example, comprised 13.1% of all the stems, but only 5.3% of the trees. Quina (*Exostema caribaeum*- #4, Table 2), on the other hand, made up 6.3% of the stems, but 8.0% of all trees. Using stem density to compare species contributions gives somewhat greater weight to Cinazo than to Quina relative to using tree counts as a measure of species dominance.

Table 2 Relative measures of density for forty-four species in the silvicultural thinning study at the Mao-ISA subtropical dry forest experimental station. Calculations are based on measurements taken at knee height (0.5 m). Species are listed in descending order of their importance value.

#	Species (local name)	Relative stem density (%)	Relative tree density (%)	Relative basal area density (%)	Relative frequency (%)	Importance value
1	Baitoa	24.3	29.3	29.7	8.9	92.1
2	Cinazo	13.1	5.3	5.5	6.7	30.7
3	Guatapanal	5.7	4.7	10.1	6.5	27.0
3	Quina	6.3	8.0	4.9	6.2	25.3
5	Brucón	5.2	6.4	4.9	7.1	23.6
6	Candelón	5.4	6.6	7.8	3.7	23.5
7	Guayacán	4.7	5.2	2.5	7.2	19.6
8	Almácigo	2.0	2.7	8.6	4.1	17.3
9	Cambrón	4.7	4.8	3.5	4.0	17.0
10	Aroma	3.6	3.2	2.7	4.0	13.5
11	Sangretoro	3.3	2.9	2.4	4.1	12.7
12	Mostazo	2.7	2.2	2.6	4.3	11.7
13	Cafetán	3.2	2.9	1.5	3.4	10.9
14	Frijol	1.4	1.6	2.8	3.3	9.2
15	Palo amargo	1.6	1.7	1.4	2.8	7.5
16	Uvero	2.0	1.5	1.7	2.2	7.4
17	Palo de burro	1.1	1.4	0.9	3.0	6.3
18	Ojo de paloma	1.6	1.5	0.9	2.0	6.1
19	Palo blanco	1.2	0.9	0.6	1.8	4.6
20	Clavellina	0.6	0.8	0.4	1.6	3.4
21	Sopalpo	0.7	0.4	1.0	1.0	3.1
22	Trejo	0.5	0.7	0.2	1.6	3.0
23	Tabacuelo	0.5	0.7	0.3	1.3	2.7
24	Canelilla	0.6	0.7	0.2	1.1	2.6
25	Hueso de chivo	0.5	0.5	0.5	1.0	2.4
26	Frijolillo	0.6	0.4	0.5	0.9	2.4
27	Amarra carnero	0.4	0.4	0.3	1.0	2.1
28	Cereza	0.4	0.4	0.1	1.0	1.9
29	Palo de caimán	0.2	0.3	0.2	0.7	1.5

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Table 2, continued

#	Species (local name)	Relative stem density (%)	Relative tree density (%)	Relative basal area density (%)	Relative Frequency (%)	Importance Value
30	Asajaí de breña	0.2	0.3	0.1	0.7	1.3
31	Paría	0.2	0.3	0.1	0.6	1.2
32	Guaconejo	0.2	0.3	0.2	0.4	1.1
33	Ciguamo	0.2	0.2	0.1	0.6	1.1
34	Canela	0.3	0.3	0.1	0.4	1.1
35	Cuabilla	0.3	0.2	0.2	0.2	0.9
36	Penda	0.1	0.1	0.0	0.3	0.5
37	Escobón	0.1	0.1	0.0	0.2	0.3
38	Candeli	0.1	0.0	0.0	0.1	0.3
39	Bayahonda	0.1	0.0	0.0	0.1	0.2
40	Ciruela	0.1	0.0	0.0	0.1	0.2
41	Cuerno de buey	0.0	0.0	0.0	0.1	0.2
42	Cabra	0.0	0.0	0.0	0.1	0.2
43	Uña de gato	0.0	0.0	0.0	0.1	0.2
44	Chicharrón	0.0	0.0	0.0	0.1	0.2

Tree density appears to correspond more closely with basal area density for Cinazo. Quina, however, made up only 4.9% of the total basal area at knee height, while Guatapanal (*Caesalpinia coriaria*- #3, Table 2), with only 4.7% of the trees, made up 10.1% of the basal area. Tree density therefore gives more weight to Quina than to Guatapanal. Using basal area density on the other hand, gives significant weight to Almácigo (*Bursera simaruba*- #8, Table 2), with 8.6% of the basal area, although the species comprised only 2.0% of all the stems and 2.7% of the trees. Because the Mao forest is composed of species which are structurally diverse, each measure of species dominance gives a different weight to a different set of species and none of the measures is perfect.

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In preliminary analyses, all three measures were used. Preliminary calculations focused on stem and tree counts because an initial review of the data sets showed that diameter measurements were variable. For example, some stems were measured as smaller in 1992 than in 1986. At least two factors contributed to this measurement error. First, pre- and post-thin inventories used the average of two caliper readings for stem diameter measurements. Subsequent inventories were less rigorous (Checo, personal communication). Second, many dry forest trees have significant taper and subsequent yearly measurements on the stems may not have always been at the same point. In the dry woodlands of Arizona in the United States, diameters are measured at the root collar (DRC) (McPherson 1992) presumably making consistent measurements easier and avoiding the problem of multiple stems.

In the end it was decided that basal area would be used to represent species-site interactions in the ISA-Mao silvicultural study. Basal area often shows a strong relationship with total tree biomass and canopy cover (Barth and Klemmedson 1982, Maxwell 1985, Lamprecht 1989). Grigal and Goldstein (1971) used basal area contributions in their multivariate analysis of species relationships across an oak hickory watershed in Tennessee. Finally, in the temperate zone, basal area is usually assumed to be independent of stand age, versus tree and stem counts, which change radically over time. To decrease the effect of measurement error, diameters at knee height (DKH) were chosen over diameters at breast height (DBH) to calculate basal area. Diameters at knee height may introduce less error for tw

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for two reasons: (1) More of the trees are single stemmed (82% at knee height versus 70% at breast height) and are therefore represented by a single measurement rather than multiple measurements. And (2) stem taper at 0.5 m above ground level is less acute, making subsequent measurements less variable. Residual trees were remeasured in 1986 immediately after thinning. Basal area summations calculated from diameter measurements for trees present in both pre- and post-thin inventories were averaged and the average used in subsequent analyses.

Species Identification

Data collected in the silvicultural study used local names for tree species. Sources for the Latin names of the sixteen species selected for species-site analyses are van Paasen (1986) and Knudson et al. (1988). Where the two sources conflict, the Latin name used by Knudson et al. (1988) was followed. Further verification for some of the species was possible using **Common trees of Puerto Rico and the Virgin Islands** (Little and Wadsworth 1964) and **Trees of Puerto Rico and the Virgin Islands** (Little et al. 1974). In general, the description for each species provided in this source matched the characteristics noted by van Paasen (1986). However, two species, Cafetán and Palo amargo, which are listed by Knudson et al. (1988) as *Lasianthus lanceolatus* and *Trichilia pallida*, respectively, did not match with the habitat distributions described by Little and Wadsworth (1964). Nevertheless, the Latin names provided by Knudson et al. (1988) will be used in this study. Table 3 gives the Latin names for all of the species. García and Alba

(1989) and Little and Wadsworth (1964) were used as a source for family designations and for some of the original sources for the Latin names.

Table 3 Local names for species used in the species-site analyses of the ISA-Mao dry forest with their corresponding Latin names.[1]

Local name	Latin name	Source	Family
Almácigo	*Bursera simaruba*	(L.) Sarg.	Burseraceae
Aroma	*Acacia farnesiana*	(L.) Willd.	Mimosaceae
Baitoa	*Phyllostylon brasiliensis*	Cap.	Ulmaceae
Brucón	*Cassia emarginata*	L.	Caesalpinaceae
Cafetán	*Lasianthus lanceolatus*	(Griseb) G. Maza	Rubiaceae
Cambrón	*Prosopis juliflora*	(Sw.) DC.	Mimosaceae
Candelón	*Acacia scleroxyla*	Tuss.	Mimosaceae
Cinazo	*Pithecellobium circinale*	(L.) Benth.	Mimosaceae
Frijol	*Capparis cynophallophora*	L.	Capraridaceae
Guatapanal	*Caesalpinia coriaria*	(Jacq.) Willd.	Caesalpinaceae
Guayacán	*Guaiacum officinale*	L.	Zygophyllaceae
Mostazo	*Capparis flexuosa*	(L.) L.	Capraridaceae
Palo amargo	*Trichilia pallida*	Sw.	Meliaceae
Quina	*Exostema caribaeum*	(Jacq.) R. & S.	Rubiaceae
Sangretoro	*Maytenus buxifolia*	(A. Rich.) Griseb	Celastraceae
Uvero	*Coccoloba leoganensis*	Jacq.	Polygonaceae

[1]Source: Little and Wadsworth (1964), van Paasen (1986), Knudson et al. (1988), García and Alba (1989).

Multivariate Analyses

Cluster Techniques

Cluster analyses operate on distance matrices derived from initial data sets. In this study, species composition by site was tabulated using DKHBA. Data from before the initial harvest (1986) was used to create a species-site data matrix. Before submitting the data to cluster analyses, species densities were converted to relative basal area contributions by calculating basal area of species x as a proportion of total basal area for each of the respective sites. No other standardization of the data was considered necessary. Fisher (1994) used a similar conversion for cluster analyses with tree counts. Because interpretations of the MVA procedures are complex, the initial analyses were done with a subset of forty-five sites. Forty of these represented the original control sites, plus five additional sites designated as controls based on actual basal area removed. Patterns of species composition observed in these initial analyses were subsequently used to help interpret the results from the full data set analyses. The initial cluster analysis used a data matrix representing 16 species and 45 sites (16 X 45). Subsequent analyses used a data matrix representing 16 species and all of the 120 silvicultural sites (16 X 120). Data from the pre-harvest inventory were used in all of the MVA procedures.

Two hierarchical methods were selected to examine the data based on a distance matrix derived using the Euclidean squared distance metric (the SAS default option). The two hierarchical methods used were flexible beta and Ward's minimum variance, both of which are options within the SAS Proc Cluster procedure (SAS Institute Inc. 1985). The default beta value of -0.25 was used for flexible beta. Because Ward's minimum variance method is sensitive to outliers (SAS Institute Inc. 1985), the "trim" option was used, with 1% of the values removed prior to analysis. Results of the hierarchical clustering were examined visually. A series of preliminary analyses led to the selection of a level of classification which optimized for the maximum number of groups with the greatest stability of group membership, as well as the most consistent species composition within each group. Using these criteria, the same number of cluster groups were formed from both hierarchical methods. In the initial analyses, six groups were formed from the subset of 45 sites. In the full data set analyses, seven groups were formed from the set of 120 sites.

Based on the groupings apparent from the hierarchical analyses, a range of groups was selected to use in a series of nonhierarchical cluster techniques, also using a distance matrix based on the Euclidean squared distance metric. SAS Proc Fastclus was used to split the sites into k groups, based on a maximum of ten iterations. In all of these analyses, group membership became stable in fewer than ten iterations. In the initial analyses, 45 sites were clustered three times using SAS Fastclus, using k = four, five and six. Subsequently, all 120 sites were clustered twice, once with k = six and again with k= seven. A greater range of k values were used in some additional analyses for both data sets. Higher values resulted in additional groups of one or two sites. Lower values resulted in the combination of sites with widely disparate species compositions. The ranges presented here resulted in groupings of the data which were relatively stable across clustering techniques based on characteristic species compositions and site membership. "Characteristic species" for each of the major cluster groups were selected using two criteria. First, a species was considered characteristic of a cluster group if the average basal area contribution was at least two times the average contribution across all sites within the data set. Second, a species was considered characteristic of a cluster group if the average basal area contribution was greater than the contribution across all sites and the standard deviation was less than the standard deviation across all sites. In their study of a Tennessee watershed, Grigal and Goldstein (1971) identified species as characteristic of a particular cluster group based on an average basal area contribution which was large relative to the contribution across the entire watershed.

Groupings within each of the cluster techniques were assigned numbers which corresponded to one or two of the characteristic species determined to best represent a particular group of sites. For example, in preliminary analyses, one of the groupings was observed to represent a large contribution by the species *Bursera simaruba*. This grouping was given the designation Group One. Thereafter, any grouping of sites which showed a strong dominance by *B. simaruba* was designated as Group One. A similar procedure occurred for each of the other group designations. In this way, group membership could be compared across cluster techniques.

As found by Grigal and Goldstein (1971), within each cluster analysis, the characteristic species composition of the major groups corresponded to the characteristic compositions of one of the major groups in each of the other techniques. Likewise, as observed by Grigal and Goldstein, some of the sites remained consistent across all analyses, while other sites changed group membership depending on the technique used and/or the number of *k* used to separate the data. Sites which clustered consistently were considered "core" sites representing groups with distinct species compositions. In the ranges used for SAS Proc Fastclus, certain groups of sites consistently separated out in the same order moving from a lower *k* to a higher *k*. For example, if a given site was member of Group Six in the hierarchical techniques, *k*-clustering assigned it to some other group when *k* was equal to four in the nonhierarchical analyses and a member of Group Six only when *k* was equal to six. Such sites were not considered to have changed group membership. Thirty of 45 sites were designated core sites in the initial analyses and 67 of 120 in the full data set.

Sites which did not fall into the same groupings across all techniques are referred to here as noncore sites. These were assigned letter designations based on the cluster group with which they were most closely associated. For example, in the initial analyses, sites which were designated as Group One in at least three of the five analyses were given the letter designation "A". Sites which were designated as Group Two sites in at least three of the analyses were given the designation "B", and so on. In the full data set analysis, a similar procedure was followed. If a site was split between two cluster groups, it was given both designations. For example, if a site was assigned to Group Two by both the Ward's minimum variance and the flexible beta methods, but was assigned to Group Seven in both versions of the nonhierarchical techniques, the site was designated as "BG", with "B" representing the group two assignations and "G" representing the group seven assignations. This secondary classification does not necessarily represent expected

associations with other site characteristics, such as overstory structure or growth and mortality. However, if the core sites represent discrete points along the species-site continuum, it was expected that characteristics of the noncore sites might provide insight into the relationships of the sites representing intermediate areas.

Correspondence Analysis

To examine the relationships between sites from a different perspective, correspondence analysis was applied to the original species-site data set without converting basal area summations to relative basal area contributions. CA assumes no grouping within the data set. Therefore, cluster groups would not be expected to remain cohesive. CA was used primarily to check for consistency in the association of sites associated in the cluster analyses. The data set examined with correspondence analyses can be considered a two-way contingency table of counts, with basal area (DKHBA) as a weight. Since basal area is continuous rather than discrete data, the correspondence analyses did not meet the assumptions of chi-square distributions. Therefore, distances observed in graphing the principal axes cannot be strictly interpreted. However, apparent distances were used to approximate the relationships of sites within cluster groups relative to the relationships between groups to determine if sites grouped using cluster techniques showed any consistent relationships. The directions of sites with relative to the origin was also interpreted with respect to possible environmental and disturbance factors. Since CA allows for an interpretation of species relationships as well as site relationships, CA was used to examine which species were associated with each cluster group. Two correspondence analyses were applied, using first only core sites, then using both core and noncore sites. In the initial analyses, a data matrix representing 16 spp and 30 core sites was analyzed, followed by a matrix representing 16 spp and 45 sites. Full data set analyses were first applied to a matrix representing 16 spp and 67 core sites, followed by a matrix representing 16 spp and core sites.

Canonical Discriminant Analysis

Operating on the same data sets with the same variables as cluster analyses, canonical variate analysis (CVA) can be used as an ordination procedure to examine the relationships between the cluster groups (Grigal and Goldstein 1971). Grigal and Goldstein also used CVA to determine if groupings of sites formed using cluster techniques actually occupied discreet areas in canonical space. In SAS, the procedure which separates groups based on the ratio of between group variation to within group variation is referred to as canonical discriminant analysis (CDA) (SAS Institute, Inc. 1985). Proc Candisc (SAS Institute, Inc. 1985) was used to examine the quality of separation between cluster groups and to examine ordinal relationships which could potentially relate to underlying gradients (Grigal and Goldstein 1971). As in other ordinations procedures, canonical discriminant analysis first centers the data using means of each variable within each cluster group. A function is then created which maximizes the ratio of between group variance to within group variance, optimizing the separation of the groups along a series of axes. The number of axes created is less than or equal to the min (*p*, *g*-1), where *p* represents the number of variables and *g* is the number of groups (Digby and Kempton 1987). Because the data is centered, the origin, or centroid, represents the grand mean across variables for all groups and the position of the groups with respect to the origin is indicative of their variation from this mean.

Initially, CDA was used to examine relationships between thirty core sites representing five cluster groups. Subsequently, noncore sites were returned to the data set and forty-three sites representing five groups (16 spp X 43 sites) were analyzed. Noncore sites were assigned the group designation with which they were most closely associated. Two sites designated as a minor cluster group were eliminated. In the full data set analyses, the first CDA was applied to a data matrix with 16 spp and 67 core sites representing six core site cluster groups. A second CDA procedure eliminated five of the initial core sites. The five sites represented a single cluster group of limited sample size relative to the other cluster groups that appeared to distort the results of the CDA procedure. The third CDA was applied to 16 spp and 118 sites representing six core cluster groups and seven subgroups (two sites were eliminated which clustered randomly across all cluster analyses). This analysis was done to examine the relationship of noncore sites- sites theoretically representing the continuous portion of the species distribution continuum.

Overstory Analyses

Following the results of the classification and ordination procedures, structural characteristics were examined for each cluster group. Diameter class distributions were analyzed for trees with single stems, based on the following class distributions:

Diameter Class	Diameter distribution (DKH)
1	< 3.0 cm
2	≥ 3.0 cm and < 4.0 cm
3	≥ 4.0 cm and < 5.0 cm
4	≥ 5.0 cm and < 6.0 cm
5	≥ 6.0 cm and < 7.0 cm
6	≥ 7.0 cm and < 8.0 cm
7	≥ 8.0 cm and < 10.0 cm
8	≥ 10.0 cm and < 13.0 cm
9	≥ 13.0 cm

A tenth class, labeled MS, was also used, which included all trees with more than one stem at knee height. Trees in this category consisted of 17.8% of all the trees in the 1986 inventory before thinning.

Average tree height and average diameter (DKH) for each site were calculated, as were basal area at knee height (m^2 ha^{-1}), total trees (ha^{-1}) and total stems (ha^{-1}). Total trees and total stems were used to estimate an average measure for the frequency of multiple-stems at each site. Each of these variables was subjected to the Kruskal-Wallis distribution-free test of differences between rank means for cluster groups. Differences between groups were examined graphically using box plots. All of these structural characteristics were examined for significance with respect to disturbance history and potential site quality. The assumptions were that better sites support more basal area and taller trees, while poorer sites generally have lower canopy heights and shorter vegetation (Beard 1944, Asprey and Robbins 1953, Loveless and Asprey 1956). Disturbance generally creates similar conditions, reducing overall tree height, causing a greater number of multiple-stemmed trees and increasing total dominance by smaller diameter trees (Tamayo 1963, Holdridge 1967, Powell and Mercedes 1986, Kellman and Roulet 1990, Poynton 1990, Vora and Messerly 1990). Values for each parameter for each site are listed in Appendix B.

Site Characteristics

Originally, a goal of this study was to collect data on the environmental characteristics of the study sites to assess the association of species composition and site characteristics. Due to limitations of time and resources, this segment of the study was reduced to a brief review of the forty designated control sites. During a five day period in March 1994, the principal researcher and an assistant carried out a rapid inventory of a limited set of variables on each site. The parameters examined included slope angle, slope position, degree of canopy cover, surface soil texture, and identification of ground vegetation. Basal area estimates were also made using factor five of a CRUZALL tool, recording each stem by local species name. Identification of all species was done by the assistant. The site data collected is found in Appendix C. Ground vegetation and CRUZALL data is found in Appendix D.

Slope angle was estimated visually, with the terms "none", "slight", "moderate", "steep" and "very steep" denoting increasingly acute slopes. Slope positions were designated as "plain", "toe", "midslope", "shoulder", "low ridge" and "high ridge". Canopy cover was estimated as >10% (category 2), but less than 25%, >25% but less than 50% (category 3), >50% but less than 75% (category 4) and >75% (category 5). Soil texture was a rough field evaluation of the soil horizon immediately below the organic layer. Designations ranged from silty clay to clay sand. The stoniness of these samples was noted, using the labels "none", "some" and "very". Ground vegetation was identified by common name. Species which were unfamiliar to the assistant were designated as "herb". In analysis of ground vegetation information, many of the species occurring only once or twice were redesignated as "herbs". Table 4 is a list of the ground vegetation species identified by the assistant. Data were collected to evaluate the relative dominance of cacti species, which were not included in the original silvicultural study. Table 5 lists the dominant overstory species identified.

Data collected from this trip were analyzed using two-way contingency tables based on frequencies by cluster group. For all of the parameters examined, the results presented are useful only inasmuch as they serve to help interpret results from the other analyses. The sample size and expected frequencies were too small in these analyses to accept the results on their own merit.

Table 4 Ground vegetation identified in the forty designated control sites in the ISA-Mao silvicultural study. "Data designation" refers to the classification used in data analysis.[1]

Local name	Latin name	Family	Data designation
Cabuya	*Frucraea hexalpetala*	Amaryllidaceae	Frucraea
Camphor			Herb
Cayuco	*Lemaireocereus hystrix*	Cactaceae	L.hystrix
Desconocido			Herb
Espartillo	*Andropogon gracilis*	Gramineae	A.gracilis
Guinea		Gramineae	Grass 2
Guasábara	*Cylindropuntia caribaea*	Cactaceae	C.caribaea
Hierba			Herb
Lamba vaca		Gramineae	Grass 1
Maguey	*Agave*, sp.	Amaryllidaceae	Agave
Maya	*Bromelia pinguin*	Bromeliaceae	B.pinguin
Palo prieto			Herb
Pilotera			Herb
Tremolina	*Croton*, spp.	Euphorbiaceae	Herb
Tuna		Cactaceae	Tuna
Verbena	*Stachytarpheta cayennensis*	Verbenaceae	Herb

[1]Source: Burgos et al. (1986).

Table 5 Prominent canopy species identified using a factor five CRUZALL tool on forty sites representing the original control sites in the ISA-Mao silvicultural study.[2]

Local Name	Latin Name	Source	Family
Almácigo	*Bursera simaruba*	(L.) Sarg.	Burseraceae
Alpargata	*Consolea moniliformis*		Cactaceae
Baitoa	*Phyllostylon brasiliensis*	Cap.	Ulmaceae
Brucón	*Cassia emarginata*	L.	Leguminosae
Cafetán	*Lasianthus lanceolatus*	(Griseb.) G. Maza	Rubiaceae
Cambrón	*Prosopis juliflora*	(Sw.) D.C.	Mimosaceae
Candelón	*Acacia scleroxyla*	Tuss.	Mimosaceae
Cayuco	*Lemaireocereus hystrix*	(Haw) B & R	Cactaceae
Cinazo	*Pithecellobium circinale*	(L.) Benth	Mimosaceae
Frijol	*Capparis cynophallophora*	L.	Capraridaceae
Guatapanal	*Caesalpinia coriaria*	(Jacq.) Willd.	Caesalpinaceae
Guayacán	*Guaiacum officinale*	L.	Zygophyllaceae
Palo de burro	*Leuceana trichodes*		Mimosaceae
Quina	*Exostema caribaeum*	(Jacq.) R & S	Rubiaceae
Sangretoro	*Maytenus buxifolia*	(A. Rich.) Griseb	Celastraceae
Uvero	*Coccoloba leoganensis*	Jacq.	Polygonaceae

[2]Source: Britton and Rose (1963), van Paasen (1986), Knudson et al. (1988), García and Alba (1989).

Site Productivity

To evaluate sites on their relative growth potential, some measure of site productivity had to be selected. In the temperate zone, tree height and age are used to calculate site index. This is a common measure of site potential that was developed for single species in even-aged stands (Carmean 1975, Pritchett and Fisher 1987). Because site index curves have not developed for the Mao forest, tree heights were used only as a relative indication of site potential. Observations by Loveless and Asprey (1956) suggest that overall canopy height under dry forest conditions is influenced by local environmental conditions. The principal indicators of relative site productivity used in this study were growth and mortality. These measures were estimated using diameter increments (DKH), basal area summations (DKHBA) and stem counts at knee height. One measure of growth for trees present in both the post-harvest inventory in 1986 and in the annual inventory of 1992 was calculated as the difference between DKHBA summations in 1992 and after thinning in 1986. Positive differences were summed for each site and the variable was named BARGRTH. A second measure, called BARAVE was calculated as the total DKHBA growth divided by the number of trees alive per site in 1992. This parameter is an estimate of the average basal area increment by site, per tree. A third variable, called DKHDIF, was created by calculating the difference between 1992 and 1986 diameters of single-stemmed trees. Positive differences were then averaged for each site. One measure of mortality, STEMMORT, was calculated as the difference between the number of stems recorded for each tree post-thin 1986 and the number recorded in 1992. A second measure of mortality, BARMORT, was calculated as the difference between post-thin 1986 and 1992 basal area summations for each tree, assuming one or more stems (DKH) were missing. For both variables, positive differences were then summed for each site. Mortality was assumed for missing stems, although a number may have been cut green for fence posts and poles.

A sixth variable was created based on the difference between basal area growth and basal area mortality. The variable, referred to as NETGRTH, estimates the net change in biomass on each site over six years. On many sites, there was a net loss of biomass as estimated by the change in basal area. Although a number of factors may have affected all of the growth and mortality estimates, they are considered to be sufficiently precise for determining the relative trends in site productivity. Differences in growth and morality were tested between cluster groups across all cutting levels. Differences between groups across cutting levels were tested for a significant difference using the Kruskal Wallis distribution free one-way test of differences, assuming independence of sites. The values for each parameter in each site are listed in Appendix E.

Nonparametric Analysis of Thinning Effects

The initial premise that thinning effects were not significant was retested after the sites were assigned to cutting levels based on the actual basal area removed. Nonparametric analyses were deemed most appropriate because assumptions related to the original experimental design were not considered to be valid. The

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Kruskall-Wallis test of differences between treatments was used because block means did not accurately represent the range of responses within treatment levels (Hollander and Wolfe 1973). Sites were considered as independent samples. Cutting level 5 (> 72% basal area removal) was discarded since the sample size (n=5) was small relative to the other cutting levels. The treatments tested were:

Controls	**< 1.0% basal area removed**
Cutlevel 1	**≥ 1.0% and ≤ 15.0% basal area removed**
Cutlevel 2	**> 15.0% and ≤ 36.0% basal area removed**
Cutlevel 3	**> 36.0% and ≤ 55.0% basal area removed**
Cutlevel 4	**> 55.0% and ≤ 72.0% basal area removed**
Cutlevel 5	**> 72.0% basal area removed**

The six measures of site productivity used to test differences between cluster groups were also used to test differences between cutting levels. The hypothesis to test for overall differences was:

$$H_0\text{: } TC = T1 = T2 = T3 = T4.$$

For variables found to differ significantly between treatments, a distribution-free test of multiple comparisons was also applied (Hollander and Wolfe 1973). See Appendix F for details on the test assumptions and test statistic calculations.

Results and Discussion

The ultimate goal of this study is to examine and explain species-site interactions in a dry forest ecosystem using multivariate methods of classification and ordination. Understanding species-site relationships is necessary in order to design effective management techniques. Site evaluation and classification have occurred in tropical and temperate regions, but in the temperate zone classification has been more focused on developing efficient and sustainable systems for forest management. In the process of establishing these management systems, a comprehensive understanding of species-site interactions has developed, relating factors of climate, topography and soils to the total complement of overstory and understory vegetation.

Multivariate techniques have been used in many temperate zone studies to explore species-site relationships. Similar methods should be effective with species composition data from the ISA-Mao subtropical dry forest. However, there are three important factors which make this study significantly different from the temperate studies. First, studies examining species-site relationships using multivariate techniques have not previously dealt with ecosystems recently disturbed by human intervention. In the ISA-Mao forest, relatively recent disturbance has affected species distributions in unknown ways. Second, in most such studies, site conditions were known or data were later collected to confirm and/or modify models and classifications developed using species distributions.

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Rowe (1984) recommends using field based criteria to delimit groups of sites with similar production potential. Numerical analyses can then be used to modify these classifications. In this study, information about site characteristics is limited. More importantly, no definitive information is available which predicts site productivity based on specific site characteristics in the subtropical dry forest. Finally, most of the multivariate analyses have dealt with temperate species whose ecologies are relatively well known. The ecologies of dry forest species have received very little study (Fries 1992). Literature pertinent to the species prominent in the ISA-Mao forest was found to be limited in scope and in detail, although the studies do suggest a number of important relationships (Beard 1944, Record 1944, Holdridge 1945, 1967, Asprey and Robbins 1953, Loveless and Asprey 1956, Tamayo 1963, Peacock and McMillan 1968, Jacobs 1965, Lugo et al. 1978, Ruskin 1980, Scott and Martin 1984, Murphy and Lugo 1986b, Otis and Buskirk 1986, Rogers 1987, Stevens 1987, García and Alba 1989, Kellman and Roulet 1990, Poynton 1990, Vora and Messerly 1990, van Auken and Bush 1991, Johnson 1992, Lees et al. 1992, Hunter and Steward 1993, Buskirk and Otis 1994). Despite these differences, temperate zone studies will be used as a basis for interpreting the results of classification and ordination procedures. Literature from other studies in the semiarid tropics will be used to modify and clarify ideas developed using temperate zone concepts. Additional information from the silvicultural study will also be used to add to the interpretation of species data.

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This chapter consists of five sections, each with a discussion of the analyses applied to the data. Section one outlines the results of initial analyses on a subset of forty-five sites, the forty original control sites and five undisturbed sites. Section one is also an introduction to the multivariate methods used to classify sites and examine relationships between groups. Section two presents and discusses the MVA analyses for the full data set of 120 sites. Section three examines the overstory structural characteristics of the sites with respect to the cluster groups formed from the full data set analyses. Section three also examines the data collected on site characteristics with respect to the cluster groups. Section four presents and discusses differences in growth and mortality between cluster groups. The final section examines the effects of thinning on growth and mortality.

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Initial Analyses

Cluster Techniques

Based on the results of the two hierarchical cluster techniques, five major groups and one minor group were identified. See Appendix F for SAS output, including dendograms. Using a nonhierarchical technique, a range of groups from four to six were examined. With a *k* of six, all six groups identified in the hierarchical techniques were present, based on the species composition of each cluster. Thirty of the initial forty-five sites clustered consistently into the five major groups (Table 6). These thirty sites are referred to as "core" sites and are considered as representing discrete points along a species-site continuum (Grigal and Goldstein 1971, Goldstein and Grigal 1972). The minor group consisted of only two sites and was not treated as a core site group. Based on the criteria outlined previously, three species were determined to be characteristic of the four Group One sites, including *Bursera simaruba* with 44.0% of the basal area, on average. *Exostema caribaeum* (8.0%) and *Guaiacum officinale* (1.9%) were of secondary importance. In Group Two, also with four sites, *Phyllostylon brasiliensis* (23.1%) and *Prosopis juliflora* (20.9%) represented the largest proportions of the basal area. *Pithecellobium circinale* (9.8%), *Maytenus buxifolia* (6.0%), *Guaiacum officinale* (2.4%) and *Coccoloba leoganensis* (2.0%) were secondary species. Group Three, with eight sites, was dominated by *Acacia scleroxyla* (44.5%) and *Exostema caribaeum* (20.6%). *Trichilia pallida* (6.9%) was a secondary characteristic species.

Table 6 Results of two hierarchical cluster techniques and three versions of SAS Fastclus on species data from a subset of 45 sites from subtropical dry forest in the Dominican Republic. The first digit in the ID number indicates the block number (1 through 4). The second and the third digit represent the site number (1 through 30 for each block). Group indicates the cluster designation assigned based on the five tests. Numbers indicate sites consistent across all cluster techniques. Letters indicate the core group with which the site was most closely associated (i.e. "A" indicates a site which clustered most consistently in cluster Group One, etc.)

ID	Group	Flexible Beta	Ward's	Fastclus k=4	Fastclus k=5	Fastclus k=6
101	E	5	5	3	5	2
102	2	2	2	2	2	2
103	E	2	5	5	5	2
104	4	4	4	4	4	4
105	4	4	4	4	4	4
110	5	5	5	5	5	5
126	1	1	1	2	1	1
127	6	6	0	2	2	6
128	5	5	5	5	5	5
129	2	2	2	2	2	2
130	E	2	2	5	5	5
206	5	5	5	5	5	5
207	3	3	3	3	3	3
208	3	3	3	3	3	3
209	3	3	3	3	3	3
210	3	3	3	3	3	3
212	3	3	3	3	3	3
213	1	1	1	2	1	1
214	E	5	5	3	5	2
215	C	5	5	3	3	3
221	5	5	5	5	5	5
222	C	3	3	2	2	3
223	3	3	3	3	3	3
224	3	3	3	3	3	3
225	3	3	3	3	3	3
301	B	2	2	2	1	1

Table 6, continued

ID	Group	Flexible Beta	Ward's	Fastclus k=4	Fastclus k=5	Fastclus k=6
302	1	1	1	2	1	1
303	D	2	2	4	4	4
304	4	4	4	4	4	4
305	D	2	2	4	4	4
316	B	2	2	4	2	2
317	B	2	2	4	2	2
318	B	2	2	4	2	2
319	2	2	2	2	2	2
320	5	5	5	5	5	5
401	4	4	4	4	4	4
402	4	4	4	4	4	4
403	4	4	4	4	4	4
404	4	4	4	4	4	4
405	D	2	2	4	4	4
426	6	6	0	2	2	6
427	5	5	5	5	5	5
428	2	2	2	2	2	2
429	1	1	1	2	1	1
430	5	5	5	5	5	5

Group Four, with seven sites, was dominated by *Phyllostylon brasiliensis*, with 73% of the total basal area. *Capparis cynophallophora* (3.3%) was a secondary species. Group Five consisted of seven sites, in which *Caesalpinia coriaria* dominated with 43.6% of the basal area on average. *Capparis flexuosa* (7.4%), *Cassia emarginata* (6.9%) and *Acacia farnesiana* (3.8%) were also characteristic. Table 7 summarizes the species compositions of each group.

Correspondence Analyses

Correspondence analysis (CA) was the next step in the analysis of the initial forty-five sites. Correspondence analysis is used here to examine the relationships between sites as expressed by the cluster analyses and to explore species relationships more explicitly. Since CA assumes that all sites and species, respectively, are independent, no *a priori* reason exists for patterns observed in the previous analyses should be repeated. Because the data used in the correspondence analyses do not meet the strict definition of chi-square distributions (i.e. continuous versus interval data), the emphasis in interpretation will be on direction rather than distance. However, the relative difference of within group spacing versus the spacing between groups will be used as an estimate of the quality of groups formed using cluster analyses. For groupings of sites which are consistent with the results of cluster techniques, the relationships between species and between sites will be examined for implications in terms of underlying environmental factors.

Table 7 Average species composition of the six groups determined for 30 core sites showing consistent membership across cluster techniques. Order of species follows the first dimension of correspondence analysis. Order of the five main groups is based on the first canonical axis of canonical discriminant analysis.

Species	Group 5 (n=7)		Group 2 (n=4)		Group 3 (n=8)		Group 4 (n=7)		Group 1 (n=4)		Total means (n=45)	
	Mean (%)	S.D.	**Mean (%)**	S.D.	**Mean (%)**	S.D.	**Mean (%)**	S.D.	**Mean (%)**	S.D.	**Mean**	S.D.
Coccoloba leoganensis	**0.1**	0.4	**2.0**	3.9	**0.0**	0.0	**0.9**	2.4	**0.8**	1.7	**1.7**	6.2
Prosopis juliflora	**4.6**	8.8	**20.9**	15.1	**0.0**	0.0	**3.7**	4.7	**0.5**	1.0	**5.4**	9.5
Acacia farnesiana	**3.8**	3.9	**0.0**	0.0	**0.0**	0.0	**0.1**	0.4	**0.4**	0.7	**2.9**	8.8
Phyllostylon brasiliensis	**8.2**	10.2	**23.1**	1.2	**2.9**	5.7	**73.2**	11.7	**14.5**	15.1	**24.8**	26.0
Capparis cynophallophora	**0.0**	0.0	**1.8**	3.7	**1.3**	2.0	**3.3**	5.7	**0.4**	0.5	**2.2**	6.5
Capparis flexuosa	**7.4**	8.9	**2.9**	5.7	**0.0**	0.0	**0.7**	1.2	**2.3**	4.6	**2.4**	5.1
Cassia emarginata	**6.9**	5.1	**6.0**	9.7	**1.4**	3.2	**3.8**	6.3	**9.4**	9.1	**5.8**	7.5
Pithecellobium circinale	**2.4**	4.1	**9.8**	7.8	**1.9**	3.9	**2.3**	3.9	**1.3**	2.3	**3.2**	5.0
Guaiacum officinale	**0.7**	1.1	**2.4**	1.9	**1.4**	1.8	**2.6**	3.1	**1.9**	1.4	**1.9**	2.4
Lasianthus lanceolatus	**1.2**	2.3	**0.7**	1.5	**0.1**	1.1	**0.3**	0.7	**1.1**	1.7	**1.8**	4.3
Bursera simaruba	**0.0**	0.0	**0.8**	1.6	**0.4**	0.8	**1.2**	2.1	**44.0**	8.3	**5.1**	13.0
Caesalpinia coriaria	**43.6**	10.9	**0.6**	1.2	**7.3**	9.3	**4.6**	7.8	**1.2**	1.4	**12.1**	16.9
Maytenus buxifolia	**3.9**	6.1	**6.0**	6.0	**3.3**	7.5	**0.2**	0.7	**0.6**	0.7	**2.2**	5.1
Exostema caribaeum	**3.8**	8.5	**1.4**	2.8	**20.6**	11.1	**0.6**	1.0	**8.0**	7.9	**7.1**	9.8
Trichilia pallida	**1.9**	3.3	**0.0**	0.0	**6.9**	5.3	**0.1**	0.2	**1.2**	1.3	**2.4**	4.3
Acacia scleroxyla	**5.5**	10.5	**0.0**	0.0	**44.5**	11.9	**0.0**	0.0	**7.3**	10.2	**10.7**	18.0

In Figure 3, the site scores are plotted for the first two dimensions of a CA applied to the thirty core sites representing five cluster groups. Site and species scores are listed in Appendix G. Figure 3 shows that the spread between sites within groups One, Three and Four is relatively small, while spaces between groups are relatively "clean." Pielou (1969), Grigal and Goldstein (1971) and Digby and Kempton (1987) suggest that classification systems can recognize discrete points along a continuous species-site gradient, or gradients. Correspondence analysis is inherently an ordinal technique, rather than a method of classification. The results of CA using the thirty core sites representing five groups supports the concept that three of the five main cluster groups represent discrete points along a species-site continuum dominating the ISA-Mao forest. While Group Five sites suggest a less cohesive relationship within the group, there is no overlap with the spaces occupied by other sites. This suggests that Group Five sites also represent a discrete position. Group Two sites, on the other hand, cluster relatively closely, but the space they occupy overlaps with group four sites. This suggests that sites classified as Group Two represent more complex relationships than the other groups- relationships which may be continuous, rather than discrete.

An important advantage of correspondence analysis is its ability to capture a significant proportion of the variance in the data set in a few dimensions. Table 8 lists the singular values for each of the fifteen dimensions necessary to represent all of the data variance. In the first two dimensions of the CA procedure, a total

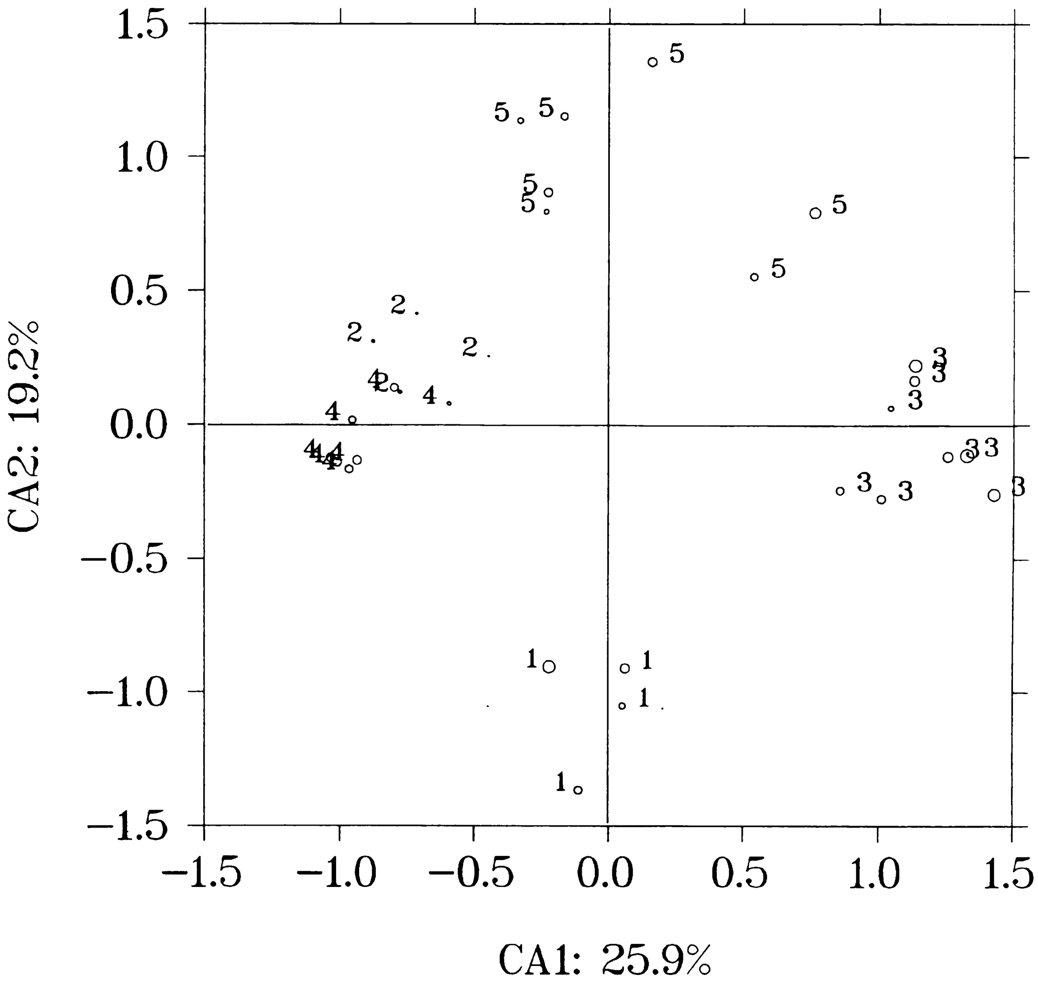

Figure 3 Positions of thirty subplots from the ISA-Mao silvicultural study along the first two principal axes of a correspondence analysis. 45.1% of the total variance is explained by the first two of fifteen axes. Analysis used basal area contributions of sixteen species. The size of the plotting symbol is proportional to the sum of the squared cosines in two dimensions. The label indicates the cluster group assigned to each site using three cluster techniques.

Table 8 Singular values, principal inertias and proportional representation for each of fifteen dimensions of a correspondence analysis of sixteen species and thirty sites representing core cluster group sites.

Dimension	Singular Values	Principal inertias	Percent	Accumulative percentage
1	0.77763	0.60471	25.90	25.90
2	0.6693	0.44881	19.22	45.12
3	0.62099	0.38562	16.52	61.64
4	0.49850	0.24850	10.64	72.28
5	0.3692	0.13662	5.85	78.13
6	0.32383	0.10487	4.49	82.62
7	0.31414	0.09868	4.23	86.85
8	0.29566	0.08741	3.74	90.59
9	0.24682	0.06092	2.61	93.2
10	0.21163	0.04479	1.92	95.12
11	0.19412	0.03768	1.61	96.73
12	0.16594	0.02754	1.18	97.91
13	0.15726	0.02473	1.06	98.97
14	0.11476	0.01317	0.56	99.53
15	0.10361	0.01074	0.46	99.99
		2.33479		

of 45.1% of the total variation is represented. This proportion is referred to as the display quality of the graph. Fifty-five percent (54.9%) is not represented. This is the display error. Relative to the challenge of displaying each site using all sixteen species variables, Figure 3 represents an improvement for a reasonable analysis of the data. However, although patterns observed are consistent with the previous analyses, the unexplained proportion of the data could represent serious glitches for interpretations.

The quality of representation usually differs between sites and species within each dimension. The total variance explained in one dimension can be defined as the sum of the individual variances attributable to each of the points in that dimension. Therefore, the variance explained for one point in that dimension can be defined as a proportion of the sum of all the variances attributable to that point across all dimensions. The squared cosine associated with a site or a species represents the variance explained in a particular dimension for a particular site or species in that dimension. The squared cosines associated with a site (or a species) sum to one across all dimensions. The squared cosine in a given dimension therefore represents the proportion of variance explained for that site or species (Greenacre 1993).

In Figure 3, the size of each plotting symbol is proportional to the summed values of the squared cosines for the first two dimensions. The median value for Group Three sites is 60.9%. For Group One sites, the median value is 52.5%. For

Group Four sites, the median value is 48.5%. The median value is 44.7% for Group Five sites and 15.9% for Group Two sites. These values indicate that the display qualities for Group Three sites are relatively good, even though the overall quality of the graph is relatively poor (display error equals 54.9%). On the other hand, the display qualities for Group Two sites are very bad (the display error is over 80% for two of the sites). Display qualities for the other sites are intermediate.

If we add the third dimension to the graphical display of the thirty core sites, we increase the display quality to 61.6%. Figure 4 represents the positions of the thirty core sites in three-dimensions. The median of the summed cosine values for Group One sites is now 86.9%. The median for Group Three sites is 71.1%, for Group Four sites it is 69.6% and for Group Five sites, 61.1%. The median value for Group Two sites is still a very low 17.3%. The relationships among Group Two sites appear to be complex- many dimensions would be necessary to describe the precise position of each of these sites. Nevertheless, in three dimensions, Group Two sites still cluster together. The relationships within and between groups One, Three, Four and Five are represented fairly well by three dimensions. Scatter within Group Four sites is still relatively small. Scatter within the other groups has increased, but groups One, Three, Four and Five still appear to occupy discrete areas of space. Based on the results of correspondence analysis using thirty core sites, the combined use of five cluster analyses appears to have captured nonrandom patterns inherent in the data.

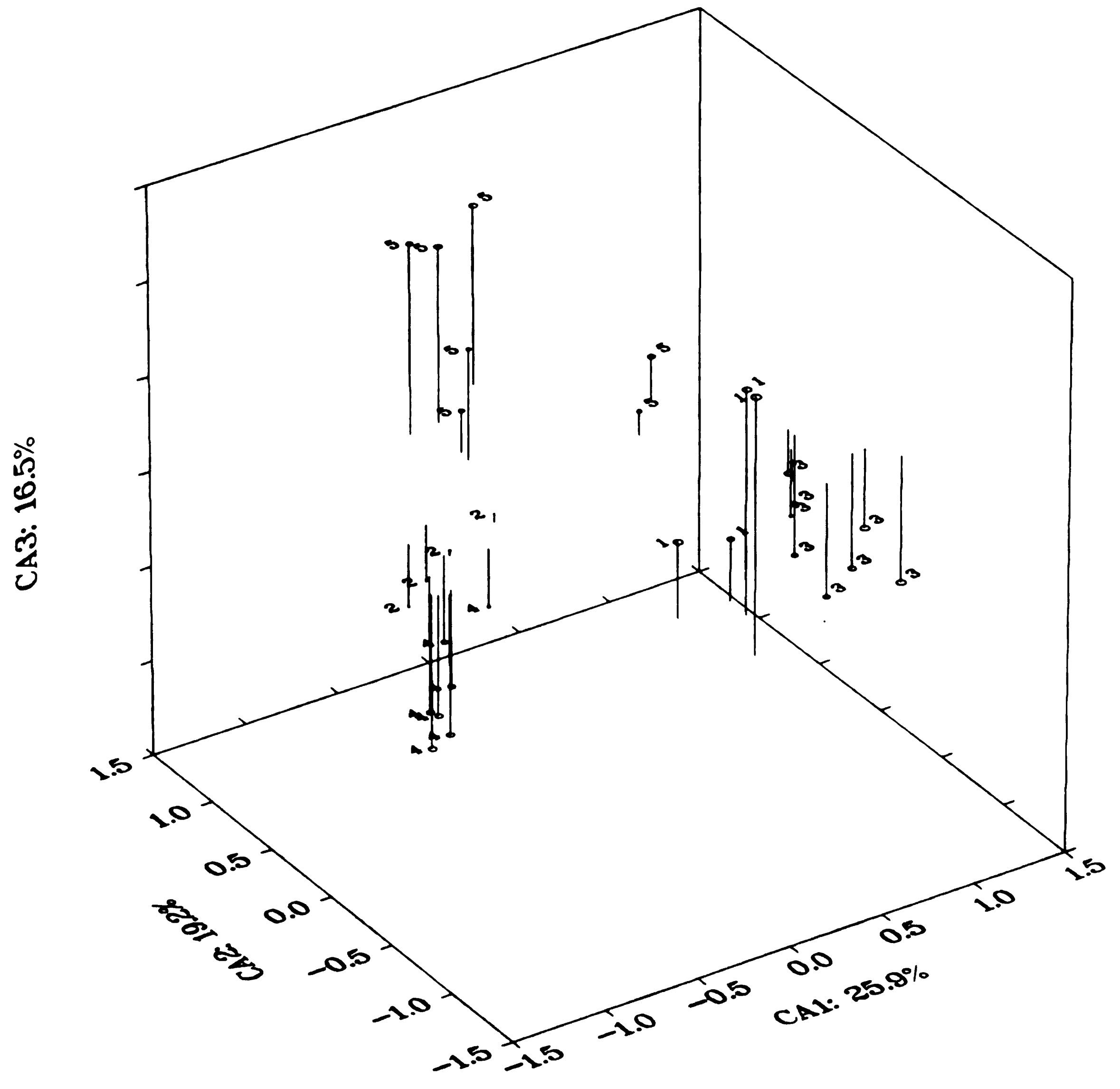

Figure 4 Position of thirty core sites in three dimensions of a correspondence analysis using the basal are contributions of sixteen species. The size of each plotting symbol is proportional to the sum of the squared cosines in three dimensions. The label indicates the cluster designation given based on five cluster analyses using the relative basal area contributions of sixteen species. The length of each spike is proportional to the distance from zero along the third axis. Sixty-two percent (61.6%) of the total variation is accounted for by the three dimensions.

Given that groupings of sites observed in CA correspond with groupings formed from cluster analyses, species relationships observed in CA should correspond with species selected as characteristic of each cluster group. Figure 5 represents the position of each species plotted in two dimensions, in the same space as the sites. These positions can serve as a reference for interpreting the site scores as well as providing a description of interactions between species (Digby and Kempton 1987, Greenacre 1993). These positions correspond with some of the "characteristic species" listed for each cluster group. *Bursera simaruba* ("AL") is located at the extreme bottom, below the origin along the second axis, in the same position as Group One sites. *Phyllostylon brasiliensis* ("BA") and *Coccoloba leoganensis* ("UV") are located to the extreme right of the origin along the first axis, "near" the same area occupied by Group Two sites. *Prosopis juliflora* ("CM") and *Capparis flexuosa* are located to extreme right of the first axis and approximately half way up the second axis, also in the same area as Group Two sites. *Acacia scleroxyla* ("CA"), *Exostema caribaeum* ("QU") and *Trichilia pallida* ("PA") are grouped to the extreme left along the first axis, in the same position as Group Three sites. *P. brasiliensis* is located in the same position as Group Four sites. Towards the top, above the origin along the second axis, *Caesalpinia coriaria* ("GU"), *A. farnesiana* ("AR") and *Capparis flexuosa* ("MO") are in the same space occupied by Group Five sites. All of these relationships correspond with the species nominated as "characteristic" based on average basal area contributions within core cluster group sites. Several species are missing. *Guaiacum officinale* ("GY") is missing from Group One, *Pithecellobium circinale*

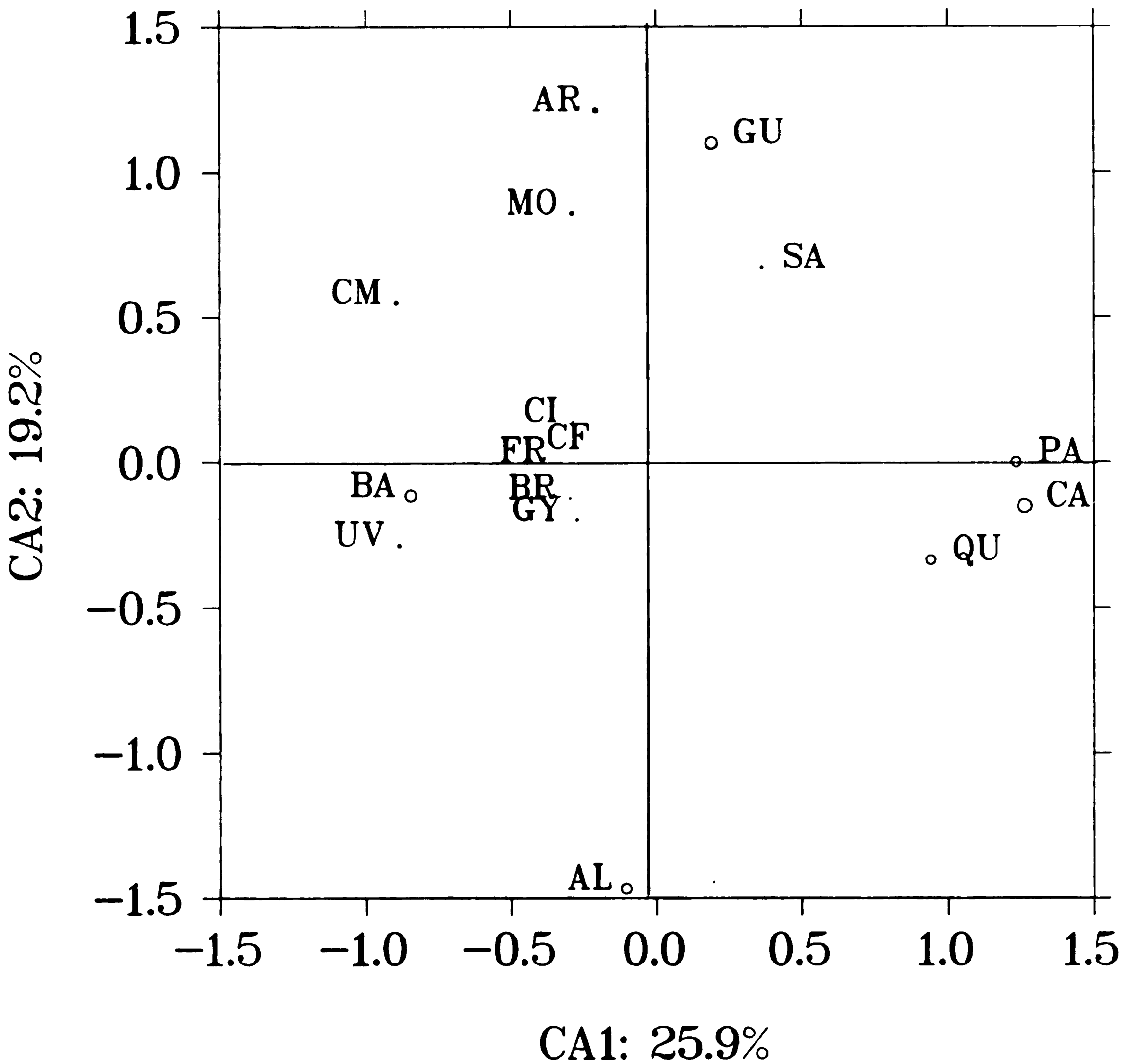

Figure 5 Position of sixteen species along the first two axes of correspondence analysis. Data comes from basal area contributions in 30 'core' plots in the ISA-Mao silvicultural study representing distinct species compositions. Plotting symbol is proportional to the sum of the squared cosines in two dimensions. Symbols are: UV= *C. leoganensis*, CM= *P. juliflora*, AR= *A. farnesiana*, BA= *P. brasiliensis*, FR= *C. cynophallophora*, MO= *C. flexuosa*, BR= *C. emarginata*, CI= *P. circinale*, GY= *G. officinale*, CF= *L. lanceolatus*, AL= *B. simaruba*, GU= *C. coriaria*, SA= *M. buxifolia*, QU= *E. caribaeum*, PA= *T. pallida*, CA= *A. scleroxyla*.

("CI") is missing from Group Two, *Capparis cynophallophora* ("FR") from Group Four and *Cassia emarginata* ("BR") from Group Five. However, all of the primary species correspond.

The problem with this interpretation of the species' orientations is the same as with the sites. The display error is over 50.0%. Therefore, limited confidence can be placed in the overall positions of the species. However, also like the site orientations, the display quality differs among the species. Based on the summed values of the cosines associated with each species in two dimension, the display quality for *A. scleroxyla* is 80%, 66% for *C. coriaria*, 64% for *P. brasiliensis*, 60% for *B. simaruba*, 51% for *E. caribaeum* and 53.4% for *T. pallida*. All other sums are less than 50%. Again, by adding a third dimension (Figure 6), we increase the overall display quality to 61.6%. Values for the above species increase to 92%, 83%, 92%, 97%, 53% and 59%, respectively. Summed values for all other species remain below 50%. Because the values for *A. scleroxyla*, *C. coriaria*, *P. brasiliensis* and *B. simaruba* are so high, we can be fairly confident in the significance of their relative positions in Figure 6. Comparing relative positions is harder in three dimensions, so species scores have been plotted together with site scores. *B. simaruba* is clearly associated with Group One sites, *A. scleroxyla* with Group Three sites, *P. brasiliensis* with Group Four sites and *C. coriaria* with Group Five sites. More over, although their display qualities are relatively low, *E. caribaeum* and *T. pallida* are still associated with Group Three sites and *A. farnesiana* and *C.*

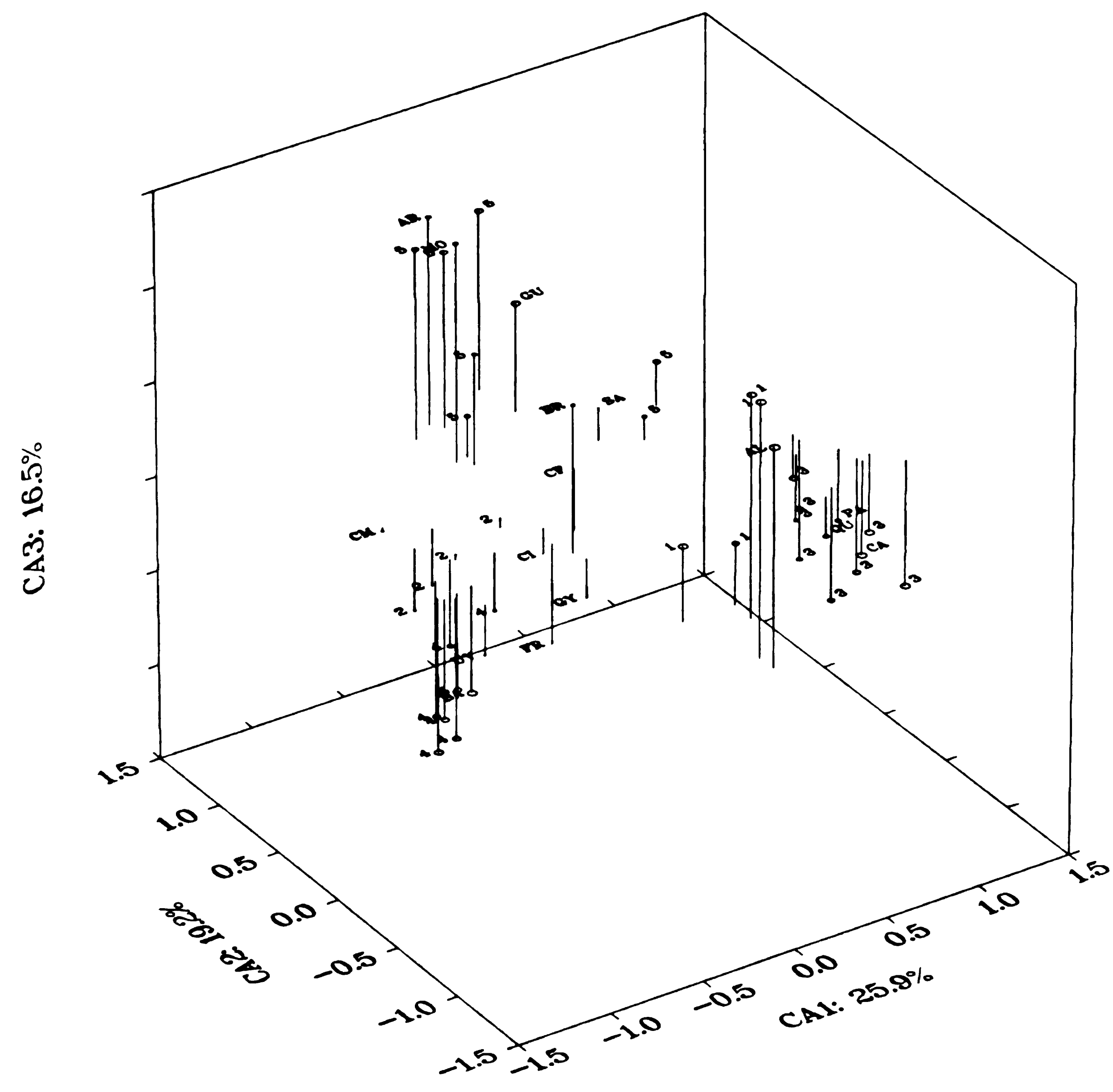

Figure 6 Positions of thirty sites and sixteen species in three dimensions based on a correspondence analysis. Analysis used basal area contributions of sixteen species. The size of the plotting symbol is proportional to the sum of the squared cosines in three dimensions. Numbers represent cluster group designation of each site. Letters indicate species. UV= *C. leoganensis*, CM= *P. juliflora*, AR= *A. farnesiana*, BA= *P. brasiliensis*, FR= *C. cynophallophora*, MO= *C. flexuosa*, BR= *C. emarginata*, CI= *P. circinale*, GY= *G. officinale*, CF= *L. lanceolatus*, AL= *B. simaruba*, GU= *C. coriaria*, SA= *M. buxifolia*, QU= *E. caribaeum*, PA= *T. pallida*, CA= *A. scleroxyla*. The length of each spike is proportional to the distance from zero along the third axis. Variance explained is 61.6% of the total.

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flexuosa are still associated with Group Five sites. None of the species are strongly associated with Group Two sites, although *P. juliflora* is located in the same area of space. This may reflect again the complexity of Group Two sites, which appear to represent a diversity of species loosely associated with *P. brasiliensis*.

The results of this correspondence analysis coincide both with the groupings of sites using five cluster analyses and with the species nominated as characteristic of the respective cluster groups. If the species are responding to underlying environmental or site history conditions, the relative positions of both the groups and the species could have ecological significance. The first axis suggests a contrast between sites dominated by *P. brasiliensis* versus those dominated by *A. scleroxyla*. The second axis suggests a contrast between sites dominated by *C. coriaria* versus those dominated by *B. simaruba*. Given multiple factors affecting species distributions, the first dimension suggests one factor which affects the relative dominance of *P. brasiliensis* and *A. scleroxyla*. The second dimension suggests a second factor which affects the relative dominance of *C. coriaria* and *B. simaruba*. These two factors appear to be independent, since the first axis does not separate groups One and Five, and the second dimension does not separate groups Three and Four. The third axis suggests a complication because both groups Three and Four are below the origin while both groups One and Five are above it. This third dimension (by itself) would suggest an association between groups One and Five (as does the first dimension) and between Three and Four (as do

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(as does the second dimension). Since the third dimension combines the effects of the first two dimensions, it may represent an interaction between hypothetical factors One and Two. Similar results have been found in other ecological studies using correspondence analysis (Digby and Kempton 1987, Fisher 1994).

A second correspondence analysis examined the relationships between both core and noncore sites. Figure 7 represents the positions of forty-five sites in two dimensions. Scores for sites and species are listed in Appendix G. Groups One and Three still occupy discrete areas of space. Group Five is intermixed with subgroup E, but remains spatially separate from the other groups. Group Four sites are intermixed with a number of other sites, but they remain "close" to each other. The relative positions of groups Three and Four and One and Five along the first and second axes remain the same. Group Two sites remain mixed with Group Four sites.

Table 9 lists the proportional representation of each of the sixteen dimensions for the second CA. The variation represented by two dimensions decreased to 35.1%. This suggests that species-site relationships are more complex when noncore sites are included in the analysis. The positions of the sites now suggest a continuous gradient, moving from Group One sites through sites representing Groups Four, Two and Five, arriving at Group Three sites at the opposite end of an arc. If core sites represent discrete points along a species continuum and noncore sites

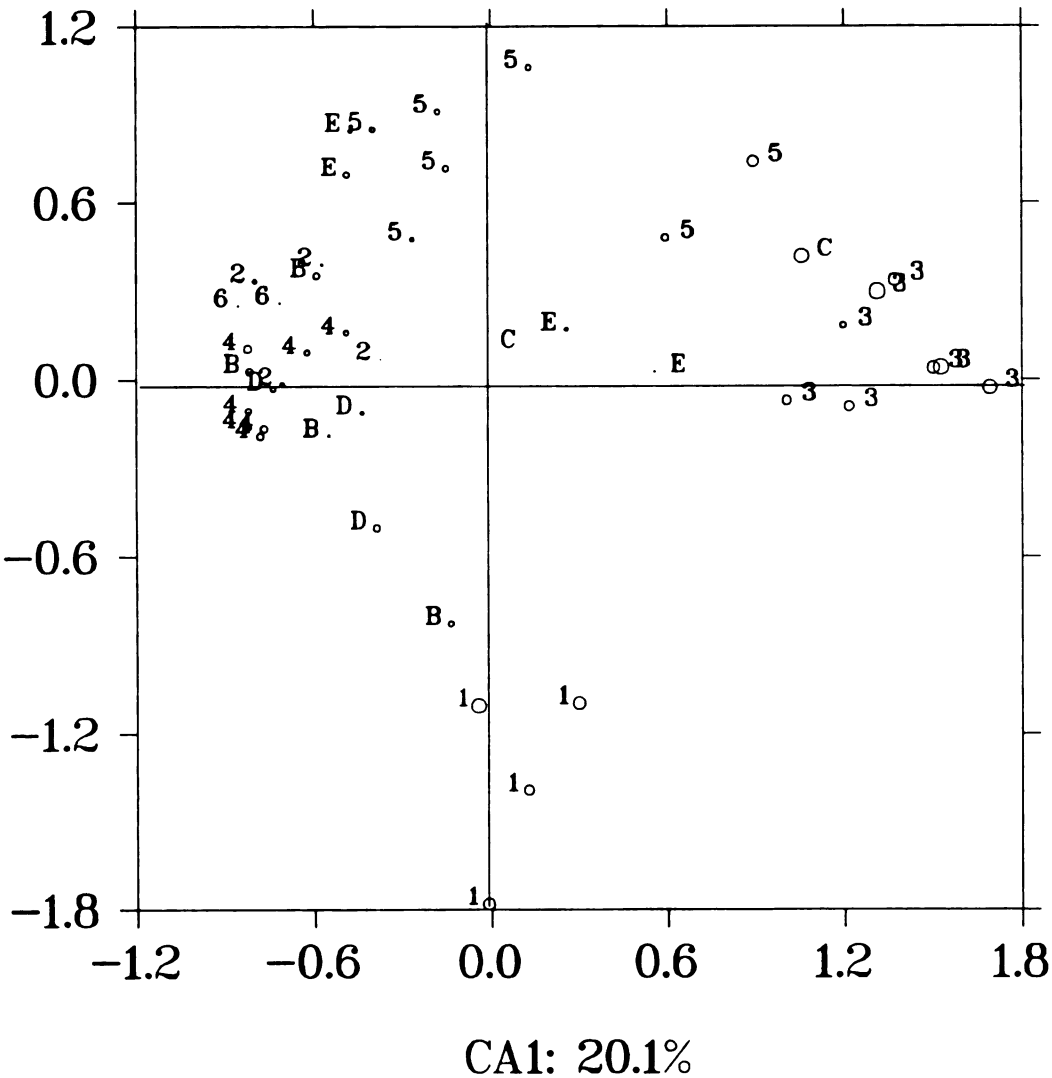

Figure 7 Position of forty-five sites from the ISA-Mao silvicultural study in the first two dimensions out of fifteen of a correspondence analysis. The analysis used the basal area contributions of sixteen dry forest species. The size of the plotting symbol is proportional to the sum of the squared cosines in two dimensions. The label indicates cluster group designations assigned using five different cluster analyses. Thirty-five percent (35.1%) of the total variance is represented by these two dimensions.

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Table 9 **Singular values, principal inertias and proportional representation for each of fifteen dimensions of a correspondence analysis of sixteen species and forty-five sites in the ISA-Mao silvicultural study.**

Dimension	Singular Values	Principal inertias	Percent	Accumulative percentage
1	0.74884	0.56076	20.09	20.09
2	0.64634	0.41776	14.97	35.06
3	0.58767	0.34535	12.37	47.43
4	0.54936	0.30179	10.81	58.24
5	0.52025	0.27066	9.70	67.94
6	0.43015	0.18503	6.63	74.57
7	0.38322	0.14685	5.26	79.83
8	0.37732	0.14237	5.10	84.93
9	0.35765	0.12797	4.58	89.51
10	0.30456	0.09276	3.32	92.83
11	0.26560	0.07055	2.53	95.36
12	0.21461	0.04606	1.65	97.01
13	0.20860	0.04351	1.56	98.57
14	0.14512	0.02106	0.75	99.32
15	0.13766	0.01895	0.68	100
		2.79137		

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represent the continuous points, more information (i.e. more axes) should be between the areas where distributions are discrete. More information is probably available from the additional axes, but two dimensions suffice to illustrate that the relationships between the core sites are not radically affected by including noncore sites in the analysis. Figure 8 illustrates the relationships between species in two dimensions using both core and noncore distributions. The relative positions of the minor species are somewhat different, but the positions of *P. brasiliensis*, *A. scleroxyla*, *C. coriaria* and *B. simaruba* remain the same.

Canonical Discriminant Analyses

Correspondence analysis confirmed that there is a strong relationship between sites within groups formed from the cluster techniques. Canonical discriminant analysis (CDA) can therefore be used with greater confidence to examine the relationships between these cluster groups. The use of CDA implicitly assumes that an individual site is a valid samples of a particular population, in this case, a cluster group. In these analyses, CDA is used as an ordination technique (Digby and Kempton 1987) rather than as a test of the significance of differences between groups. Probability tests would require multivariate normality within groups and homogeneity of variances between groups, neither of which was tested.

After removing all noncore sites from the initial analysis, the thirty remaining sites were analyzed with CDA. Plotting the first two canonical axes, 89% of the

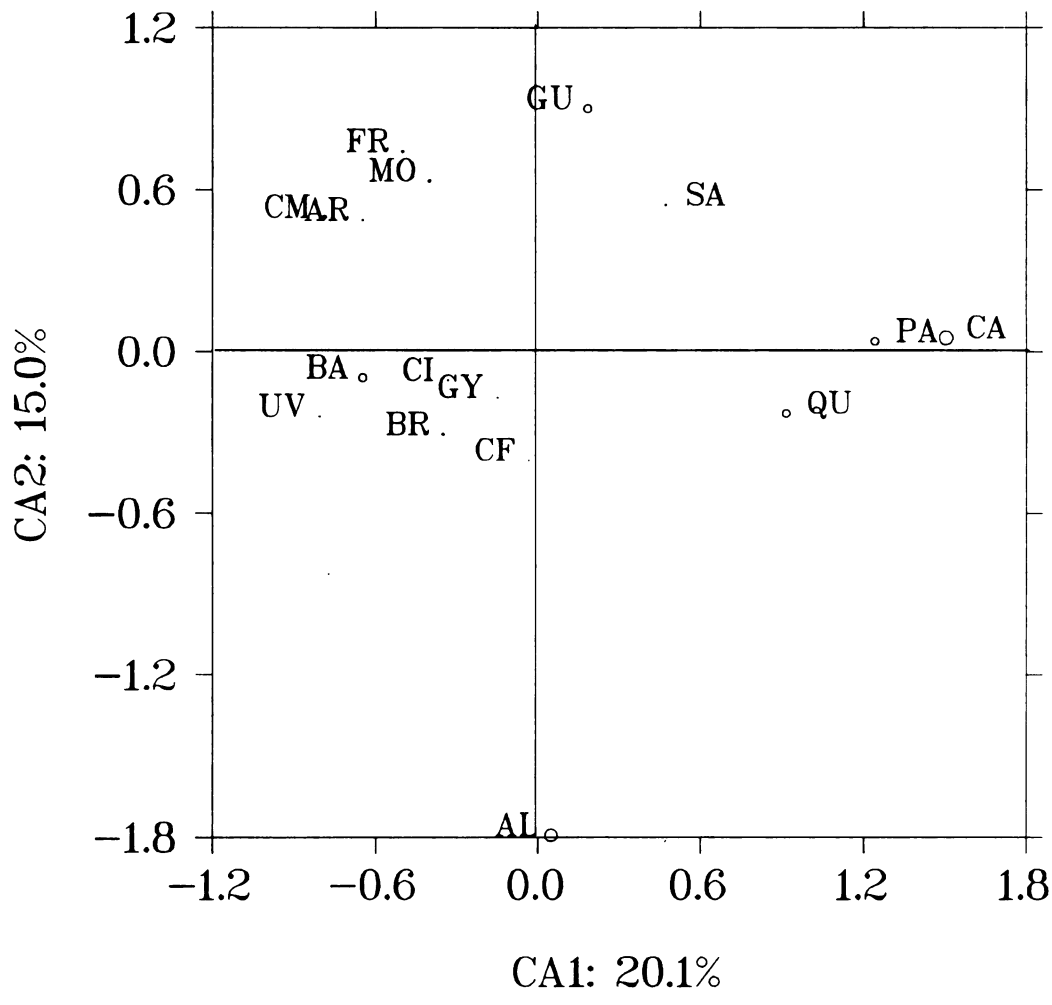

Figure 8 Position of sixteen species along the first two axes of correspondence analysis. 35.1% of the total variance explained in the first two of fifteen axes. Analysis used basal area contributions on 45 subplots from the ISA-Mao silvicultural study. The size of the plotting symbol is proportional to the sum of the squared cosines in two dimensions. Species code are: UV= *C. leoganensis*, CM= *P. juliflora*, AR= *A. farnesiana*, BA= *P. brasiliensis*, FR= *C. cynophallophora*, MO= *C. flexuosa*, BR= *C. emarginata*, CI= *P. circinale*, GY= *G. officinale*, CF= *L. lanceolatus*, AL= *B. simaruba*, GU= *C. coriaria*, SA= *M. buxifolia*, QU= *E. caribaeum*, PA= Palo amargo, CA= *A. scleroxyla*.

variance was explained (Figure 9). Scores are listed in Appendix H. Eigenvalues associated with each dimension are listed in Table 10. Groups One, Three and Four clearly separate from all other clusters. Groups Five and Two clearly separate out from groups Three and Four, but remain very close to each other. Grigal and Goldstein (1971) used canonical variate analysis to determine if site groupings formed using cluster analyses represented discrete groups in canonical space. The clear separation of groups One, Three, Four and Five reinforces the separation of these groups observed in CA. On the other hand, it would be reasonable to suggest that groups five and two were arbitrarily separated by the cluster techniques and in fact, the two groups should be considered as a single population. However, Grigal and Goldstein (1971) found that the groups which overlapped had common species associations. In this case, there are no "characteristic" species common between groups Two and Five. Therefore, there is no immediate suggestion of why groups Five and Two overlap. On the other hand, while the CDA procedure ensures that the first two axes are the best representation of the relationships apparent in the data, it does not guarantee that the axes represent the most important relationships. The remaining eleven percent of the variance unexplained in the first two axes may represent the most important differences between groups two and five, differences which are independent of the relationships expressed by the other four groups.

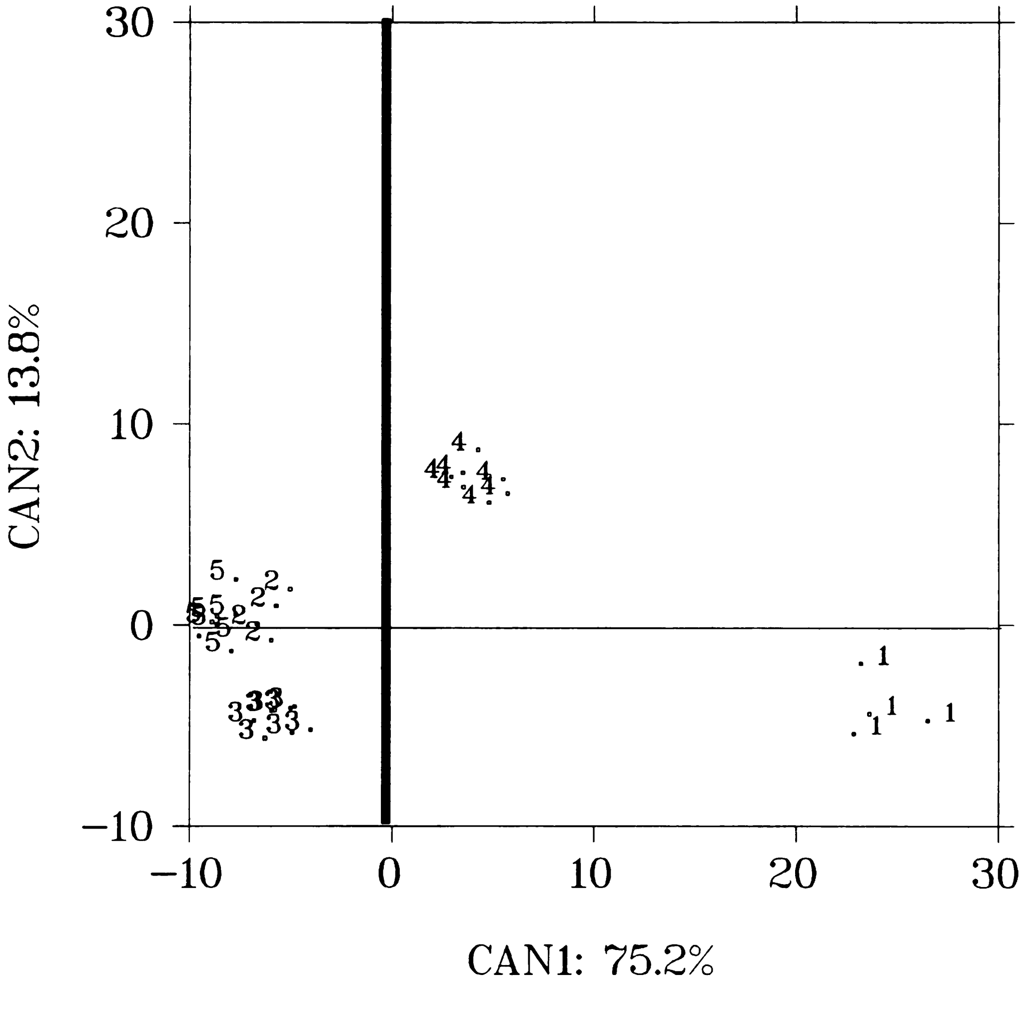

Figure 9 Position along first two canonical axes of thirty subplots from the ISA-Mao silvicultural thinning study. The thirty subplots represent five groups determined using three cluster analyses on data representing relative basal area contributions of sixteen dry forest species. Labels indicate cluster group designation. 89% of the total variance is explained by axes one and two.

Table 10 Eigenvalues associated with each axis of CDA applied to 16 species and 30 core sites representing five groups from the ISA-Mao silvicultural study.

Dimension	Eigenvalue	Percent	Cumulative
1	132.7587	75.19	75.19
2	24.3619	13.80	88.99
3	13.4948	7.64	96.63
4	5.9431	3.37	100

Representing 75% of the variation, the first dimension separates Groups One and Four from Groups Two, Three and Five. The second dimension separates Group Three from Groups Two and Five. The second dimension also places Group Four in the northeast quadrant formed by the juxtaposition of the two axes, Group Three in the southwest quadrant and Group One in the southeast. Grigal and Goldstein (1971) found that each of their core site clusters were positioned in a different quadrant in two dimensional canonical space. Site information indicated that these positions represented ecological extremes created by moisture and topographic relationships (Grigal and Goldstein 1971, Kercher and Goldstein 1978). In this case, Group One would represent the most extreme environmental characteristics based on its position at the extreme right of the primary axis. As in CA, groups Three and Four appear to represent a contrast with each other, positioned as they are in opposite quadrants. While Group One is at the furthest extreme along the first axis, its position in a quadrant between groups Three and Four represents a movement away from the origin that is independent of the relationships express by groups Three and Four.

The species composition of each group illustrates these relationships. Group Three is dominated by *A. scleroxyla* (44.5%) with very little *P. brasiliensis* (2.9%). Group Four is dominated by *P. brasiliensis* (73.2%) and has no *A. scleroxyla*. Group One, however, while dominated by *B. simaruba* (44.0%), includes both *P. brasiliensis* (14.5%) and *A. scleroxyla* (7.3%) (Table 7). Although Group Five does not clearly dominate the northwest quadrant, Group Five sites show the inverse pattern to Group One site. Group Five sites are dominated by *C. coriaria* (43.6%) with no *B. simaruba* while both *P. brasiliensis* (8.2%) and *A. scleroxyla* (5.5%) are represented. These contrasts between One and Five and Three and Four are identical to the relationships observed in the correspondence analyses. Two independent site factors would appear to control separately the relationships between species compositions in groups One and Five versus groups Three and Four.

To examine the effects of the noncore sites on CDA, these sites were temporarily designated the cluster group number with which they were most closely associated (*i.e.* sites designated as "D" were given the designation "4", etc.). The two sites designated as Group Six sites were removed. The remaining 43 sites were then submitted to CDA. The scores for each site are listed in Appendix H. Plotting the sites in two dimensions, 79.2% of the variance is illustrated in Figure 10. Eigenvalues associated with each dimension are listed in Table 11. Noncore sites are plotted with their original letter designations. With 20.8% of the variance unaccounted for, Figure 10 still represents a fairly good visual estimation of the

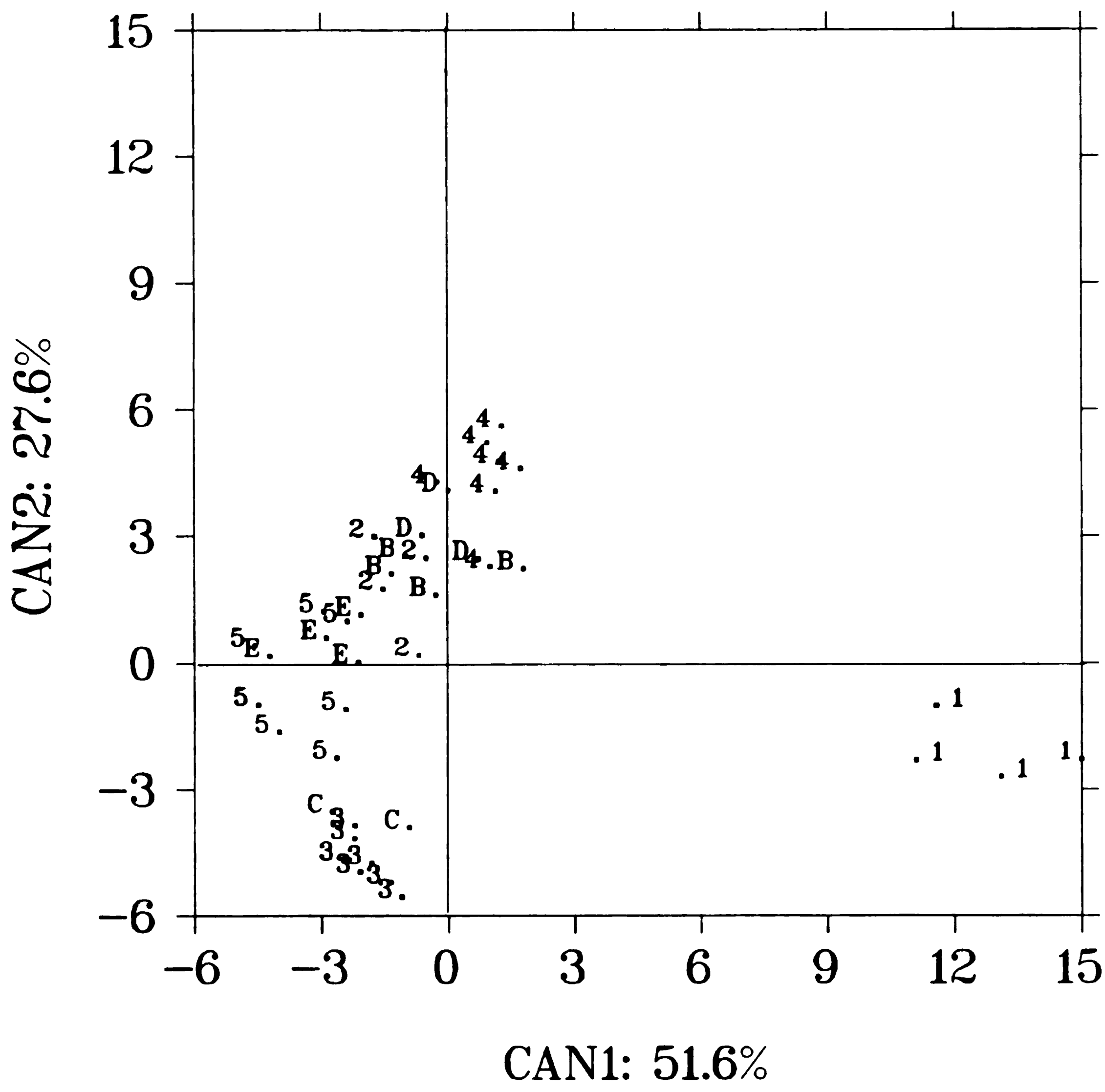

Figure 10 Position along first two canonical axes of forty-five sites from the ISA-Mao silvicultural thinning study. The forty-five sites represent five groups determined using three cluster techniques on data representing relative basal area contributions of sixteen dry forest species. Labels indicate cluster group designation. Numbers indicate core sites which clustered consistently across all techniques. Letters indicate sites which did not cluster consistently. 'B' represents sites clustering most often in group two, 'C' represents sites clustering in group three, 'D' in group four and 'E' in group five. 79.2% of the total variance is explained by axes one and two.

Table 11 Eigenvalues associated with each axis of CDA applied to 16 species and 45 sites representing five cluster groups.

Dimension	Eigenvalue	Percent	Cumulative
1	21.1195	51.61	51.61
2	11.3066	27.63	79.24
3	6.1641	15.06	94.3
4	2.3315	5.70	100

relationships between the groups, although not as good as the previous CDA plot. As in CA, including sites which may represent continuous species distributions increases the complexity implicit in the data, making more information (more axes) necessary to describe the precise position of each group.

In this analysis, Group One is still positioned to the extreme right of the first axis. Group Three still dominates along the lowest portion of the second axis. However, the ordination of sites in groups Two, Three, Four and Five suggests a continuum, with Group Three sites towards the bottom, Group Four sites towards the top, and groups Five and Two in between. Unlike the previous CDA, the separation between each of these groups is "fuzzy". The two site factors suggested by CA would also apply to this CDA procedure. However, one factor would appear to determine the dominance by *B. simaruba* while a second factor would result in a continuum of species distributions, moving from *A. scleroxyla* through *C. coriaria* and a mix of other species, to *P. brasiliensis* at the opposite extreme. In CA, the continuum could be described as moving from *A. scleroxyla* to *C. coriaria* to *P. brasiliensis* to *B. simaruba* at the opposite extreme.

If a great deal were known about the ecology of the species used in these analyses, inferences could be drawn about the relative positions of each cluster group. Conversely, if more were known about moisture relationships across the ISA-Mao landscape, inferences could be made with respect to the ecology of each species. As mentioned previously, very little information is available in either of these areas. What is known, is that soil depths and topography vary a great deal across the landscape. Soil and topography are closely interrelated and together affect moisture relationships which in turn affect species distributions and relative site quality. What has also been observed is that the relative intensity of disturbance also differs from area to area, and even from site to site (Powell and Mercedes 1986). Disturbance is also known to affect species distributions, and if sufficiently severe, may result in site degradation and reduce relative productivity. Given that both relative moisture availability (as it relates to topography and soils) and disturbance history are known factors within the ISA-Mao silvicultural study, the following suggests a relationships between four of the cluster groups.

	Undisturbed	Disturbed
Moist	Group 5	Group 4
Dry	Group 3	Group 1

The positions of the cluster groups in this model are consistent with their positions both in CA and CDA. However, a great deal of additional information would be necessary to test the model's viability.

Summary

Several observations are worth emphasizing at this point: (1) Patterns of species compositions can be described for a subset of the silvicultural study sites. Based on a series of cluster analyses, two-thirds of the sites can be assigned to of one of five groups, each representing a unique species composition. (2) These groupings are consistent with an independent analysis using CA. (3) Three of the five groups occupy discrete areas of canonical space, while two of the groups overlap. (4) The positions of four of these groups can be interpreted by comparing their relative positions using CA and CDA, and by comparing the relationships between species characteristic of each group. The results of the same procedures applied to 120 sites will be examined next.

Full Data Set Analyses

Cluster Techniques

With some basic patterns of species composition established using a subset of the data set, the full data set was then analyzed, beginning with the same cluster analyses described earlier. See Appendix F for output from SAS for the two hierarchical classifications. The cluster group classifications established in the initial analyses served as markers for the groupings of sites exhibited in the new analyses. Based on the two hierarchical methods and two versions of the nonhierarchical technique (k=7 and k=8), eight groups were identified. Of the eight groups identified, six were represented in each of the four methods. Sixty-seven sites clustered consistently into one or another of these six groups. These sites are those referred to as "core" in subsequent analyses and are designated with the corresponding cluster group number. Letters indicate "noncore" sites and represent the core cluster group with which a site is most closely associated. Two sites clustered with a different group in each analysis and are therefore designated with an "X" (Table 12). Of the eight cluster groups identified in the initial analyses, four corresponded to the major groups identified in the partial data set analyses based on species composition. Groups One (*B. simaruba*), Three (*A. scleroxyla*), Four (*P. brasiliensis*) and Five (*C. coriaria*) were clearly represented by the new results. Group Six (*A. farnesiana*) corresponds with a minor group of two sites formed from the initial analyses. The species composition for each group based on the core sites is given in Table 13.

Table 12 Results of two hierarchical cluster techniques and two versions of SAS Fastclus applied to species data from 120 sites in a subtropical dry forest in the Dominican Republic. The first digit in the ID number indicates the block number (1 through 4). The second and third digit represent the subplot number (1 through 30 for each block). Final Group indicates the cluster designation assigned based on the four cluster techniques applied to all 120 sites. Numbers indicate sites which clustered consistently across all techniques, referred to as "core" sites. Letters indicate non core sites. Each letter designation is associated with a core cluster designation. I.e. "A" is associated with sites which clustered in Group One more than once. "B" is associated with sites that clustered in Group Two more than once, etc. A double letter designation indicates that a site clustered in one group twice and in another group twice. Initial Group indicates the group designation assigned based on initial analyses using a subset of 45 sites. *NA* indicates sites not in the initial analyses.

ID	Final Group	Initial Group	Ward's	Flexible Beta	Fastclus k=6	Fastclus k=7
101	BG	E	2	2	7	7
102	7	2	7	7	7	7
103	BG	E	2	2	7	7
104	D	4	4	2	4	4
105	BD	4	2	2	4	4
106	BD	*NA*	2	2	4	4
107	C	*NA*	5	3	3	3
108	BG	*NA*	2	2	7	7
109	4	*NA*	4	4	4	4
110	5	5	5	5	5	5
111	D	*NA*	4	2	4	4
112	4	*NA*	4	4	4	4
113	D	*NA*	4	2	4	4
114	D	*NA*	4	2	4	4
115	FG	*NA*	6	7	7	6
116	BG	*NA*	2	2	7	7
117	D	*NA*	4	2	4	4
118	1	1	1	1	1	1
119	5	*NA*	5	5	5	5
120	3	*NA*	3	3	3	3
121	E	*NA*	5	5	5	6
122	D	*NA*	4	2	4	4
123	EH	*NA*	5	5	8	8

Table 12, continued

ID	Final Group	Initial Group	Ward's	Flexible Beta	Fastclus k=6	Fastclus k=7
124	6	*NA*	6	6	5	6
125	E	*NA*	5	5	5	6
126	1	1	1	1	1	1
127	6	6	6	6	8	6
128	E	5	5	5	5	6
129	G	2	2	7	7	6
130	E	E	5	5	5	6
201	3	*NA*	3	3	3	3
202	3	*NA*	3	3	3	3
203	3	*NA*	3	3	3	3
204	BG	*NA*	2	2	7	7
205	3	*NA*	3	3	3	3
206	E	5	5	3	5	5
207	3	3	3	3	3	3
208	3	3	3	3	3	3
209	3	3	3	3	3	3
210	3	3	3	3	3	3
211	3	*NA*	3	3	3	3
212	3	3	3	3	3	3
213	1	1	1	1	1	1
214	X	E	5	3	7	6
215	C	C	5	3	3	3
216	1	*NA*	1	1	1	1
217	3	*NA*	3	3	3	3
218	1	*NA*	1	1	1	1
219	C	*NA*	5	3	3	3
220	7	*NA*	7	7	7	7
221	E	5	5	3	5	5
222	FG	C	6	7	7	6
223	3	3	3	3	3	3

Table 12, continued

ID	Group	Initial Group	Flexible Beta	Ward's	Fastclus k=6	Fastclus k=7
224	3	3	3	3	3	3
225	3	3	3	3	3	3
226	3	*NA*	3	3	3	3
227	1	*NA*	1	1	1	1
228	7	*NA*	7	7	7	7
229	3	*NA*	3	3	3	3
230	1	*NA*	1	1	1	1
301	7	B	7	7	7	7
302	1	1	1	1	1	1
303	D	D	4	2	4	7
304	4	4	4	4	4	4
305	D	D	4	2	4	4
306	7	*NA*	7	7	7	7
307	6	*NA*	6	6	5	6
308	5	*NA*	5	5	5	5
309	5	*NA*	5	5	5	5
310	G	*NA*	7	7	7	6
311	E	*NA*	5	5	5	6
312	D	*NA*	4	2	4	4
313	B	*NA*	2	2	4	7
314	7	*NA*	7	7	7	7
315	7	*NA*	7	7	7	7
316	G	B	2	7	7	7
317	G	B	2	7	7	7
318	BG	B	2	2	7	7
319	G	2	2	7	7	8
320	5	5	5	5	5	5
321	1	*NA*	1	1	1	1
322	BG	*NA*	2	2	7	7

Table 12, continued

ID	Final Group	Initial Group	Flexible Beta	Ward's	Fastclus k=6	Fastclus k=7
323	7	*NA*	7	7	7	7
324	BG	*NA*	2	2	7	7
325	4	*NA*	4	4	4	4
326	7	*NA*	7	7	7	7
327	4	*NA*	4	4	4	4
328	7	*NA*	7	7	7	7
329	4	*NA*	4	4	4	4
330	FH	*NA*	6	6	8	8
401	4	4	4	4	4	4
402	4	4	4	4	4	4
403	D	4	4	2	4	4
404	4	4	4	4	4	4
405	D	D	4	2	4	4
406	3	*NA*	3	3	3	3
407	4	*NA*	4	4	4	4
408	B	*NA*	2	2	4	7
409	7	*NA*	7	7	7	7
410	5	*NA*	5	5	5	5
411	BG	*NA*	2	2	7	7
412	X	*NA*	2	5	7	8
413	D	*NA*	4	2	4	4
414	G	*NA*	6	7	7	1
415	B	*NA*	2	2	4	7
416	D	*NA*	4	2	4	4
417	7	*NA*	7	7	7	7
418	4	*NA*	4	4	4	4
419	7	*NA*	7	7	7	7
420	D	*NA*	4	2	4	4
421	1	*NA*	1	1	1	1
422	7	*NA*	7	7	7	7

Table 12, continued

ID	Final Group	Initial Group	Flexible Beta	Ward's	Fastclus k=6	Fastclus k=7
423	6	*NA*	6	6	7	6
424	A	*NA*	6	7	1	1
425	G	*NA*	6	7	7	7
426	6	6	6	6	7	6
427	5	5	5	5	5	5
428	G	2	2	7	7	6
429	1	1	1	1	1	1
430	5	5	5	5	5	5

Group Two was not consistently represented in all four clustering procedures. That is, the sites designated as Group Two sites in the initial analyses did not group together consistently across methods in the full data set analyses. Group Two was therefore not considered a viable cluster group. Although Group Two did not remain coherent in the new analyses, another cluster group appeared which had sites assigned together consistently across methods. This group was designated as Group Seven.

Species "characteristic" of each group formed were determined using the same criteria outlined in the methodology. Based on these criteria, species characteristic of Group One (n=11) are *B. simaruba* (46.7%) and *E. caribaeum* (7.3%). The dominant species in Group Three (n=18) is *A. scleroxyla* (44.2%). *E. caribaeum* (17.3%), *Maytenus buxifolia* (5.4%) and *T. pallida* (4.5%) are secondary species. The dominant species in Group Four (n=11) is *P. brasiliensis*,

Table 13 Average species composition of the six groups determined for 67 core subplots showing consistent membership across cluster techniques. Order of species follows the first dimension of correspondence analysis. Order of the groups is based on the first canonical axis of canonical discriminant analysis.

Species	Group 4 (n=11)		Group 7 (n=14)		Group 1 (n=11)		Group 5 (n=8)		Group 6 (n=5)		Group 3 (n=18)		Total means (n=120)	
	Mean (%)	S.D.	**Mean (%)**	S.D.	**Mean (%)**	S.D.	**Mean (%)**	S.D.	**Mean (%)**	S.D.	**Mean (%)**	S.D.	**Mean (%)**	S.D.
Phyllostylon brasiliensis	**79.6**	6.3	**28.8**	10.7	**12.3**	13.1	**12.6**	10.4	**3.2**	2.8	**3.2**	5.4	**26.6**	25.7
Prosopis juliflora	**2.7**	2.3	**0.3**	0.9	**0.2**	0.6	**2.4**	3.7	**10.5**	11.6	**0.0**	0.0	**4.4**	8.8
Acacia farnesiana	**2.1**	4.6	**1.4**	3.4	**0.9**	2.4	**5.8**	7.7	**35.2**	14.8	**0.0**	0.0	**3.5**	8.6
Coccoloba leoganensis	**0.7**	1.9	**1.0**	2.3	**0.4**	1.0	**0.1**	0.3	**16.8**	22.7	**0.0**	0.0	**1.7**	6.2
Lasianthus lanceolatus	**1.0**	2.9	**3.6**	6.0	**0.6**	1.2	**1.1**	2.2	**0.6**	0.8	**0.9**	3.0	**1.4**	3.5
Cassia emarginata	**6.7**	8.3	**5.8**	5.5	**3.8**	6.7	**6.3**	5.7	**6.0**	10.0	**2.0**	4.3	**5.4**	8.8
Pithecellobium circinale	**1.3**	1.8	**23.3**	11.9	**5.8**	9.7	**2.8**	3.5	**4.8**	6.6	**2.3**	3.5	**5.7**	9.3
Capparis flexuosa	**0.8**	1.6	**2.6**	4.4	**2.4**	3.6	**4.8**	6.8	**0.0**	0.0	**0.1**	0.3	**2.7**	5.1
Capparis cynophallophora	**0.6**	2.0	**0.9**	1.5	**0.6**	1.0	**0.0**	0.0	**1.2**	2.7	**1.0**	1.6	**2.1**	5.8
Bursera simaruba	**0.1**	0.2	**7.1**	7.4	**46.7**	12.6	**0.2**	0.6	**0.0**	0.0	**0.7**	2.3	**6.5**	14.3
Guaiacum officinale	**2.3**	2.6	**2.8**	4.1	**1.5**	1.3	**2.9**	3.4	**2.2**	4.1	**2.3**	2.7	**2.6**	4.0
Caesalpinia coriaria	**0.1**	0.5	**1.0**	2.3	**4.1**	5.9	**49.9**	17.8	**11.5**	12.3	**7.8**	9.4	**11.2**	15.9
Trichilia pallida	**0.3**	0.9	**2.9**	4.9	**1.3**	2.2	**0.0**	0.0	**0.0**	0.0	**4.5**	4.8	**1.6**	3.5
Maytenus buxifolia	**0.3**	1.1	**1.4**	3.4	**1.4**	1.4	**3.4**	5.7	**0.6**	1.3	**5.4**	8.1	**2.6**	5.6
Exostema caribaeum	**0.3**	0.7	**3.9**	4.4	**7.3**	5.5	**1.1**	1.4	**1.8**	3.9	**17.3**	12.0	**5.5**	8.6
Acacia scleroxyla	**0.0**	0.0	**1.6**	4.5	**5.3**	7.2	**1.1**	3.2	**0.0**	0.0	**44.2**	13.4	**8.8**	16.7

with 79.6% of the basal area on average. *Cassia emarginata* (6.7%) is a secondary species. Characteristic of Group Five (n=8) is *C. coriaria* (49.9%). *C. emarginata* (6.3%), *A. farnesiana* (5.8%) and *Guaiacum officinale* (2.9%) are secondary species. Dominating Group Six (n=5) is *A. farnesiana* (35.2%). *Coccoloba leoganensis* (16.8%), *C. coriaria* (11.5%), and *P. juliflora* (10.5%) are all important secondary species. *P. brasiliensis* (28.8%) and *Pithecellobium circinale* (23.3%) are the two most dominant species in Group Seven (n=14). *B. simaruba* (7.1%) and *Lasianthus lanceolatus* (3.6%) were secondary species.

Because only half of the sites in the silvicultural study could be classified into a distinct cluster group, the noncore sites will also be examined to provide insight into the species-site relationships in the intermediate areas between the main cluster groups. Table 14 contains the species composition of six noncore cluster groups referred to here as "subgroups". Each of these six subgroups represents sites which showed the same clustering pattern (i.e. the Subgroup BG represents all the sites which clustered in Group Two twice and in Group Seven twice). The first criteria for picking characteristic species was somewhat more rigorous for noncore subgroups. To be nominated as characteristic, a species needed to represent an average basal area contribution three times greater within a subgroup than across all sites. The second criteria remained the same.

In the noncore groups, four species are characteristic of Subgroup B (n=3), including *P. brasiliensis* (44.8%), *C. coriaria* (17.8%), *G. officinale* (4.3%) and

Table 14 Average species composition of six subgroups. Each subgroup is represeented by noncore sites which showed the same clustering pattern. Letters are associated with the corresponding main cluster group (i.e. Subgroup D represents sites which clustered most frequently in group four). Order of species follows the first dimension of correspondence analysis. Order of the groups is based on the first canonical axis of canonical discriminant analysis applied to six core site cluster groups and seven subgroups represented by a total of 118 sites.

Species	Subgroup D (n=14)		Subgroup B (n=3)		Subgroup BG (n=9)		Subgroup G (n=8)		Subgroup E (n=7)		Subgroup C (n=3)		Total means (n=120)	
	Mean (%)	S.D.	**Mean (%)**	S.D.	**Mean (%)**	S.D.	**Mean (%)**	S.D.	**Mean (%)**	S.D.	**Mean (%)**	S.D.	**Mean (%)**	S.D.
Phyllostylon brasiliensis	**57.0**	7.6	**44.8**	2.1	**34.0**	5.4	**18.9**	13.9	**7.1**	8.8	**0.0**	0.0	**26.6**	25.7
Prosopis juliflora	**4.8**	7.0	**3.6**	3.5	**0.9**	2.1	**17.2**	12.5	**21.8**	15.3	**0.0**	0.0	**4.4**	8.8
Acacia farnesiana	**3.7**	6.6	**3.2**	3.0	**0.0**	0.0	**0.8**	1.7	**7.5**	8.6	**3.8**	3.6	**3.5**	8.6
Coccoloba leoganensis	**1.1**	2.1	**2.3**	3.9	**5.9**	10.0	**1.0**	2.8	**0.8**	2.0	**0.0**	0.0	**1.7**	6.2
Lasianthus lanceolatus	**0.9**	2.0	**1.1**	1.9	**1.9**	2.0	**1.9**	3.0	**0.0**	0.0	**0.0**	0.0	**1.4**	3.5
Cassia emarginata	**5.6**	8.7	**2.7**	4.7	**2.5**	4.8	**7.9**	6.6	**4.5**	4.6	**1.5**	1.7	**5.4**	8.8
Pithecellobium circinale	**2.0**	3.8	**5.0**	4.3	**5.0**	6.4	**9.8**	11.3	**1.3**	2.7	**2.0**	3.4	**5.7**	9.3
Capparis flexuosa	**5.6**	5.8	**2.6**	4.4	**2.3**	4.6	**3.5**	7.0	**2.9**	7.6	**8.9**	8.0	**2.7**	5.1
Capparis cynophallophora	**1.4**	2.9	**0.3**	0.6	**16.6**	13.8	**0.9**	2.6	**0.0**	0.0	**0.9**	1.5	**2.1**	5.8
Bursera simaruba	**4.2**	7.9	**0.0**	0.0	**4.6**	8.2	**2.5**	4.9	**0.0**	0.0	**0.0**	0.0	**6.5**	14.3
Guaiacum officinale	**1.8**	1.8	**4.3**	3.8	**2.9**	2.5	**2.0**	2.6	**0.6**	1.0	**7.5**	10.9	**2.6**	4.0
Caesalpinia coriaria	**3.4**	6.2	**17.8**	6.9	**9.3**	7.4	**5.5**	9.5	**38.0**	5.9	**25.1**	3.8	**11.2**	15.9
Trichilia pallida	**0.0**	0.0	**0.8**	1.4	**0.0**	0.0	**0.0**	0.0	**1.9**	3.3	**3.2**	5.6	**1.6**	3.5
Maytenus buxifolia	**2.9**	7.0	**2.4**	4.2	**0.4**	0.9	**6.5**	9.7	**1.2**	3.1	**0.8**	1.4	**2.6**	5.6
Exostema caribaeum	**2.0**	4.2	**0.0**	0.0	**3.4**	4.5	**2.9**	4.2	**3.3**	8.7	**17.3**	16.4	**5.5**	8.6
Acacia scleroxyla	**0.6**	2.1	**0.0**	0.0	**3.2**	6.4	**0.0**	0.0	**5.5**	10.5	**20.8**	7.7	**8.8**	16.7

Coccoloba leoganensis (2.3%). In Subgroup BG (n=9), *Phyllostylon brasiliensis* (34.0%), *Capparis cynophallophora* (16.6%), *Coccoloba leoganensis* (5.9%) *G. officinale* (2.9%) and *L. lanceolatus* (2.3%) are characteristic. In Subgroup C (n=3) *C. coriaria* (25.1%) and *A. scleroxyla* (20.8%) are dominant. *E. caribaeum* (17.3%), *Capparis flexuosa* (8.9%) and *A. farnesiana* (3.8%) are secondary species. Characteristic of Subgroup D (n=14) are *P. brasiliensis* (57.0%), *Cassia emarginata* (5.6%), *P. juliflora* (4.8%) and *A. farnesiana* (3.7%). In Subgroup E (n=7), *C. coriaria* (38.0%) and *Prosopis juliflora* (21.8%) are dominant. *A. farnesiana* (7.5%) and *T. pallida* (1.9%) are secondary species. Three species are characteristic of Subgroup G (n=8), *Prosopis juliflora* (17.2%), *Cassia emarginata* (7.9%) and *L. lanceolatus* (1.9%).

Among the four core site cluster groups which correspond to the initial analyses, there are some differences in the "secondary" species characteristic of each group. Group One lacks *Guaiacum officinale*, Group Four lacks *Capparis cynophallophora* and Group Five lacks *Capparis flexuosa*. A change in the data set affected the apparent associations suggested by the distributions of these species. This indicates the some of the patterns observed in the initial data set may have been a random pattern related to sample size (Pielou 1969). On the other hand, *E. caribaeum* is still a characteristic secondary species of groups One and Three, *T. pallida* is still characteristic of Group Three and *Cassia emarginata* and *A. farnesiana* are still characteristic of Group Five. The persistent presence of these species regardless of sample size indicates that their associations with their

respective groups may not be random. Including *P. brasiliensis*, *B. simaruba*, *Caesalpinia coriaria* and *A. scleroxyla*, this group of eight species may represent the most significant patterns of species distributions in the ISA-Mao forest.

Correspondence Analyses

Correspondence analysis is used next to examine the relationships between the sites within the cluster groups and to explore species relationships suggested in the previous section. The positions of core and noncore sites are examined to see if groupings of sites were apparent which correlate with those identified using cluster analyses. As noted previously, CA does not assume any structure within the data set. Therefore, there is no *a priori* exists for sites associated with a cluster group to plot in close proximity. As noted previously, because the data used in the CA procedure are continuous rather than interval, they do not meet the assumption of chi-square distributions normally used to interpret the results of CA. Therefore, the observed distances between points plotted using CA scores are not well-defined. Nevertheless, relative distances between points will be used to estimate the quality of site groupings formed using cluster analyses. The relative positions of the species will also be examined for associations with the respective cluster groups. For groupings of sites which are consistent with the results of the cluster techniques, the relationships between species and between sites will be examined for implications with respect to underlying environmental factors.

Figure 11 represents the position of 67 sites plotted with the first two principle axes of a CA procedure applied to the core sites. Scores for the sites and species are listed in Appendix I. The first two axes account for 37.9% of the total variation in the data set. The proportion of variance attributable to each axis is listed in Table 15. Although the first two axes account for a relatively small proportion of the total variance, the representation is still an improvement over using 15 axes (16 species less one degree of freedom: Greenacre 1993) to describe the precise position of each point. Based on 37.9% of the variation, the relationships between sites suggested by the cluster analyses are repeated. Sites within each cluster group plot in relatively close proximity to each other and each of these clusters is located in an area of space which is discrete relative to the other groups. Group Three sites represent the most discrete cluster. Groups Five and Six are well separated from the other groups, but suggest a loose association between each other. Likewise, groups One, Four and Seven appear to be associated, with little distance between Group Four and Group Seven, or Group Seven and Group One. Group Four sites appear to form the most tightly clustered group, while groups Five and Six have the "loosest" associations among sites within the respective groups.

As noted in the previous section, the display quality differs for each of the sites. Each cluster group seems to suggest a characteristic level of display quality for sites within a group. The median display quality for Group One sites is 38.0%, for Group Three, 67.4%, for Group Four, 43.2%, for Group Five, 39.4%, for

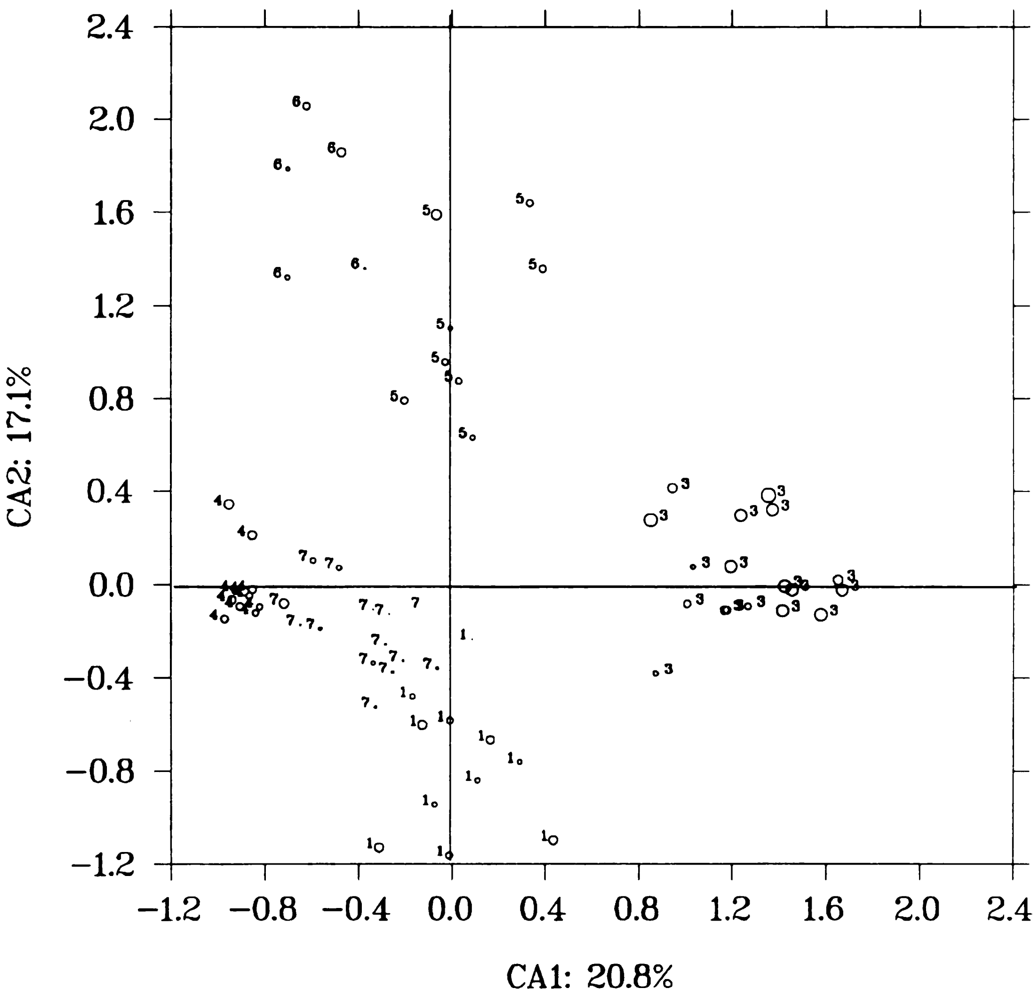

Figure 11 Positions of sites from the ISA-Mao silvicultural study based on their scores from the first two dimensions of a CA procedure using basal area contributions of sixteen species in the 67 core sites. The size of the plotting symbols are proportional to the sum of the squared cosines in two dimensions. Labels represent cluster groups designations. Thirty-eight percent (37.9%) of the total variance is represented by the first two dimensions.

Table 15 Singular values, principal inertias and proportional representation for each of fifteen dimensions of a correspondence analysis of sixteen species and sixty-seven sites representing core cluster group sites.

Dimension	Singular Values	Principal inertias	Percent	Accumulative percentage
1	0.75483	0.56976	20.78	20.78
2	0.68434	0.46832	17.08	37.86
3	0.61642	0.37998	13.86	51.72
4	0.56887	0.32361	11.80	63.52
5	0.46979	0.22070	8.05	71.57
6	0.43505	0.18927	6.90	78.47
7	0.34491	0.11896	4.34	82.81
8	0.30906	0.09552	3.48	86.29
9	0.29361	0.08621	3.14	89.43
10	0.27560	0.07596	2.77	92.2
11	0.25540	0.06523	2.38	94.58
12	0.23938	0.05730	2.09	96.67
13	0.19638	0.03857	1.41	98.08
14	0.17325	0.03002	1.09	99.17
15	0.15150	0.02295	0.84	100.01
		2.74235		

Group Six, 28.3% and for Group Seven, 14.8%. The relatively high values for Group Three sites indicate that the visual position of this group is a good representation of the information inherent in the data. Group Three sites are relatively homogeneous and they represent a species relationships unique among all of the sites. However, values for the other groups are poor, and an interpretation of their positions is difficult to verify based on only two dimensions.

Figure 12 represents the same CA procedure, using three dimensions to plot each point. The display quality improves to 51.7 in three dimensions, which still leaves a display error of just under 50%. Median values for the cluster groups are now 68.0% for Group One, 72.0% for Group Three, 69.5% for Group Four, 42.8% for Group Five, 39.9% for Group Six and 16.8% for Group Seven. The relationships between and within groups One, Three and Four are moderately well-described by three dimensions. Scatter within Group Four is very small, within Group Three is moderate and is greater within Group One. Although distances between sites within these groups differs, each cluster is positioned in a discrete area of the plot. Therefore, the sites within these respective cluster classifications can be understood to be closely associated. The display errors of sites in groups Five and Six remain high. Scatter within these groups is also quite high. Species relationships among sites within these two groups appear to be more complex than for groups One, Three and Four, but together, groups Five and Six do occupy a discrete area of the plot. Differences between these two groups are not

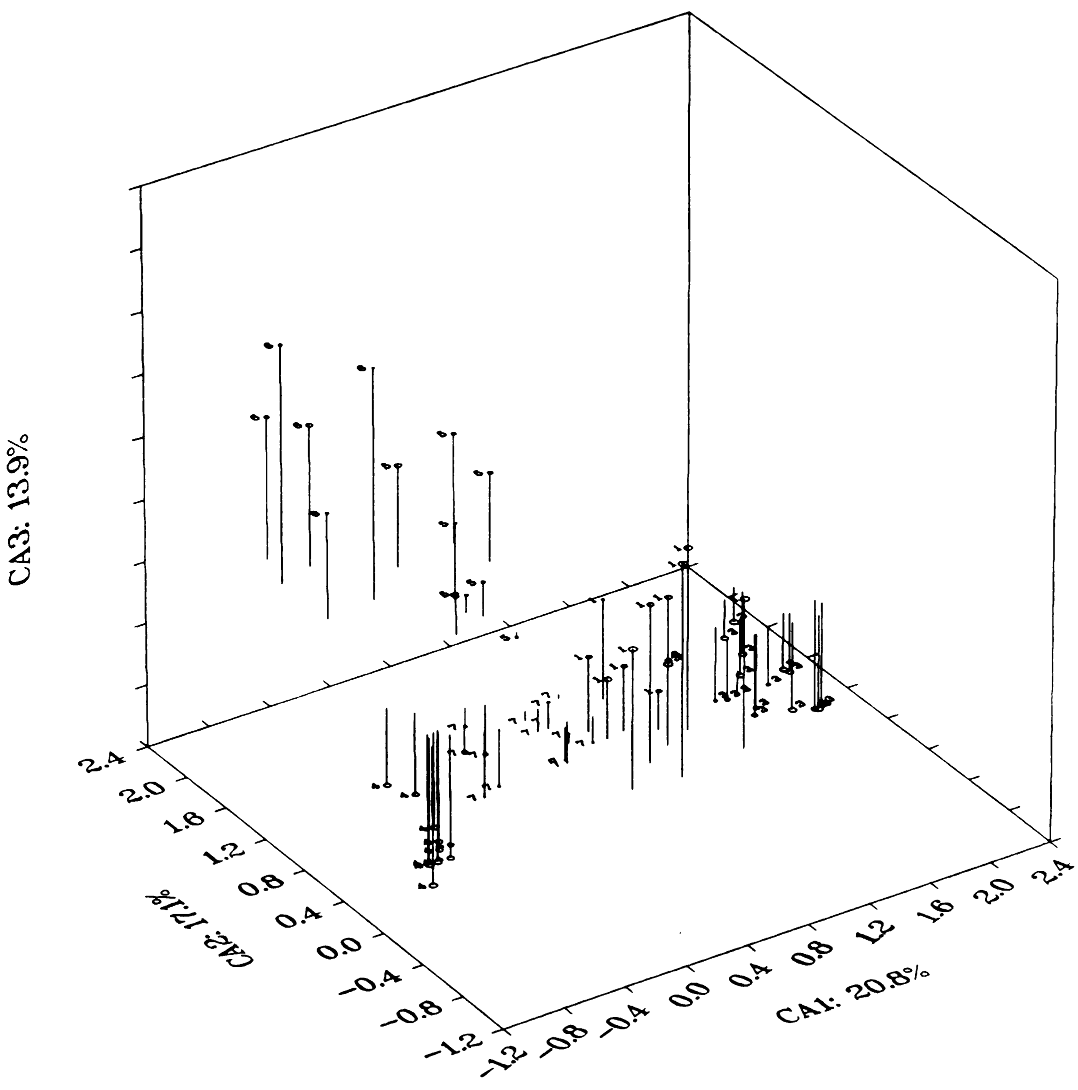

Figure 12 Positions of 67 'core' sites in three dimensions of a correspondence analysis using the basal area contributions of sixteen species. The size of the plotting symbols are proportional to the sum of the squared cosines in three dimensions. Labels represent cluster group designations. The length of each spike is proprotional to the distance from zero along the third axis. Fifty-two percent (51.7%) of the total variance is represented by the three dimensions.

well-defined by CA, but relative to all other sites, sites in groups Five and Six represent distinct species relationships. Like Group Two sites in the initial analyses, Group Seven sites represent the most complex species relationships- many dimensions are required to describe the precise positions of these sites. Nevertheless, in three dimensions there is relatively little scatter within Group Seven. These sites also are positioned in a discrete area of space relative to the other cluster groups. The species relationships for Group Seven sites are poorly defined in Figure 12, but differences in composition within the group still appear to be less than differences between Group Seven sites and all other sites.

The graphical description of the relationships between the 67 core sites using CA represents a high degree of error for some of the sites. However, the similarity between groupings of sites using cluster analyses and groupings apparent using CA is a strong indication that the core site cluster groups do not represent random associations. The significance of the visual positions of each cluster group differs according to the proportion of variance described for sites within the respective groups. The positions of sites in groups One, Three and Four can be interpreted with the most confidence.

As in the initial analyses, the similarity between groupings observed in CA and groupings observed in the cluster analyses suggests that species relationships implicit in the cluster groupings should correspond to species relationships observed in CA. Figure 13 represents the position of each species plotted in two

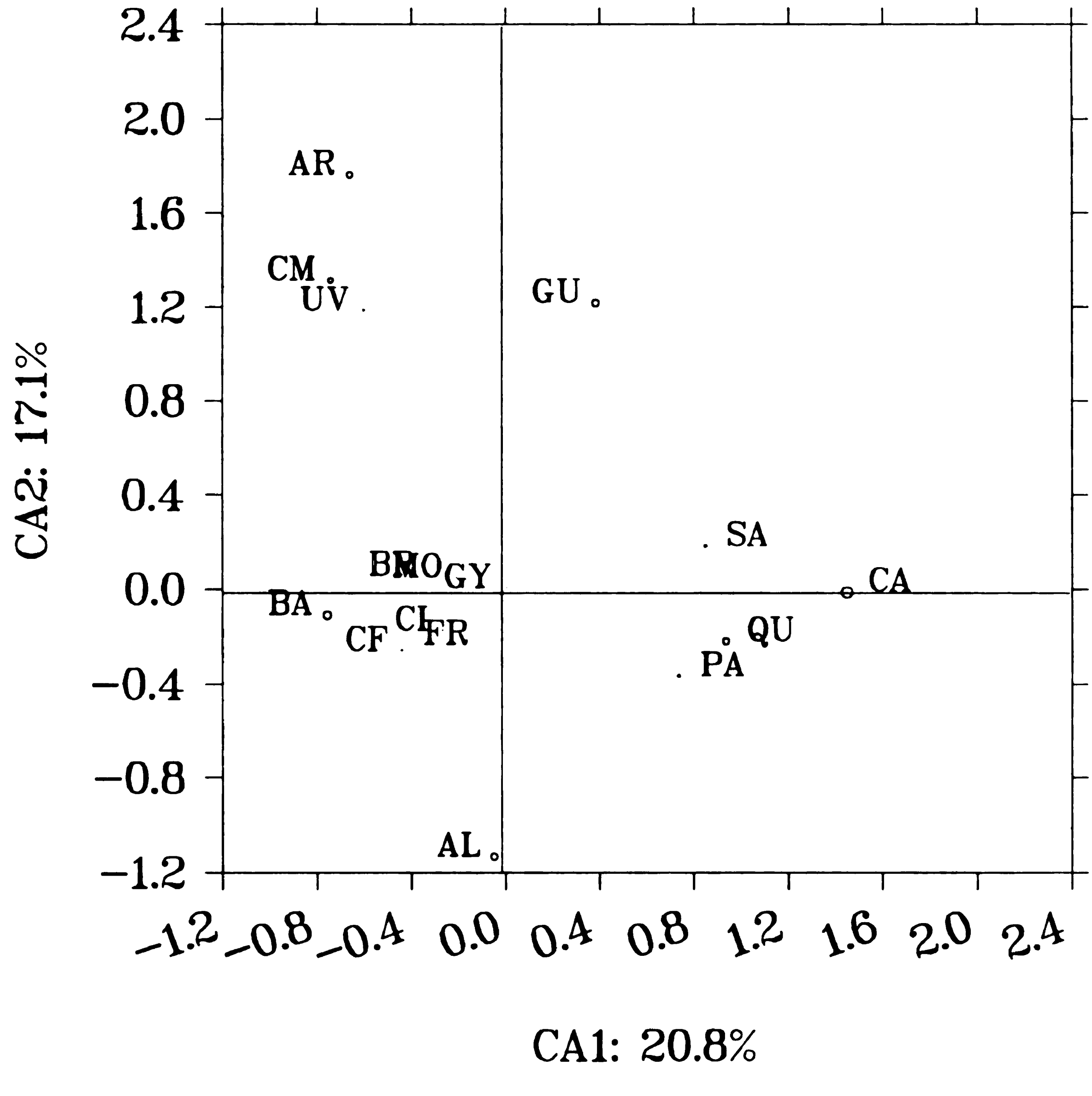

Figure 13 Positions of sixteen dry forest species based on their scores in the first two dimensions of a CA procedure using basal area contributions from 120 sites in the ISA-Mao silvicultural study. The plotting symbols are proportional to the sum of the squared cosines in two dimensions. Symbols are: BA= *Phyllostylon brasiliensis*, CM= *Prosopis juliflora*, AR= *Acacia farnesiana*, UV= *Coccoloba leoganensis*, CF= *Lasianthus lanceolatus*, BR= *Cassia emarginata*, CI= *Pithecellobium circinale*, MO= *Capparis flexuosa*, FR= *Capparis cynophallophora*, AL= *Bursera simaruba*, GY= *Guaiacum officinale*, GU= *Caesalpinia coriaria*, PA= Palo amargo, SA= *Maytenus buxifolia*, QU= *Exostema caribaeum*, CA= *Acacia scleroxyla*. Thirty-eight percent (37.9%) of the total variance is explained by the first two dimensions.

dimensions. Some of these positions do correspond with the "characteristic species" listed for each cluster group. *B. simaruba* ("AL") is located at the extreme lower portion of the second axis along the origin of the first, in the general area of Group One sites. *A. scleroxyla* ("CA"), *E. caribaeum* ("QU"), *T. pallida* ("PA") and *M. buxifolia* ("SA") are all located to the left of the first axis, along the origin of the second, in the same position as Group Three sites. *Phyllostylon brasiliensis* ("BA") is located to the extreme left of the first axis along the origin of the second, in the area occupied by Group Four sites. *Caesalpinia coriaria* ("GU"), *A. farnesiana* ("AR"), *Prosopis juliflora* ("CM"), and *Coccoloba leoganensis* ("UV") are located along the upper portion of the second axis, in the area occupied by sites representing groups Five and Six. The remaining species are clustered around the origin of both axes, in the area occupied by Group Seven sites. Species missing from the cluster groups include *E. caribaeum* from Group One and *Cassia emarginata* from groups Four and Five. All four species interpreted as characteristic of Group Three sites correspond precisely, as do the four species characteristic of Group Six sites. Nevertheless, with a display quality of only 37.9%, the position of each species is not well described and apparent associations with particular sites may be misleading. The sums of the squared cosines are low for most of the species. *A. scleroxyla* has the highest value with 78.9% of the variance explained for this species in two dimensions. Other values are 58.3% for *Phyllostylon brasiliensis*, 51.3% for *Caesalpinia coriaria*, 48.5% for *B. simaruba*, 46.0% for *E. caribaeum* and 44.1% for *A. farnesiana*. All other species had values lower than 40%. Based on the relatively high values for Group Three

sites and the high value for the species *A. scleroxyla*, the association between this group and can be considered to be confirmed. All other relationships are suspect.

By adding the third dimension (Figure 14), the values for the sums of the squared cosines were increased to 88.5% for *A. scleroxyla*, 92.5% for *P. brasiliensis*, 58.0% for *C. coriaria*, 94.4% for *B. simaruba*, 46.2% for *E. caribaeum* and 55.3% for *A. farnesiana*. All other species still had values below 40%. Because of the high values of *B. simaruba*, *A. scleroxyla* and *P. brasiliensis*, we can be confident in the significance of their relative positions. Because the sums of the squared cosines for groups One, Three and Four tended to be high, we can also be confident in the apparent associations between these species and their respective groups. The associations between the species located in close proximity to groups Five and Six are less strong. Nevertheless, the positions of *C. coriaria* and *A. farnesiana* are clearly in the same direction from the origin as groups Five and Six. The association of these two species with their respective groups is probably not random.

In the same way, *E. caribaeum* is still associated with Group Three sites, although its precise position is not well described by three dimensions. Likewise, *T. pallida*, with only 19.7% of its variance describe is still associated with Group Three sites. Although only 39.0% of its variance is described by three dimensions, *P. juliflora* is positioned in the same region as groups Five and Six, as is *Coccoloba*

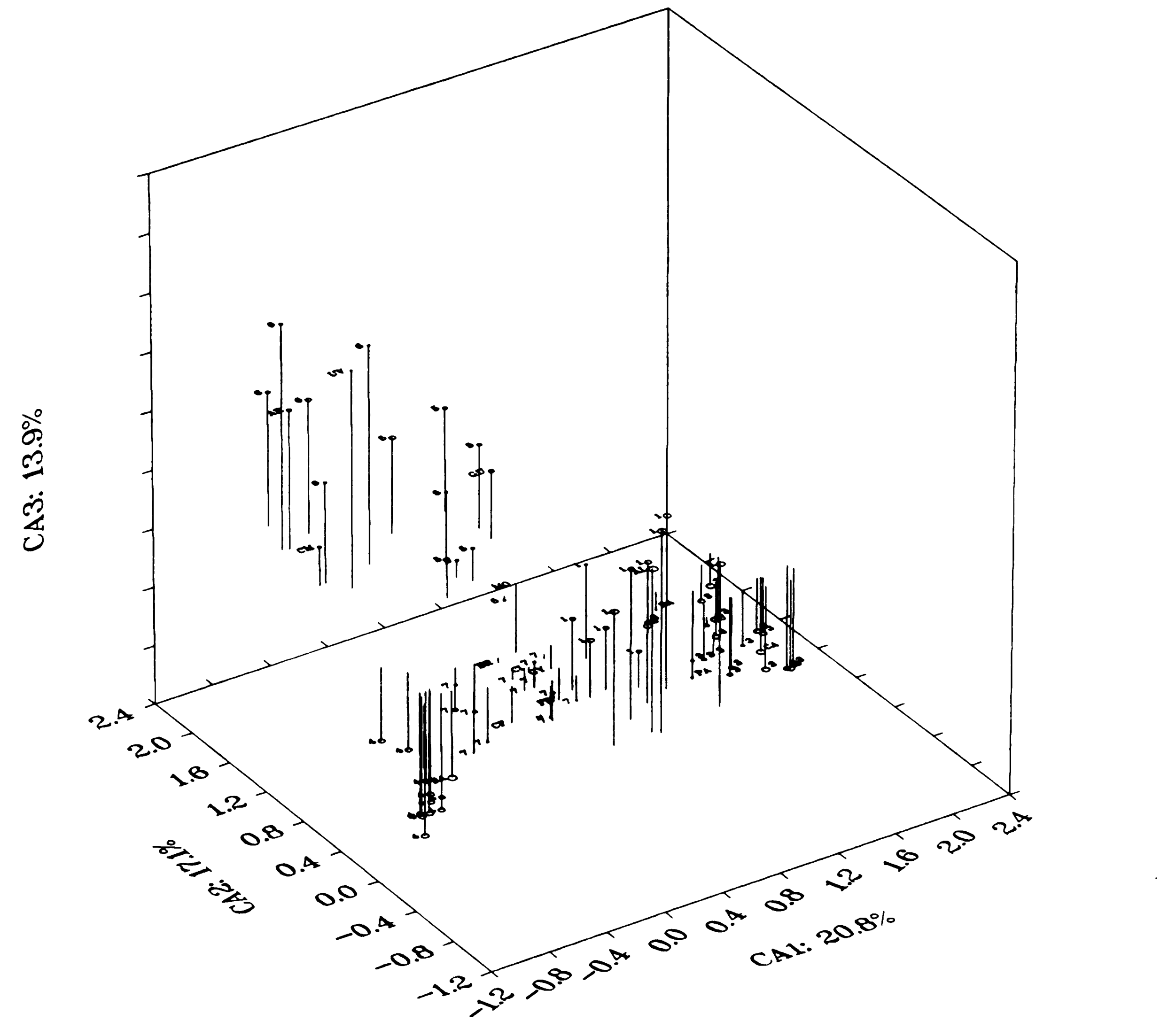

Figure 14 Positions of sixty-seven sites and sixteen species in three dimensions based on a correspondence analysis. The analysis used the basal area contributions of the sixteen species in each site. The size of the plotting symbol is proportional to the sum of the squared cosines in three dimensions. Numbers represent cluster group designation of each site. Letters indicate species. UV= *C. leoganensis*, CM= *P. juliflora*, AR= *A. farnesiana*, BA= *P. brasiliensis*, FR= *C. cynophallophora*, MO= *C. flexuosa*, BR= *C. emarginata*, CI= *P. circinale*, GY= *G. officinale*, CF= *L. lanceolatus*, AL= *B. simaruba*, GU= *C. coriaria*, SA= *M. buxifolia*, QU= *E. caribaeum*, PA= *T. pallida*, CA= *A. scleroxyla*. The length of each spike is proportional to the distance from zero along the third axis. Variance explained is 51.7% of the total.

leoganensis, with 20.2% of its variance represented. The interpretation of the relationships suggested by these species is not strong. However, the positions of the species strongly deviate from the origin in the direction of the respective groups. Because these same patterns were observed independently using cluster analyses, the probability that the associations are random is reduced.

On the other hand, clustered close to the origin, Group Seven sites are not clearly associated with any particular species. Since the origin represents the average distribution of all the species, the position of Group Seven sites in this area makes it difficult to interpret. The grouping of these sites together across four cluster techniques suggests that they represent a discrete position along the species continuum. Nevertheless, their position in CA suggests they represent intermediate sites, with characteristics in common with several of the other groups. The relationships suggested for these sites by cluster analyses cannot be completely confirmed using CA.

The results of CA for sites in groups One, Three, Four, Five and Six do correlate well with the results of the cluster analyses. Species associated with the groups based on CA also generally correspond well with species nominated as characteristic of the respective cluster groups. Given that species distributions are responding to underlying environmental or site history conditions, the relative positions of both the groups and the species may have ecological significance. The relative positions of groups One, Three, Four and Five are the same as those

observed using a subset of data. The first axis suggests a contrast between sites dominated by *P. brasiliensis* versus sites dominated by *A. scleroxyla*. The second axis suggests a contrast between sites dominated by *C. coriaria* and sites dominated by *B. simaruba*. Along the third axis, Groups One, Five and Six have high values, while groups Three and Four both have low values. As noted previously, Group Seven sites are positioned close to the origin along all three axes. As suggested for the results of the initial analyses, one factor appears to explain the separation of groups Three and Four, while another affects the distributions of species associated with groups One and Five. At the same time, either a hypothetical third factor, or some interaction between the first two explains a strong separation between sites dominated by either *P. brasiliensis* or *A. scleroxyla* from sites dominated by either *C. coriaria* or *B. simaruba*.

A second correspondence analysis was applied to the full data set to examine the interrelationships between core and noncore sites. Scores for sites and species are listed in Appendix I. Figure 15 represents the positions of the 120 sites in the first two dimensions. Total variation explained is reduced somewhat to 33.2%. It is therefore even less certain that the relative positions of sites and species represent an adequate picture of the actual species-site relationships. Nevertheless, sites in Group One still cluster together at the bottom of the second axis, Group Three sites cluster together to the right along the first axis, Group Four sites form a tight cluster to the left along the first axis, groups Five and Six are spread out along the top portion of the second axis, and Group Seven sites

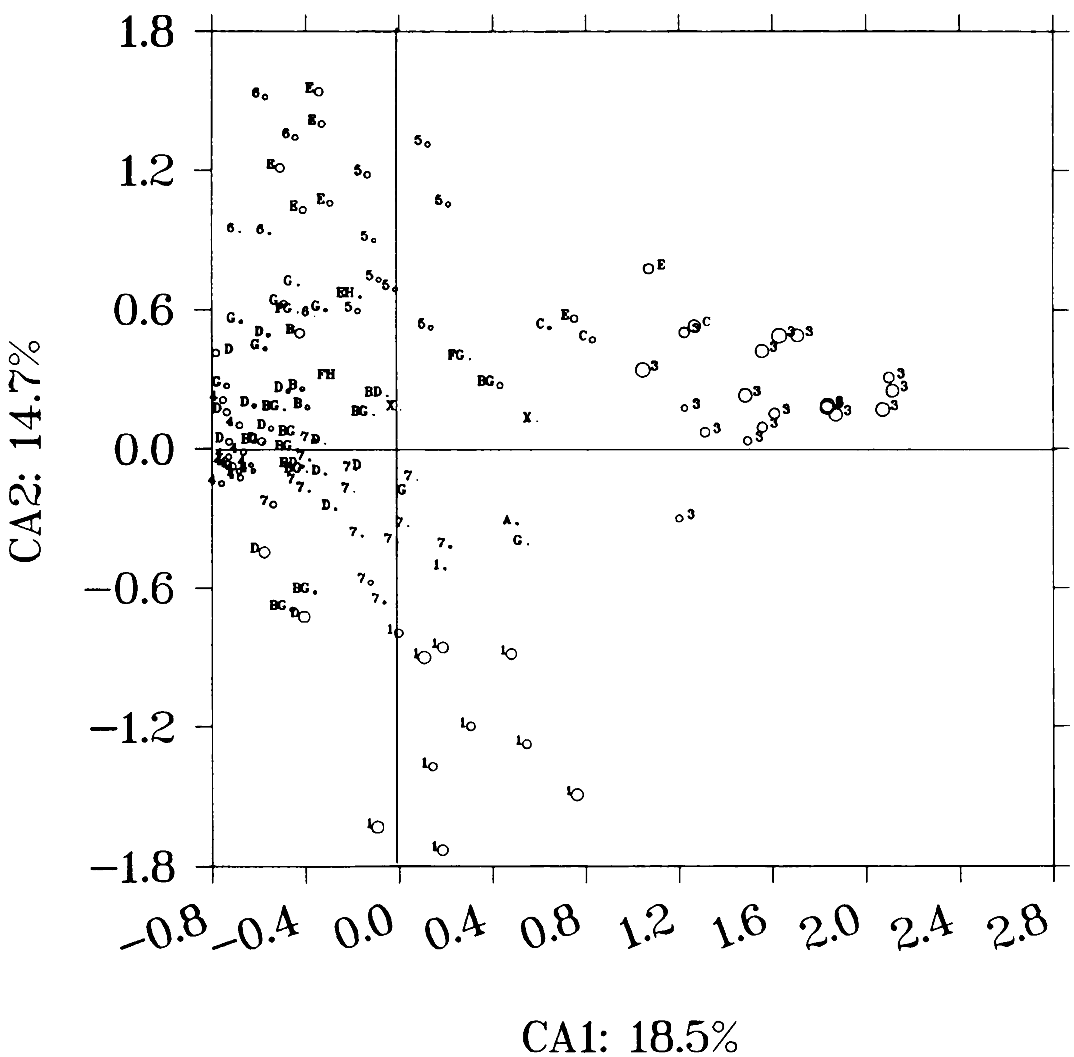

Figure 15 Positions of 120 sites from the ISA-Mao silvicultural study along the first two principle axes of a correspondence analysis using the basal area contributions of sixteen subtropical dry forest species. The label indicates the cluster group designation. Numbers indicate core sites. Letters indicate noncore sites. The size of the plotting symbol is proportional to the sum of the squared cosines associated with each point for the two-dimensions represented here. Thirty-three percent (33.2%) of the total variance is explained by the first two dimensions.

are spread along the area between groups One and Four, near the origin of both axes. Sites in Subgroup C (n=3) are associated with Group Three sites. Sites in Subgroup D (n=14) are all associated with Group Four. Sites in Subgroup E (n=7) are mostly found in the area occupied by groups Five and Six. Other subgroups do not suggest any strong patterns. Adding the third dimension would increase the display quality to 43.9% (Table 16), but the relationships between the core sites are not radically affected and the interpretation would therefore be similar to the previous CA. Figure 16 represents the positions of the species based on scores from the CA using the full data set. The relative positions of *B. simaruba*, *A. scleroxyla*, *E. caribaeum*, *T. pallida*, *P. brasiliensis*, *Caesalpinia coriaria*, *A. farnesiana* and *P. juliflora* are almost identical to Figure 13. On the other hand, *M. buxifolia* ("SA") is less closely associated with *A. scleroxyla* ("CA"), *E. caribaeum* ("QU") and *T. pallida* ("PA"). *Coccoloba leoganensis* ("UV") is less closely associated with *A. farnesiana* ("AR") and *Prosopis juliflora* ("CM"). The visual associations previously suggested for *M. buxifolia* and *C. leoganensis* may have been an artifact of the reduced data set in the first CA. Sample size and/or sample characteristics affect the patterns "recovered" by CA. However, the primary structures remain the same.

Summary

Correspondence analysis was used in these analyses to examine the relationships between sites, independent of the results of the four cluster analyses. The results

Table 16 Singular values, principal inertias and proportional representation for each of fifteen dimensions of a correspondence analysis of sixteen species and sixty-seven sites representing core cluster group sites.

Dimension	Singular Values	Principal inertias	Percent	Accumulative percentage
1	0.72040	0.51897	18.53	18.53
2	0.64242	0.41270	14.74	33.27
3	0.54279	0.29463	10.52	43.79
4	0.48965	0.23975	8.56	52.35
5	0.46161	0.21309	7.61	59.96
6	0.43402	0.18838	6.73	66.69
7	0.39142	0.15321	5.47	72.16
8	0.38930	0.15156	5.41	77.57
9	0.36991	0.13683	4.89	82.46
10	0.35335	0.12486	4.46	86.92
11	0.31169	0.09715	3.47	90.39
12	0.29424	0.08658	3.09	93.48
13	0.29361	0.08621	3.08	96.56
14	0.22374	0.05006	1.79	98.35
15	0.21527	0.04634	1.65	100
		2.80031		

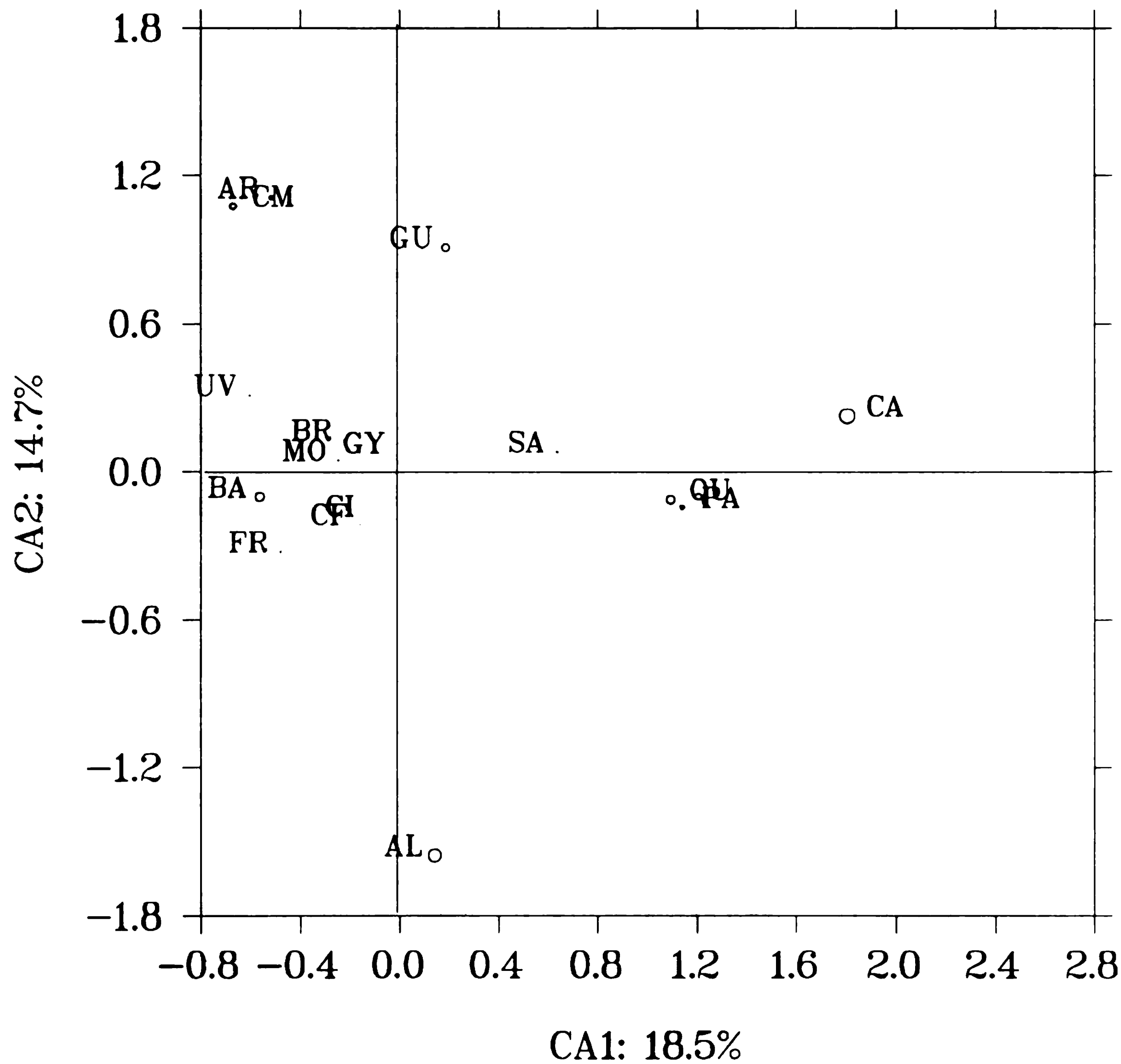

Figure 16 Positions of sixteen dry forest species based on their scores in the first two dimensions of a CA procedure using basal area contributions from 120 sites in the ISA-Mao silvicultural study. The plotting symbols are proportional to the sum of the squared cosines in two dimensions. Symbols are: BA= *Phyllostylon brasiliensis*, CM= *Prosopis juliflora*, AR= *Acacia farnesiana*, UV= *Coccoloba leoganensis*, CF= *Lasianthus lanceolatus*, BR= *Cassia emarginata*, CI= *Pithecellobium circinale*, MO= *Capparis flexuosa*, FR= *Capparis cynophallophora*, AL= *Bursera simaruba*, GY= *Guaiacum officinale*, GU= *Caesalpinia coriaria*, PA= Palo amargo, SA= *Maytenus buxifolia*, QU= *Exostema caribaeum*, CA= *Acacia scleroxyla*. Thirty-three percent (33.2%) of the total variance is explained by the first two dimensions.

of CA indicate that the groupings of core sites suggested by the cluster techniques are not random. CA also supports many of the species relationships suggested by the species contributions within each core site cluster group relative to the average species contributions across all sites. The graphical representation of groups One, Three and Four were strongest (the highest proportion of variance expressed). The graphical representation of Group Seven was the most ambiguous. Groups Five and Six appear to be closely associated and they could be considered as two components of the same grouping.

Apparent scatter within each group was greatest in groups Five and Six, somewhat less in Group One and much less in groups Three and Seven. Group Four represented the least scatter. The positions of groups One, Three, Four and Five and Six with respect to the origin tend to confirm that each represents a characteristic species composition which may relate to characteristic site conditions and/or disturbance history. The scatter within the cluster groups may relate to the relative homogeneity of site characteristics within a group. Site characteristics (site conditions and/or disturbance history) would be most alike among Group Four sites, and least similar among sites in Groups Five and Six. Because Group Seven sites have very low squared cosine values, their apparent affinity in three dimensions carries very little weight. Scatter in additional axes could be quite extensive.

The relative positions of the core site cluster groups corresponds with the positions of four clusters observed in the initial analyses. *A. scleroxyla* and *Phyllostylon brasiliensis* form one contrast (along with the secondary species, *E. caribaeum* and *T. pallida*), explained by hypothetical Factor One. *B. simaruba* and *Caesalpinia coriaria* form a second contrast, explained by hypothetical Factor Two. A third axis also appears to be very important which either represents a third factor, or an interaction between the first two. From the perspective of this silvicultural study, the primary question is which, if any, of these factors can explain differences in site productivity. That is, does the factor which results in dominance by *P. brasiliensis* over *A. scleroxyla* also affect how fast trees grow on sites classified as Group Four versus sites classified as Group Three? Likewise, does the factor which affects the relative dominance of *C. coriaria* versus *B. simaruba* affect how fast trees grow on sites classified as Group Five versus sites classified as Group One? Moisture relationships related to topography and soil attributed probably vary a great deal in the rolling landscape within the ISA-Mao study. Disturbance histories are also known to vary within the silvicultural study (Powell and Mercedes 1986). These CA procedures have shown that the cluster groupings are not arbitrary. Subsequent analyses will focus on the relative positions of the cluster groups with respect to each other, and the implications these positions have in terms of underlying gradients within the ISA-Mao landscape.

Canonical Discriminant Analyses

Based on the results of the cluster techniques and the CA procedures, core sites within each cluster group were assumed to represent samples of their respective clusters. Canonical discriminant analysis was then used to examine the relationships between the cluster groups. CDA can also be used to test for overlap between groupings of sites formed using cluster analyses. CDA was first applied to the 67 core sites representing six cluster groups. Figure 17 represents the orientation of these six core site cluster groups in two-dimensional canonical space. Probabilities associated with each axis and scores for each site are found in Appendix J. Table 17 lists the eigenvalues associated with each dimension. With 72.7% of the variation described by two dimensions, the display quality for Figure 17 is moderately good. The positions of groups One, Four, Five and Seven are very close, with some interspersion of sites in groups Four and Seven. Groups Three and Six, on the other hand, occupy discrete areas of space. Group Six, in particular, dominates the ordination, representing the lowest values on both the first and second axes.

Some of the relationships suggested by the relative positions are the same as those observed in CA. Groups Four and Three occupy space on opposite sides of the origin along the first axis. Groups One and Five occupy positions on opposite sides of the origin along the second axis. Group Five is also the closest group to Group Six. However, Group Five and Group Six are widely separated, while the relationships of the other groups appear compressed. These relationships are very

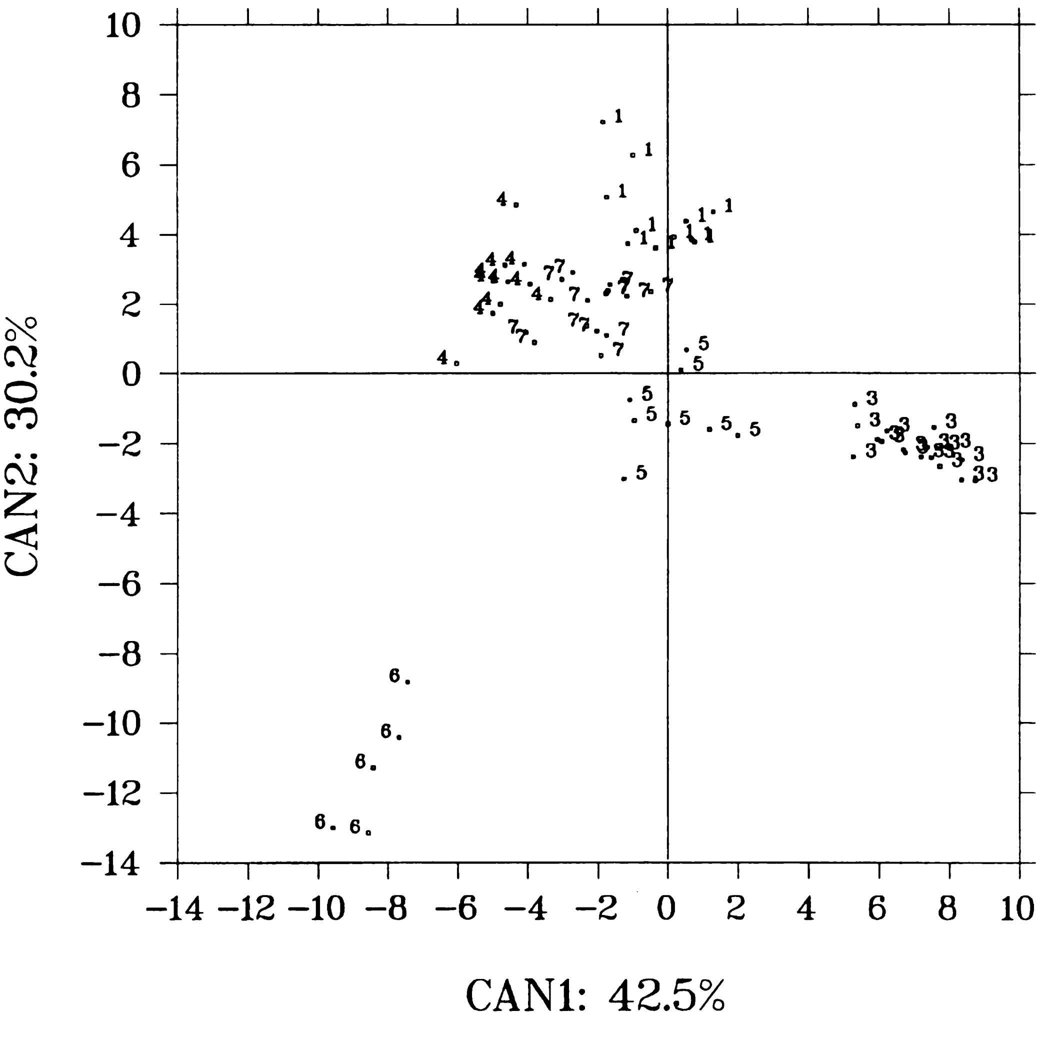

Figure 17 Positions of 67 core sites along the first two axes of a CDA procedure based on six cluster groups defined by sixteen species. Numbers represent the group designation given based on four cluster procedures. Seventy-three percent (72.7%) of the total variance is explained by the first two axes.

Table 17 Eigenvalues associated with each axis of CDA applied to 16 species and 67 core sites representing six groups from the ISA-Mao silvicultural study.

Dimension	Eigenvalue	Percent	Cumulative
1	25.1160	42.53	42.53
2	17.8247	30.18	72.71
3	8.7331	14.79	87.5
4	5.0893	8.62	96.12
5	2.2928	3.88	100

different from both the results of cluster analyses and CA. Results from preliminary analyses suggest that Figure 17 may represent a limitation of CDA. In a number of preliminary CDA procedures, cluster groups with only a few members often appeared to have a disparate impact on the relative positions of the other groups. CDA maximizes the ratio of between group to within group variance. Small groups may have less variance relative to the larger groups. If variance is affected by sample size, groups with small sample sizes may have excessive influence in canonical discriminant analysis. An analogous problem exists with CA. Species which are present in a limited number of sample sites tend to have excessive impact on the analyses and are usually removed after the initial analyses. In this case, Group Six is represented by a limited number of sites and was removed in the subsequent analysis to examine the relationships between the remaining five core site cluster groups.

CDA was applied again to 62 sites representing five groups. Figure 18 represents the positions of the groups in two dimensions. Probabilities for each dimension

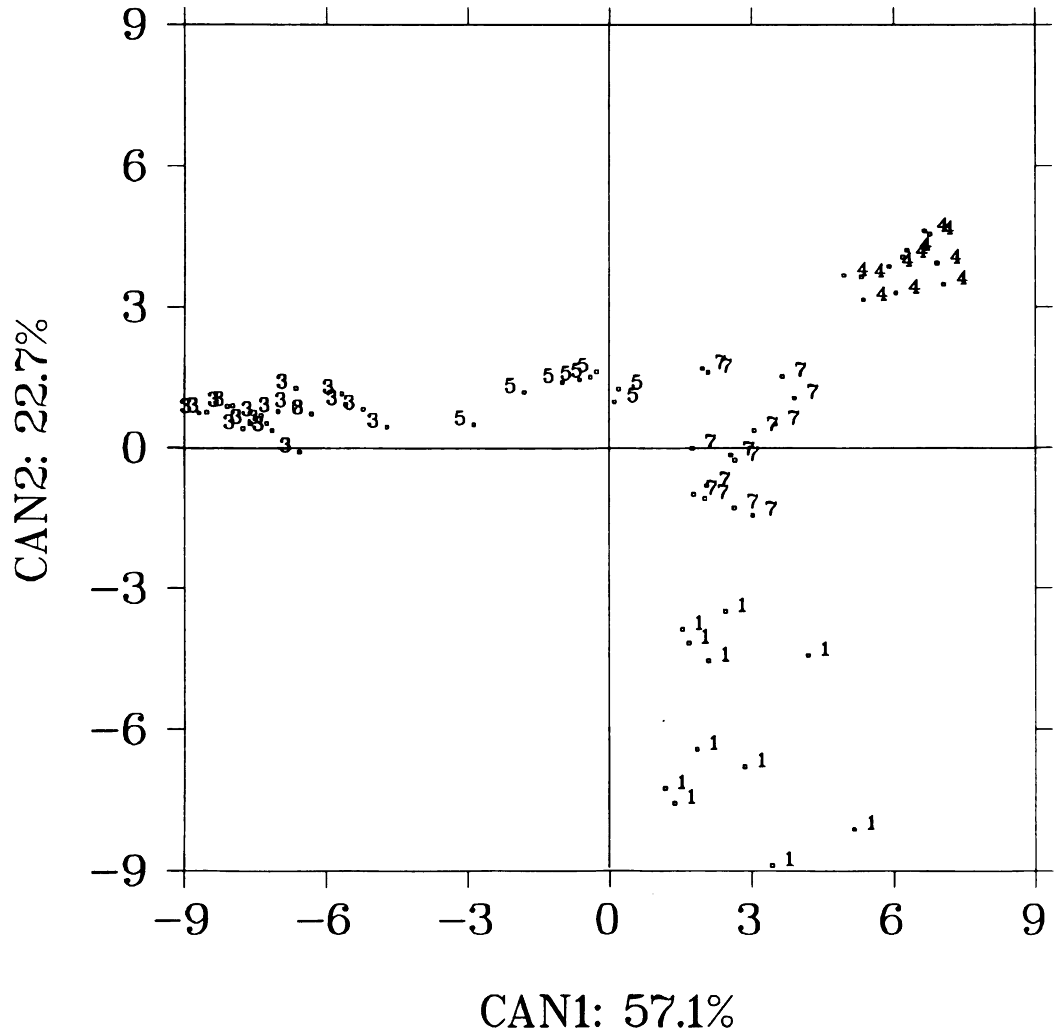

Figure 18 Positions of 62 sites representing five core site cluster groups defined by sixteen dry forest species, along the first two axes of a CDA procedure. Numbers represent the group designation given each site based on four cluster procedures. Eighty percent (79.8%) of the total variance is explained by the first two axes.

and scores for each site are found in Appendix J. Eigenvalues for each dimension are listed in Table 18. Accounting for 79.8% of the variation, the display quality of this graph is slightly higher than the previous CDA and also moderately good. In this display, each of the five groups occupies a discrete area of canonical space. This reaffirms the results of the cluster and correspondence analyses. The groupings of sites in groups One, Three, Four, Five and Seven are not arbitrary- each group does represent a species composition distinct from the other groups. This conclusion is particularly important for Group Seven, since the relationships between sites in this group were ambiguous in CA.

Although all five groups occupy discrete positions, scatter among groups One and Seven is greater than the other three groups. Scatter among Group Four sites is least. The relative degree of scatter among sites probably reflects the degree of homogeneity of species composition within the respective group. Groups in which species compositions are less homogeneous may represent groups where site characteristics are also less homogeneous. Based on the visual relationships suggested by two dimensions in Figure 18, Group Four sites would appear to represent the most homogeneous species-site characteristics while Group One would represent the least homogeneous characteristics.

Together, the two dimensions in Figure 18 position Group Three in the northwest quadrant, Group Four in the northeast and Group One in the southeast. Groups Five and Seven are positioned near the origin along both axes, which suggests

Table 18 Eigenvalues associated with each axis of CDA applied to 16 species and 62 core sites representing five groups.

Dimension	Eigenvalue	Percent	Cumulative
1	25.4679	57.09	57.09
2	10.1031	22.65	79.74
3	6.0874	13.65	93.39
4	2.9523	6.62	100.01

they have species characteristics in common with the other groups. Groups One, Three and Four occupy distinct quadrants, with Groups One and Three occupying quadrants opposite of each other. This suggests they represent the strongest contrast among the three groups. In a quadrant intermediate between groups One and Three, Group Four would appear to represent some factor independent of the contrast between groups One and Three. However, species compositions do not reflect the same relationships. As observed in the initial analyses, Group One has species characteristics in common with both groups Three and Four. *A. scleroxyla* and *E. caribaeum* are common to groups One and Three and *Phyllostylon brasiliensis* is common to groups One and Four (Table 13). Groups Three and Four, on the other hand, have no species in common which contributes more than 4.0% to the total basal area, which suggests these two groups represent the most complete contrast, while Group One would represent an intermediate position, with some independent factor accounting for dominance by *B. simaruba*. In this analysis, the relationships suggested by the quadrants are not clear.

On the other hand, looking at the two axes separately, groups Three and Four occupy positions on opposite sides of the origin along the first axis, and groups One and Five occupy positions on opposite sides of the origin along the second axis. These positions do appear to reflect differences in species compositions among the four groups, and they are very similar to the relative to positions of the groups in CA. However, the contrast between groups One and Five is much less prevalent than in CA. The dominant relationship is a continuum moving from Group Three to Group Four. Along this continuum, groups Five, One and Seven represent intermediate points, with groups One and Seven occupying about the same position on the first axis. The hypothetical factor which controls this relationship accounts for 57.1% of the variation between the groups. A second factor accounts for 22.7% of the variation and would explain the separation of groups One and Seven. Along this second axis, Group Four is positioned along the upper extreme, opposite of Group One. Groups Three, Five and Seven occupy the same position along the second axis, intermediate between groups One and Four.

If the species which characterize each of the groups are responding to underlying differences in site conditions (soil attributes, topographic characteristics) and/or disturbance history (time since last disturbance, type of disturbance, severity of disturbance), the contrasts suggested by CDA could represent different levels of these factors. For example, if the first axis represents differences in moisture relationships, Group Three would represent one extreme (either greater or lesser

moisture availability), Group Four would represent the opposite extreme, and groups One, Five and Seven would represent intermediate levels. If the second axis represents differences in species composition due to disturbance, Group Four would represent one extreme related to disturbance (the most severe or the least severe, the least time since disturbance or the most time since disturbance), Group One would represent the opposite extreme and groups Three, Five and Seven would represent intermediate levels (moderately severe, moderate amount of time since disturbance). The following diagrams represent these potential interrelationships:

Least available moisture	Intermediate	Most available moisture
Group Three	Groups One, Five and Seven	Group Four

Least disturbance /Most time since disturbance	Intermediate	Most disturbance /Least time since disturbance
Group One	Groups Three, Five and Seven	Group Four

These models are hypothetical, with the main goal being to put the results of the ordination in a real world perspective.

Since the relationships suggested by the first two dimensions of this CDA correspond in part to CA, the third dimension was examined to see if it was similar to the third dimension using CA. Figure 19 represents the positions of the five cluster groups in three dimensions and accounts for 93.4% of the total variation. With a display error of only 6.6%, considerable confidence can be

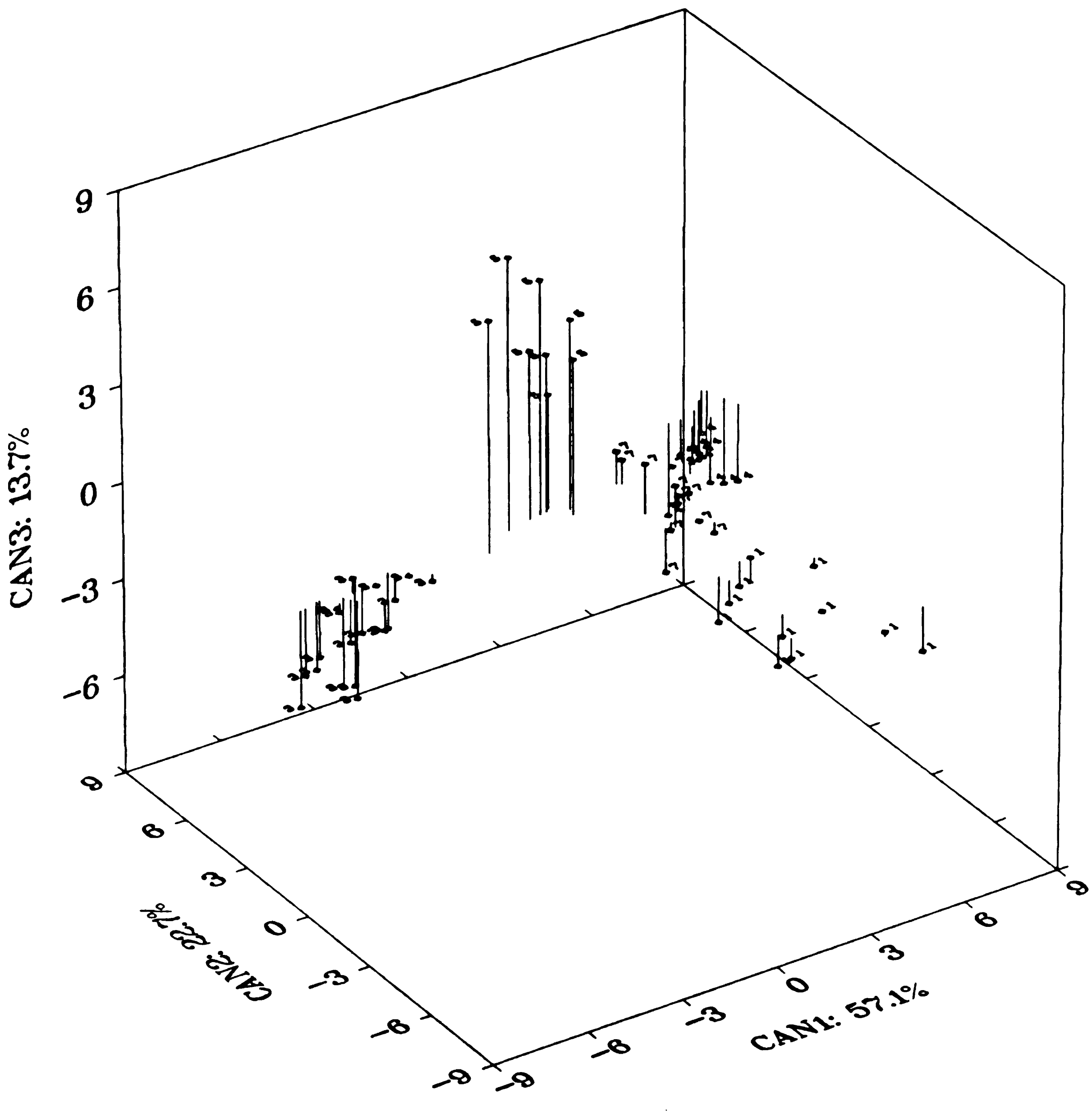

Figure 19 Positions of 62 sites representing five core site cluster groups defined by sixteen dry forest species, along the first three axes of a CDA procedure. Numbers represent the group designation given each site based on four cluster procedures. Ninety-three percent (93.3%) of the total variance is explained by the first three axes.

placed in the visual representation of the relative positions of each group. As observed with the third dimension of CA applied to 67 sites and 16 species, Group Five has large values in the third dimension, groups Three and Four have low values, and Group Seven remains close to the origin in all three dimensions. One major difference is that Group One remains close to the origin in the third dimension whereas in CA Group One sites had the same relative relationship as group Five. Visually, the relative scatter within each group remains the same in three dimensions: Group Four has the least and Group One appears to have the most. The most important relationships apparent in Figure 19 is the removal of Group Five from the origin along the third axis. Based on the two-dimensional image, Group Five was interpreted as representing an intermediate level in both of the hypothetical primary environmental factors. The third dimension suggests that the species characteristic of Group Five sites represent unique site characteristics, rather than an intermediate level of the factors controlling the primary contrasts apparent between the other groups. This relationship can be diagrammed:

Group Five	Groups One and Seven	Groups Three and Four

As in the initial analyses, CDA was also applied to a data set including both core and noncore sites. Applying CDA to the larger data set implies that each site represents a sample of its respective group. However, noncore sites represent sites which were rejected as samples of the core site cluster groups. This presents a limitation in this CDA procedure. The advantage of using most of the sites is that it gives a more complete picture of species-site interactions. Therefore, noncore sites were submitted as samples of their respective subgroups rather than as samples of the core site cluster groups. The single exception was a single noncore site labeled A, which was assigned to cluster Group One. Two sites were eliminated which grouped with a different core site cluster group in each of the four cluster techniques. Subgroups represented by fewer than three sites were combined with other subgroups. For example, there were two noncore sites labeled BD which were submitted as members of Subgroup B (n=5). The two subgroups FG (n=2) and FH (n=1) were combined into a subgroup labeled "F" (n=3). A noncore site labeled EH was combined with the seven sites representing Subgroup E (n=8). A total of thirteen groups were submitted to CDA in this analysis. The smallest groups had n=3 and the largest had n=18. Scores and probabilities are listed in Appendix J. Eigenvalues associated with each dimension are listed in Table 19.

Figure 20 represents the positions of these 118 sites representing thirteen groups in two-dimensional canonical space. The display quality of this graph is 61.2%. With a display error of 38.8%, the visual representations of group positions is not as good as the previous graphical representations. Nevertheless, with more than half of the variability visually represented, apparent relationships are probably

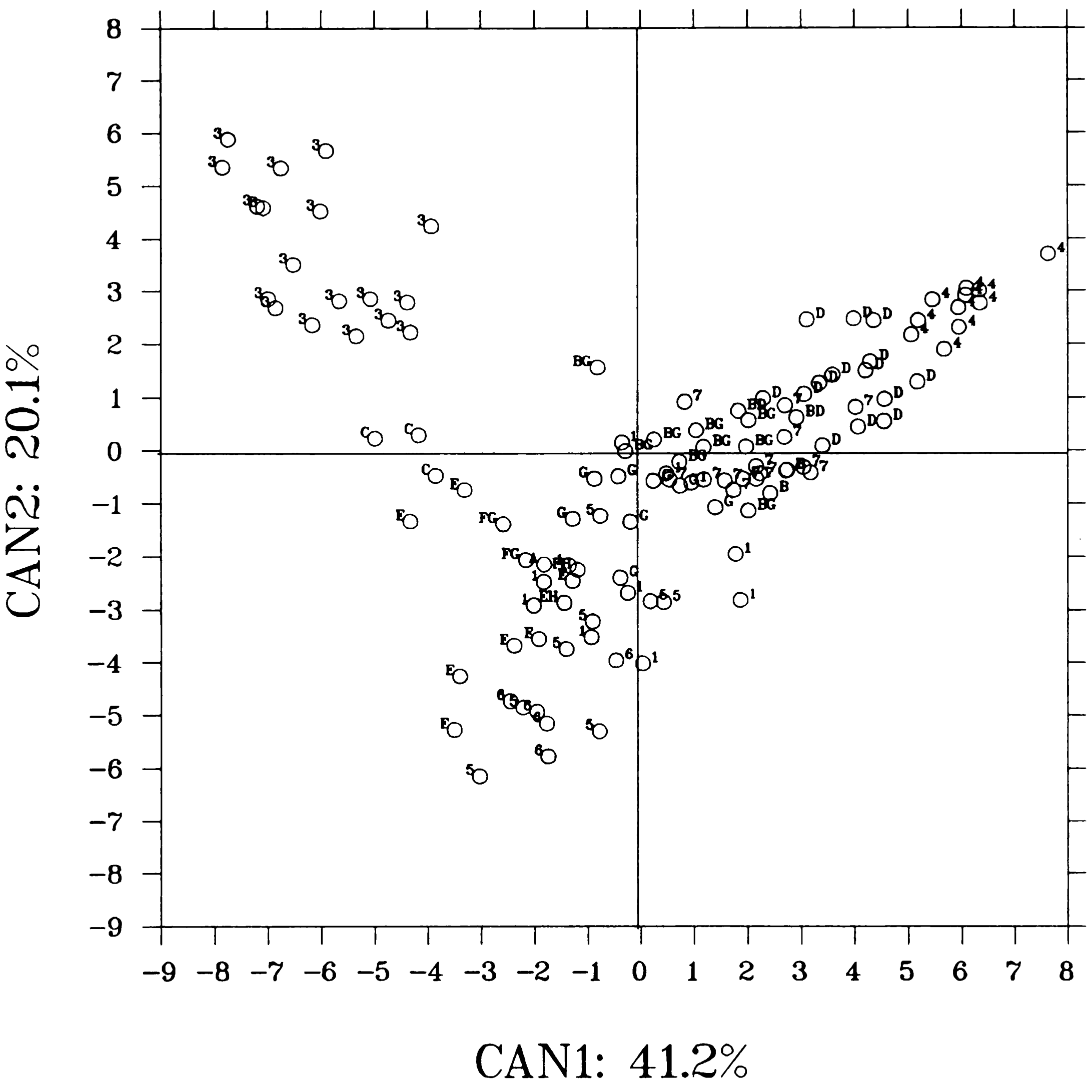

Figure 20 Positions along first two canonical axes of six core groups and seven noncore site subgroups. Groups and subgroups are represented by a total of 118 sites. Groups and subgroups represent the results of four cluster analyses applied to data representing relative basal area contributions of sixteen dry forest species. Labels indicate cluster group designations. Numbers indicate cores site clusters. Letters indicate subgroups formed from noncore sites representing the same clustering pattern (i.e. subgroup BG indicates site clustering twice in group two and twice in group seven). Sixty-one percent (61.2%) of the total variance is explained by axes one and two.

Table 19 Eigenvalues associated with each axis of CDA applied to 16 species and 118 sites representing six core site cluster groups and seven noncore site subgroups.

Dimension	Eigenvalue	Percent	Cumulative
1	14.3750	41.15	41.15
2	7.0065	20.06	61.21
3	5.3744	15.38	76.59
4	2.7168	7.78	84.37
5	2.1852	6.25	90.62
6	1.5925	4.56	95.18
7	0.9506	2.72	97.9
8	0.4458	1.28	99.18
9	0.1135	0.32	99.5
10	0.1089	0.31	99.81
11	0.0610	0.17	99.98
12	0.0051	0.01	99.99

significant. Unlike Figure 17, none of the groups with small sample sizes dominate either of the first two axes. This may reflect a great deal of variability within the subgroups with small *n* since they are composed of noncore sites, which were those sites which were not consistently associated with any one type of species distribution. Greater within group variability would decrease the ratio of between group to within group variability. Separation of the small groups would therefore also decrease. It is also possible that increasing the number of groups decreased the between group variability. If we added additional groups from increasingly diverse habitats, this would not be true- the variability between the groups would increase. But in this case, sites were added to the data set which represented points intermediate between the core groups, thereby decreasing the variability between the groups. Again, if between groups variability decreased, the ratios of between to within group variability also decreased, and no single group would have an overwhelming impact due to sample size.

As in the initial analyses, applying CDA to both core and noncore sites results in the position of the groups along a continuous gradient, versus the discrete positions represented when only core sites are used. This supports the idea that the subgroups represent intermediate points between the discrete positions of the core site cluster groups. Of the thirteen groups, Three and Four are the only two which occupy discrete positions, representing opposite ends of the continuum along the first axis. Subgroups C and D represent two groups with minor interspersion with other groups. Grigal and Goldstein (1971) found that several clusters overlapping in canonical space had common species characteristics. Adjacent to groups Three and Four, respectively, subgroups C and D suggest relationships based on the common characteristic species *A. scleroxyla* and *P. brasiliensis*. These relationships concur with the relationships observed in CA (Figure 13).

Adjacent to Subgroup D along the first axis is a mixture of sites from groups One and Seven and subgroups BG, B and G. *P. brasiliensis* is a characteristic species of Group Seven and Subgroups BG and B. *P. brasiliensis* is also a component of Group One (12.3%) and Subgroup G (18.9%). These relationships are suggested by the average contributions of each species to their respective groups (Tables 13 and 14), but were not explicitly demonstrated in the CA procedures. Immediately adjacent to Subgroup C along the first axis is a mixture of sites from groups One, Five and Six and subgroups E, F and G. The relationship among Five, Six and E can be understood as an expression of common occurrence of the characteristic species *Caesalpinia coriaria* (Five, Six and E), *A. farnesiana* (Five, Six and E) and *Prosopis juliflora* (Six and E). These relationships are consistent with explicit relationships represented in CA (Figures 11-16). The interspersion of Group One sites among groups Five and Seven is also consistent with the relative position of Group One sites along the first axis of the CA applied to 16 species and 67 core sites (Figure 11), but cannot be explained by species characteristic of all three groups. Tables 20 and 21 list the average score for each group and subgroup along the first axis.

Table 20 Group means for the core site cluster groups based on site scores along the first canonical axis of canonical discriminant analysis (CDA) using 118 of the 120 silvicultural experiment sites. Canonical discriminant analysis was based on the proportional basal area contributions of sixteen dry forest species, using groupings determined with four different cluster analysis procedures.

	Group Three	Group Six	Group Five	Group One	Group Seven	Group Four
Means	-6.033	-1.676	-1.067	-0.287	2.139	5.972

Table 21 Group means for the noncore site cluster groups based on site scores along the first canonical axis of canonical discriminant analysis (CDA) using 118 of the 120 silvicultural experiment sites. Canonical discriminant analysis was based on the proportional basal area contributions of sixteen dry forest species, using groupings determined with four different cluster analysis procedures.

	Subgroup C	Subgroup E	Subgroup F	Subgroup G	Subgroup BG	Subgroup B	Subgroup D
Means	-4.342	-2.697	-1.980	-0.100	0.896	2.526	3.852

The second axis in Figure 20 positions a mixture of groups Five, Six and E towards the lower extreme, and represents a common position of groups Three and Four towards the top. This axis suggests a curvilinear relationship with the first. Digby and Kempton (1991) suggest that an ordination of data along two principal axes will result in such a curvilinear relationship when the sites represent ecologically diverse habitats. An interpretation of the curvilinear relationship is difficult, because the effects of a possible second environmental gradient are confounded by an interaction with the first. Digby and Kempton (1991) suggest that a clear representation of such an additional gradient may be hidden in a higher dimension. In the CA analyses, the first two axes appeared to represent two independent gradients, while the third axis suggested some nonlinear relationship with the first axis. Sites with large absolute values along the first axis (groups Three and Four) had relatively high negative values on the third axis, while sites with values near zero on the first axis (groups One and Five) had relatively high positive values on the third axis (Figure 12). When CDA was applied to 62 sites representing five groups no relationship between the first dimension in either the second or the third dimensions was apparent. However, this CDA examined only half of all the sites and therefore may not represent the full complexity of species-site continuums.

Figure 21 represents the positions of each group using the first and third dimensions of the CDA applied to 118 sites representing 13 groups. The quality of this graphical representation is only 56.2%, indicating a display error of close to

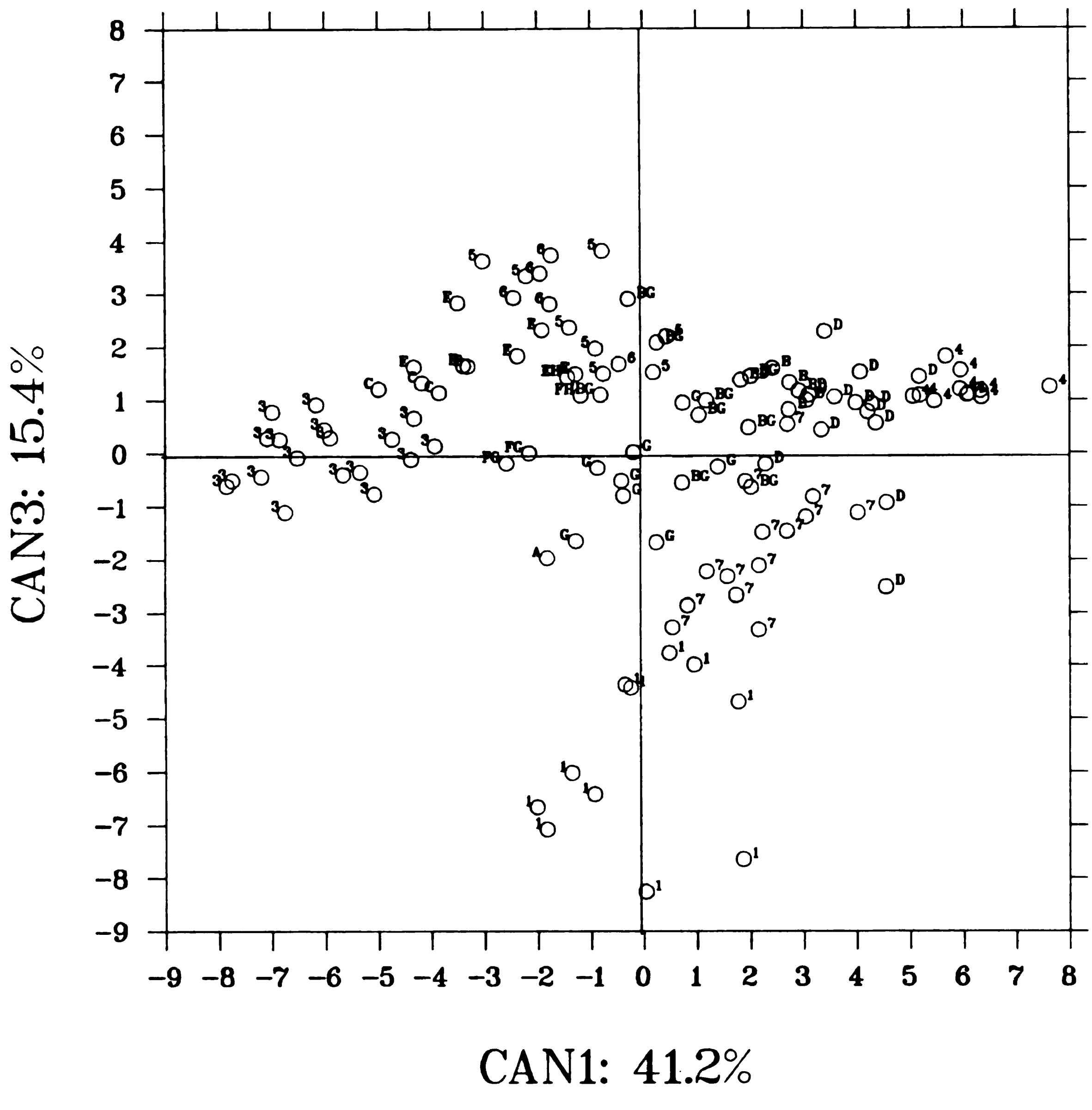

Figure 21 Positions along first and third canonical axes of six core groups and seven noncore site subgroups. Groups and subgroups are represented by a total of 118 sites. Groups and subgroups represent the results of four cluster analyses applied to data representing relative basal area contributions of sixteen dry forest species. Labels indicate cluster group designations. Numbers indicate cores site clusters. Letters indicate subgroups formed from noncore sites representing the same clustering pattern (i.e. subgroup BG indicates site clustering twice in group two and twice in group seven). Fifty-seven percent (56.5%) of the total variance is explained by axes one and three.

50%. However, this display is useful because it indicates a discrete position for Group One, while maintaining most of the separation of groups Three and Four. Group Seven also occupies a more nearly discrete position, as does the mixture of groups Five, Six and E, although there is some interspersion with sites representing subgroups BG and F. Along this third axis, Group One and groups Five and Six occupy opposite extremes, much as they did in the CA procedures. The relative positions of groups One, Three, Four, Five and Seven are all very similar to their relative positions in two dimensions based on CDA applied to five of the six core site cluster groups (Figure 17).

Figure 22 represents the positions of groups One, Three, Four, Five, Six and Seven in all three dimensions. The display quality is 77.2%, which is moderately good. The groups are plotted with the second canonical axis representing the third dimension. The second and third dimensions were switched in this display to maintain the separation of Group One from groups Five and Six. The separation of Group Five from groups Three and Four is much clearer in three dimensions. The similarity between this display and Figure 12 (CA) is significant. Groups Three and Four occupy opposite extremes along the first axis, groups One and Five occupy opposite extremes along the second axis (=third dimension) and groups Three and Four occupy one extreme along the third axis (=second dimension), while groups One and Five occupy the opposite extreme. Also as in

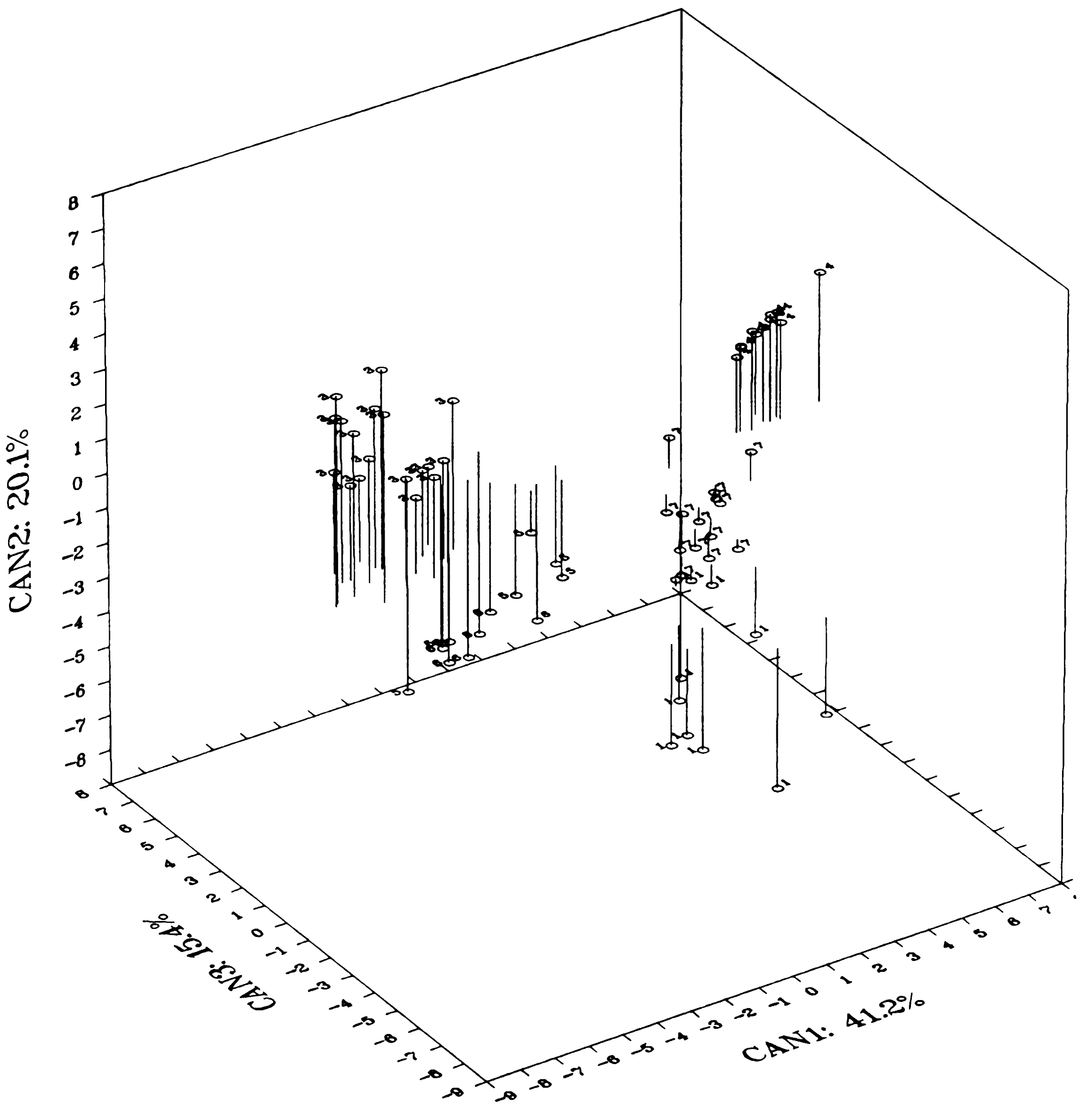

Figure 22 Positions of six cluster groups along the first, second and third axes of a CDA procedure applied to thirteen cluster groups represented by a total of 118 sites. Only the six core site cluster groups are plotted. Labels indicate cluster group designations. Seventy-seven percent (76.6%) of the total variance is explained by the three axes.

the CA procedures, Group Seven is positioned near the origin in all three dimensions. These ordinations can be diagrammed as follows:

Group Three	Groups One, Five, Six and Seven	Group Four

Group One	Groups Three, Four and Seven	Groups Five and Six

Groups Three and Four	Group Seven	Groups One, Five and Six

Apparent scatter within the groups is also similar to the results of CA. Scatter within group One appears to be the greatest, with two sites adjacent to the area occupied by Group Seven. Scatter within the complex composed of groups Five and Six is also considerable, although all of these sites remain well separated from areas occupied by other core sites. Scatter within groups Three and Seven is somewhat less than Group One and groups Five and Six. Group Four is represented by the sites with the least scatter. Although similar to CA, the proportion of variance unexplained in Figure 22 could result in radical changes in the relative degree of scatter within each group. However, these relationships are the same as observed in Figure 18, which represented over 95% of the variability in the data set. Some of these relationships may change in higher dimensions, but it can be concluded with reasonable assurance that Group Four represents the most homogeneous species compositions, groups One, Five and Six represent the least homogeneous, and groups Three and Seven represent an intermediate degree of within group homogeneity. The degree of homogeneity in species compositions may reflect the relative degree of similarity among site characteristics within each group.

The relationships diagrammed above are similar to the ones suggested by the CDA applied to five of the six groups and virtually identical to the relationships suggested by the three axes in the CA applied to 67 sites representing the six core site cluster groups. Discrepancies between the two CDA procedures are probably related to differences in the sample size of the two data sets. These discrepancies suggest that some of the relationships observed in CDA may be arbitrary. The patterns which are consistent throughout all of the analyses are least likely to represent random relationships. Groups Three and Four indicate a primary gradient operating in the forest. Group One indicates a second gradient. Groups Five and Six are closely related, and may represent the opposite extreme of the gradient affecting Group One. However, Groups One and Seven appear to have some common characteristics, as do groups Four and Seven, which means that these three groups represent a species-site continuum which could also indicate an underlying gradient. In every graphical representation, Group Seven represents an intermediate point between two other groups at opposite ends of a continuum. Finally, in the analyses including noncore sites, subgroups C, D and E are consistently positioned in close association with groups Three, Four and Five/Six, respectively. Subgroup C is represented by only three sites, but Subgroup E is represented by seven sites and Subgroup D by fourteen. In subsequent analyses, subgroups D and E will be examined along with the core site groups as

representatives of the points intermediate between the discrete positions along the species-site continuums.

Summary

The results of MVA techniques applied to the full data set confirm many of the patterns observed in the subset of 45 sites initially analyzed using the same procedures. Patterns of species compositions can be described for the entire data set. Sixty-seven of the 120 sites can be assigned to one of six groups, each representing a unique species composition. These groupings are consistent with an independent analysis using CA, although groups Five and Six (dominated by *C. coriaria* and *A. farnesiana*, respectively) tend to be closely associated. Groups One, Three, Four, Five and Seven can be shown to occupy discrete areas of canonical space, based on CDA applied to these five groups. Based on the CDA applied to all six core site groups and seven noncore site subgroups, a continuum was strongly suggested, rather than discrete positions for each group. In particular, the second dimension suggested a curvilinear relationship with the first axis, a relationship which has often been observed in temperate zone studies where samples come from sites representing diverse habitats. Groups Five and Six and Subgroup E were closely associated along this continuum.

Using the scores in three dimensions from the same CDA procedure, the relative positions of the core site groups were very similar to the relative positions of each

group in three dimensions based on CA applied to the 67 core sites representing the six core site groups. Relationships common to all of the analyses suggest one strong environmental gradient represented by the characteristic species *A. scleroxyla*, *E. caribaeum* and *T. pallida* versus *Phyllostylon brasiliensis*. Along this gradient, *C. coriaria*, *A. farnesiana*, *Prosopis juliflora* and *B. simaruba* represent an intermediate species association. In all of the analyses, a second gradient separated sites dominated by *B. simaruba* from this primary gradient. In some of the analyses, the second apparent gradient also separated out sites associated with *C. coriaria*, *A. farnesiana* and *P. juliflora*. In the CDA procedure applied to groups One, Three, Four, Five and Seven, the second axis did not suggest a contrast between groups One and Five, but the third axis did separate out Group Five from all other groups, suggesting a third gradient responsible for the distribution of *C. coriaria* and *A. farnesiana*. In each ordination, Group Seven sites were in an intermediate position near the origin, in a loose association with a number of species, including *Pithecellobium circinale*. In particular, the "characteristic species" assigned to Group Seven suggest an intermediate point along a continuum moving from Group One to Group Four. The primary question with respect to all of these apparent gradients is which, if any, can explain differences in site productivity. In the following section, review of the literature and personal observations, in combination with analyses of the overstory structures within each group will be used to examine plausible implications for environmental gradients within the ISA-Mao silvicultural study.

Species, Site and Overstory Characteristics

The primary question with respect to the silvicultural study is which, if any, of the apparent gradients reflect differences in site productivity. Differences in available moisture would affect site productivity most directly. However, site productivity is not independent of disturbance factors. On sites dominated by young trees, diameter increment may be relatively rapid. As a site develops, average diameter increment may slow, but the rate of basal area accumulation may stay the same. Differences in physiology also affect apparent productivity. Tree species with highly dense wood may actually accumulate more total mass than trees with a lower specific gravity, although diameters and basal area may increase more for the trees with the less dense wood. These are just some of the factors which make an interpretation of relative site productivity complicated.

The greatest limitation is a lack of information. Information from the literature with respect to the ecology and physiology of each species is scarce, but does suggest some important characteristics for some of the key trees. This literature will be used to examine possible site characteristics as indicated by different species dominance. Direct information on site characteristics is limited to the qualitative "measurements" made on forty of the sites in March 1993, as well as general observations with respect to topographic characteristics of the experimental areas. These measurements and observations will be used to suggest some possible ecological relationships for the dominant species. Some literature

is available which suggests possible relationships between structural characteristics and site quality and structural characteristics and disturbance. Based on relationships suggested in these studies, overstory structures of the sites within each cluster group will be examined for indications with respect to site characteristics.

Species Characteristics

Dominant in Group One and characteristic of Group Seven, *Bursera simaruba* is described by Kellman and Roulet (1990) as a major component in a well-developed selva community on fossil sand dunes with a caliche layer 140 cm below the surface. Geilfus (1989) notes that *B. simaruba* is tolerant of rocky soils, salinic soils and soils with caliche. In the southwest region of the Dominican Republic, the species can be seen growing out of shallow pockets of soil deposited in crevices of uplifted coral reefs on the steepest slopes, accompanied by small shrubby trees and cacti. In Costa Rica the tree is also associated with cacti, particularly *Lemaireocereus aragonii* (Weber), on dry limestone outcrops (Otis and Buskirk 1986). In another study done with *B. simaruba* in Costa Rican dry forest, Stevens (1987) found that annual diameter increment varied from 0.0 cm in the "worst" year to 2.5 cm in the "best" for the same individual *B. simaruba*. This suggests the high degree of variability which can exist in terms of growth from year to year. With live wood composed of over 50% water (Maxwell 1985), growth for *B. simaruba* may be particularly dependent on differences in rainfall patterns from year to year. Johnson (1992) notes that in the Sonoran desert, *B.*

simaruba occurs only in river canyons. Asprey and Robbins (1953) list *B. simaruba* and *E. caribaeum* among the important components of forest described as "dry limestone scrub" found in Jamaica in hilly or mountainous landscape with thin soil over hard limestone rock. This literature suggests that *B. simaruba* may be indicative of rocky or shallow soils and/or highly alkaline soils developed under low rainfall from limestone material.

Table 22 lists estimates of average growth and specific gravity for nine species which represent important components in one or more of the core site cluster groups. Table 23 lists some structural characteristics of each species. *Bursera simaruba* had the highest average annual growth in the study by Hernández (1986). *B. simaruba* is also the species with the lowest specific gravity. Powell and Mercedes (1986) and Maxwell (1985) note that the tree is not favored for charcoal production, which may explain its apparent dominance in some parts of the forest. Structurally, *B. simaruba* trees were the tallest and had the largest diameters. None of the individuals were multiple-stemmed. These characteristics indicate that the trees present in the forest in 1986 were not stump sprouts and may have been relatively old. Removal of other vegetation may have made resulted in a *de facto* dominance by *B. simaruba* on some sites. The tree's relatively fast growth may also have allowed it to become even more dominant as competition was removed. However, the structural characteristics suggest that disturbance did not result in new regeneration of the tree on sites where it was

Table 22 Specific gravity and average growth rates for nine species prominent in the ISA-Mao silvicultural study. Species are listed in descending order based on average annual growth. "NA" indicates species for which information is not available from the respective source.

Species	Mean diameter growth (cm $year^{-1}$)[1]	Specific gravity (g cm^{-3})[2]	Mean diameter growth (cm)[3]	Mean basal area increment (cm^2)[3]
Prosopis juliflora	NA	0.909	0.7	9.3
Bursera simaruba	0.93	0.283	0.8	11.5
Acacia farnesiana	0.55	0.931	0.5	5.8
Caesalpinia coriaria	0.39	1.038	0.8	14.9
Phyllostylon brasiliensis	0.39	0.856	0.7	9.3
Acacia scleroxyla	0.29	0.927	0.7	8.1
Trichilia pallida	0.25	NA	0.8	8.6
Exostema caribaeum	0.19	1.056	0.5	5.0
Pithecellobium circinale	0.13	0.973	0.4	8.1

previously not found. Rather, *B. simaruba* may represent a residual component of a pre-existing forest type which dominated on highly alkaline and/or shallow soils.

Exostema caribaeum is the species with secondary dominance in both groups One and Three. Hernández found that it had a very slow rate of growth. Data over six years also indicates this species grew quite slowly. Specific gravity is quite high. Few of the trees in the silvicultural study were multiple-stemmed and the average height indicates the tree was part of the upper portion of the canopy.

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[1]Source: Hernández 1986. Based on measurements taken at breast height.

[2]Source: Betances 1983

[3]Total growth after six years, based on measurements taken at knee height (0.5 m) in the 120 silvicultural sites examined in the current study.

Table 23 Structural characteristics for nine species prominent in the ISA-Mao silvicultural study. Species are listed in descending order based on average height. Data comes from the preharvest inventory done on 120 sites, each 100 m^2, in 1986. Means are based on measurements taken at knee height (0.5 m).

Species	# of trees	Mean height (m)	Mean diameter (cm)	Mean number of trunks per tree
Bursera simaruba	73	5.6	11.4	1.0
Trichilia pallida	87	5.0	4.9	1.3
Acacia scleroxyla	182	4.9	6.1	1.1
Phyllostylon brasiliensis	803	4.9	5.9	1.1
Exostema caribaeum	219	4.9	5.4	1.1
Acacia farnesiana	86	4.8	4.1	1.6
Prosopis juliflora	133	4.7	5.1	1.3
Pithecellobium circinale	146	4.5	3.7	3.3
Caesalpinia coriaria	129	4.3	9.0	1.6
Totals[1]	2442	4.6	5.8	1.3

Van Paasen (1986) notes that *E. caribaeum* is used for fence posts, house construction, firewood and charcoal. In the ISA-Mao Forestry Experimental Station, Powell and Mercedes (1986) noted a heavy dominance by *E. caribaeum* in an area previously under cultivation. Checo (personal communication) has observed the tree growing in rocky and shallow soils. As noted above, Asprey and Robbins (1953) list both *B. simaruba* and *E. caribaeum* as important components of Jamaican "dry limestone scrub". This species may be favored by some kinds of disturbance, but its use for a number of subsistent products and its slow rate of growth would not favor large specimens in areas of forest subjected to human

[1]Totals are based on measurements of all trees across all species for 120 sites.

intervention. The tree would appear to be tolerant of shallow and rocky soils and/or highly alkaline conditions.

Acacia scleroxyla is the species most dominant in Group Three. Almost nothing is available in the literature concerning this species. Neither Little and Wadsworth (1964) nor Little et al. (1974) list it as one of the trees of Puerto Rico and the Virgin Islands. Nor do Asprey and Robbins (1953) mention it as a component of any forest type in Jamaica. Hernández (1986) found it to have moderately low annual diameter increment and Betances (1983) found that it had a moderately high specific gravity. Knudson et al. (1988) note that it is one of the species most favored for charcoal production in the Mao region. With moderately slow growth, even moderate sized specimens of *A. scleroxyla* may be relatively old. Because they are in high demand as a source of charcoal, sites with moderate sized trees probably represent areas where disturbance has been minimal.

Trichilia pallida (Palo amargo) appeared consistently as a secondary species in Group Three. The scientific identification of this species is in question, based on the description provided by Little and Wadsworth (1964). Information available from the ISA-Mao studies is mostly limited to the growth rate listed in Table 22. Van Paasen (1986) notes that the tree is commonly used for charcoal, firewood and fence posts. As noted for *A. scleroxyla*, sites with this relatively slow growing species present may indicate areas where disturbance has been infrequent.

A main component of Group Four, Group Seven and Subgroup D, *Phyllostylon brasiliensis* is also the dominant species in the ISA-Mao silvicultural study as a whole (Table 2) and is noted by Knudson et al. (1988) as representing the species with the most basal area in the whole experimental station. Structurally, *P. brasiliensis* did not tend to be multiple-stemmed in the preharvest inventory. Mean height indicates it was generally part of the upper portion of the canopy, but on average, the trees had relatively small diameters. Powell and Mercedes (1986) note that the species appears to be favored by some types of disturbance. Maxwell (1985) notes that the tree has not traditionally been favored for charcoal production in the area as a whole and suggests that this is the reason for its apparent dominance in the forest. However, in a relatively undisturbed dry forest of Venezuela, Tamayo (1963) found that species dominating the overstory included *Phyllostylon rhamnioides*, *Caesalpinia coriaria* and *Cassia emarginata* as well as several cacti. It is likely that *P. brasiliensis* was also an important component of the original forest at the ISA-Mao Forestry Experimental Station.

The prevalence of *P. brasiliensis* in groups Four Seven, and Subgroup D may be partially related to disturbance. Site may have been cleared of all "valuable" species, leaving *P. brasiliensis* as the *de facto* dominant. The removal of competition may have also favored the moderately fast growing species. The small average diameter suggests many of the trees are young, but the low number of multiple stems indicates that most of the trees are not stump sprouts. Removal of other species may have also encouraged natural regeneration by *P. brasiliensis*.

However, sites with large specimens of *P. brasiliensis* are probably either areas where the tree was a "natural" component of the original forest or where disturbance occurred a long time ago. Sites with smaller trees may be areas where disturbance favored regeneration of *P. brasiliensis* over other species. These areas may also be sites where poor site conditions have prevented rapid growth.

Dominant in Group Five and Subgroup E and a characteristic species of Group Six, *Caesalpinia coriaria* has a growth rate comparable to *P. brasiliensis* based on average diameter increment. However, mean basal area increment was higher than all of the species examined here. This discrepancy between diameter increment and basal area increment may be related to the relatively large average diameters of *C. coriaria* in the preharvest inventory. This suggests these larger *C. coriaria* were vigorous, with relatively high annual diameter increments, and did not represent older growth which had reached equilibrium. Structurally, the trees were the shortest of all the species examined and tended to have more than one stem. Checo (personal communication) indicates that *C. coriaria* is a preferred species for charcoal production, which is consistent with its high specific gravity. Tamayo (1963) noted that in dry forest adjacent to population centers, in Venezuela, *C. coriaria* was managed in open groves for fruit production which was used as goat fodder and for production of tannins. Van Paasen (1986) also notes that the fruits of *C. coriaria* are sold locally in the Mao area as a source of tannin. As mentioned above, Tamayo (1963) found the species in association with

Phyllostylon rhamnioides and *Cassia emarginata* in undisturbed dry forest. Asprey and Robbins (1953) list *C. coriaria* as a component of "thorn scrub" forest in deep alluvium soils near the coast of Jamaica, along with *Prosopis juliflora* and *A. farnesiana* among other species. Although *C. coriaria* is leguminous, Hunter and Steward (1993) found that specimens grown in Honduras did not fix nitrogen.

A relatively fast growing species, *C. coriaria* may respond rapidly after disturbance. The number of trees with multiple stems may indicate the tree sprouts readily when cut, which would also allow it to respond rapidly to disturbance. Sites with very large specimens may indicate areas where disturbance related to charcoal production has been minimal. However, the commercial value of the fruits may also have provided incentive for the trees to be left alone. In either case, the area influenced by the tree would be less affected by the removal of surrounding vegetation. The literature from Jamaica suggests *C. coriaria* does best on deep soils.

The species with the next best annual growth after *B. simaruba* is *Acacia farnesiana*, the dominant species in Group Six sites, and one of the characteristic species for Group Five and Subgroup E. The results of the study by Hernández (1986) notwithstanding, *A. farnesiana* was one of the species with the worst average growth over the six years of data examined in this study. Unlike *B. simaruba*, *A. farnesiana* has a moderately high specific gravity, ranking fifth among the species with information available. With a density over three times greater

than *B. simaruba*, the same diameter growth would represent proportionally greater biomass accumulation. Ecologically, *A. farnesiana* is associated with heavy disturbance (Peacock and McMillan 1968, Powell and Mercedes 1986, Vora and Messerly 1990). Van Auken and Bush (1991) note that in the south and southwest United States, *A. farnesiana* is found in old fields or grasslands which have been heavily grazed. They also note that the tree grows best in full sunlight without herbaceous competition. Kellman and Roulet (1990) list it as a primary component of secondary succession observed in a sand dune formation. As noted, Asprey and Robbins (1953) list *A. farnesiana* as an important component in forest found on deep alluvium soils located near the coast in Jamaica, along with *Prosopis juliflora* and *Caesalpinia coriaria*. Hunter and Steward (1993) indicate *A. farnesiana* is a nitrogen fixer. *A. farnesiana* may indicate disturbed forest, but it would appear to do best on deep soils without impediments to root growth, and with little competition from other trees. It's poor performance in the ISA-Mao silvicultural study could be the effect of the surrounding forest recuperating from pre-study disturbance. As shade from the other species increased, growth of *A. farnesiana* may have been reduced.

An important component of Group Six and Subgroup E, the literature available for *Prosopis juliflora* suggests characteristics which are similar to *A. farnesiana*. It is a species frequently associated with disturbance (Vora and Messerly 1990, Poynton 1990) which does best in deep soils where roots can penetrate to permanent sources of soil moisture (Ruskin 1980). Given adequate conditions, *P.*

juliflora is highly tolerant of drought (Ruskin 1980, Lees et al. 1992). Asprey and Robbins (1953) list it as the primary component of coastal thorn scrub forest on alluvium soils exposed to ocean spray. In the southwest region of the Dominican Republic, *P. juliflora* is an important component of the forest on footslopes, but quickly disappears as slopes become steeper and/or elevation increases. Based on observations of charcoal production in this area, *P. juliflora* responds rapidly when cut, sprouting rapidly and vigorously from the remaining stump. Dominance by *P. juliflora* in this area may be related to historical use of the forest for charcoal production. In the silvicultural study, the tree tended to be moderately short, with small stems. The mean number of stems per tree was higher than for trees such as *P. brasiliensis* and *A. scleroxyla*, but less than for *C. coriaria* and *A. farnesiana*. Growth for these trees was about average compared to the other species. Hunter and Steward (1993) indicate *P. juliflora* is a nitrogen fixer. On deep soils or soils with little impediment to root growth, *P. juliflora* probably responds rapidly to disturbance.

Of the three associated legumes, *C. coriaria*, *A. farnesiana* and *P. juliflora*, *C. coriaria* probably represents a "natural" component of the original forest. On the other hand, the literature suggests *A. farnesiana* may be an invasive species. It is not clear whether or not *P. juliflora* was an original component, but it is an important species in dry forest throughout the island. Regardless of their respective origins, all three legumes appear to have attributes which would allow

them to respond positively after a disturbance, with soil characteristics being a possible limitation.

An important component of Group Seven, *Pithecellobium circinale* is a low shrubby tree with many small thorny stems. It's wood is highly dense and it is slow growing. The average height indicates its place is usually in the lower portion of the canopy. A legume in the family Mimosaceae (Table 3), *P. circinale* would appear to be a "classic" weed species which might dominate sites with poor site conditions and/or areas where cutting has resulted in site degradation. A species with similar physical characteristics, *P. unguis-cati* is listed by Asprey and Robbins (1953) in a number of forest types of Jamaica, including "strand-scrub" a forest growing on sand beaches along the coast, as well as in "thorn scrub" on alluvium soils farther in from the coast. *P. circinale* lacked a strong orientation in the correspondence analyses, which suggests that this species is also a component of more than one forest type. It's dominance in Group Seven may relate to disturbance or to poor site conditions.

Site Characteristics

Based on site characteristics systematically noted for each of forty sites, slope angle was observed to suggest the clearest relationship with the groupings of sites based on species composition. Table 24 represents the results of tabulating slope angle by cluster group. In this table, the seven Group Three sites observed all occurred on slopes visually identified as "steep" or "very steep". While clearly a

Table 24 Results of tabulating slope angle by cluster group for the forty original control sites in the ISA-Mao silvicultural study. The order the rows is based on values along the first axis of CDA applied to 118 sites representing six core site groups and seven noncore site subgroups. One of the sites tabulated as group "BG" was originally designated as "BD". One of the sites tabulated with cluster group "G" was originally designated as "FG". Data was collected in March 1984.

	None	Slight	Moderate	Steep	Very steep	Totals
Group Four	0	4	0	0	0	4
Subgroup D	2	1	2	0	0	5
Group Seven	0	2	0	0	0	2
Subgroup BG	0	4	0	0	0	4
Subgroup G	1	4	1	0	0	6
Group One	0	0	3	0	0	3
Group Five	0	1	2	0	0	3
Subgroup E	0	2	1	1	0	4
Group Six	0	1	1	0	0	2
Group Three	0	0	0	5	2	7
Totals	3	19	10	6	2	40

qualitative measurement, the designation of slope angle was objective and consistent for the sites examined. In contrast to Group Three sites, Group Four sites were all located on sites with "slight" slopes. More over, sites in Group Seven and Subgroup BG were all on slopes designated either as "slight" or "none". Three of the five sites in Subgroup D were also located on sites with one of these two designations. In all these groups, the species *P. brasiliensis* is dominant. On the other hand, three Group One sites, dominated by *B. simaruba*, were all located on sites with "moderate" slopes. These relationships suggest a natural continuum from shallow slopes to steep slopes, with species progressing from *P. brasiliensis* through *B. simaruba* to *A. scleroxyla*. This relationship is consistent with the apparent order of the groups based on both CA and CDA. Sites in

groups Five and Six and Subgroup E are less consistent. The species association on these sites may not be related to site angle. The literature suggests *C. coriaria*, *A. farnesiana* and *Prosopis juliflora* are highly tolerant of drought conditions, as long as root growth is unimpeded. Slope angle and soil depth are frequently related, but other factors are also involved, such as slope position and length. The information presented in Table 24 represents one possible factor related to the positions of groups One, Three and Four along the primary axes developed using the CA and CDA procedures. This relationship may be used in the development of further studies in the ISA-Mao forest.

A related observation is based on the location of most of Group Three sites in Block Two. Block Two consists of two sets of three 50 X 50 m plots, each laid out along the lengths of two parallel and adjacent ridges. Scaled diagrams of each experimental block are included in Appendix K. The two ridges of Block Two represent the highest and most exposed areas included in the silvicultural study. In Appendix L, diagrams are included which show the relative position of the sites in each block, using profile icons. Each profile icon is labeled with the cluster group designation and represents the basal area contributions of the sixteen species within the respective site.

The location of most Group Three sites in Block Two suggests a relationship between topographic position and the dominance by *A. scleroxyla*, *E. caribaeum* and *T. pallida*. However, relationships suggested with respect to topographic

position are confounded because these sites are also remote from access by adjacent communities. Since all three of Group Three's characteristic species are sources for products essential to daily life in the local communities and the area is difficult to access, Block Two sites are the most likely to represent areas which have remained relatively undisturbed. Nevertheless, despite the unique characteristics suggested by the positions of Group Three sites in Block Two, sites from cluster groups One, Six and Seven are also represented in Block Two. Only groups Four and Five are not present. Remoteness and slope position do not by themselves appear to determine dominance by *A. scleroxyla*, *E. caribaeum* and *T. pallida*. Differences in slope angle within the block exist and, as shown previously, do suggest a relationship with species composition.

Conversely, the absence of sites representing groups Four and Five in Block Two may suggest a relationship with slope position and/or slope angle in the distribution of *P. brasiliensis* and *Caesalpinia coriaria*. *C. coriaria* is present on the ridges, but not in the same combination of species which dominates Group Five sites, which are located lower in the topography. The same is true for *P. brasiliensis*. *P. brasiliensis* is found on the sites in Block Two, but none of the compositions found on these sites represent the same combinations and relative dominance found on Group Four sites located lower in the topography. Again, these observations are based on limited information. Their greatest value is their use in the development of further studies in the ISA-Mao forest. However, the available data does suggest the primary ordination observed in CA and CDA is

related to a visible environmental gradient. This gradient should have visible effects in terms of site productivity.

Overstory Structure

If the differences in species composition between sites are related to site histories and/or site conditions, there are structural characteristics which should be evident across sites within cluster groups. Based on literature cited previously, the better sites would be expected to support more basal area. Such sites would also be expected to have a higher canopy. Poorer sites would generally have lower canopy heights and scrubbier vegetation, represented by a higher proportion of trees with multiple stems (Beard 1944, Asprey and Robbins 1953, Loveless and Asprey 1956). Disturbance often creates situations similar to the poorer sites, reducing overall tree height, causing greater numbers of multiple-stems and generally increasing the dominance of trees with smaller boles (Tamayo 1963, Holdridge 1967, Powell and Mercedes 1986, Kellman and Roulet 1990, Poynton 1990, Vora and Messerly 1990).

In Figure 23, six structural measures are represented using box plots to illustrate the distributions of the values within each of eight cluster groups. The subgroups D and E have been included because their positions relative to the core cluster groups were relatively stable throughout CA and CDA procedures. The order of the groups along the X-axis generally follows the ordination of these groups along the primary axis in the CDA procedure applied to 13 groups represented by 118

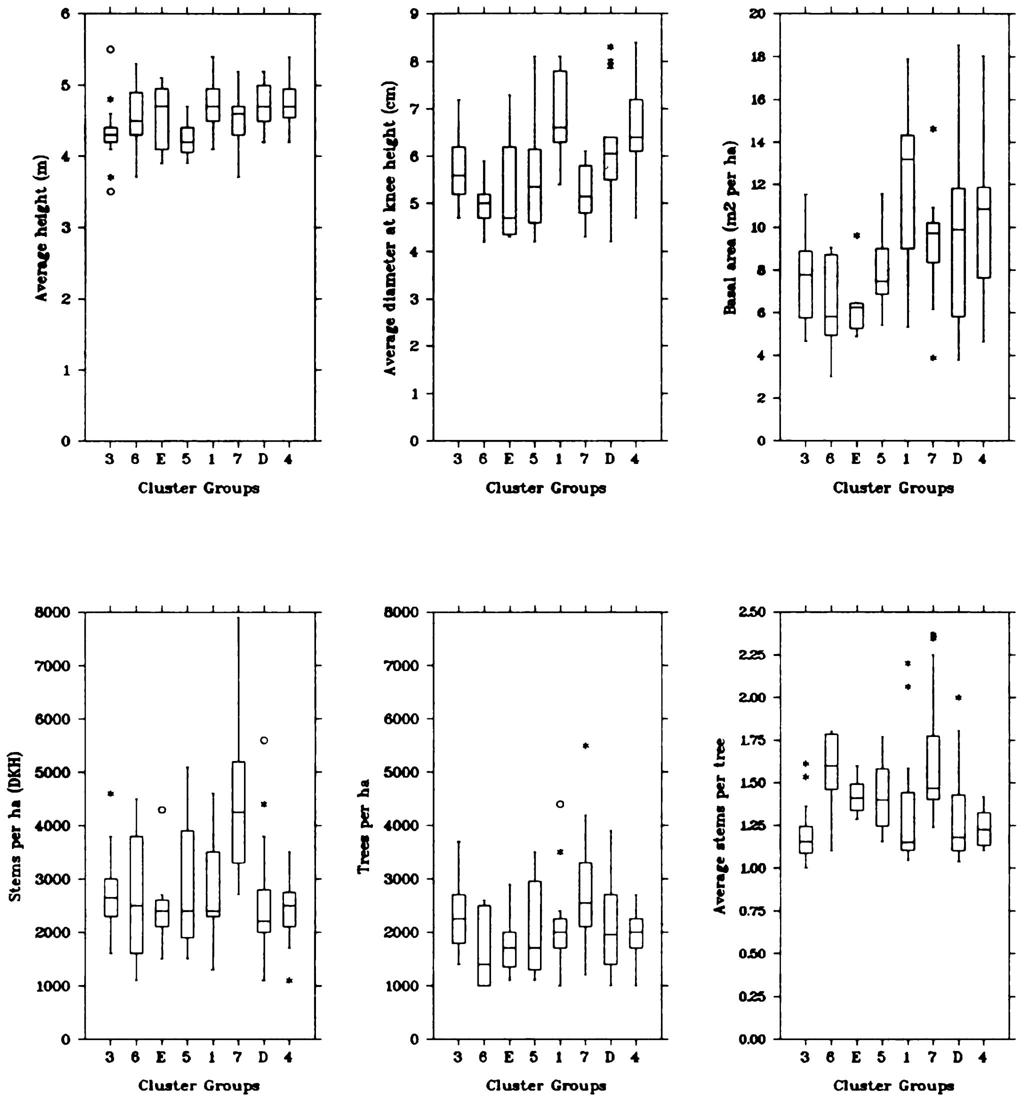

Figure 23 Box plots of structural characteristics, by cluster group. The horizontal line within each box represents the median, splitting the ordered values in half. The upper and lower edges of the boxes split the upper and lower halves, respectively, in half again. The box therefore represents the range of 50% of the values. The upper and lower edges of the boxes are referred to as the upper and lower hinges. The lines extending vertically from the upper and lower hinges extend to the last value(s) lying within one-and-a-half times the range described by the box. Stars represent points more than one-and-a-half, but less than or equal to three times the range described by the box. Circles represent values more than three times the range of the box away from the upper and lower hinges (Wilkinson 1988). Cluster group three represents 18 values, group E represents 7, group six, 5 values, group five represents 8, group one represents 11, group seven, 14, group D, 14 and group four represents 11 values. The order of the groups is based on the first principle axis of a canonical discriminant analysis using basal area contributions of sixteen species on 118 sites representing thirteen cluster groups.

sites. However, the order of groups Six and E have been reversed, because species characteristics of these three sites suggest that group E sites may represent site characteristics intermediate between groups Five and Six. The six structural parameters were tested using the Kruskal-Wallis distribution free test of differences between rank means of the respective cluster groups, based on the null hypothesis:

H_0: cluster Group One= cluster Group Three...= cluster group E.

Sites were assumed to be independent. For all parameters except trees per ha, there were significant differences between at least two groups (Table 25). The tabulated statistic assumes a chi-square distribution, with seven degrees of freedom. No statistical tests were used to separate significant differences between mean ranks. The means of the original variables, along with rank means are listed in Table 26. Means and rank means generally suggest the same relationships among the eight cluster groups examined. Where the two estimates suggest different relationships, mean ranks is given more emphasis than means for the original values.

The strongest relationship recognized in the ordinal procedures was the contrast between Group Three sites, dominated by *A. scleroxyla* and *E. caribaeum*, and Group Four sites, dominated by *P. brasiliensis*. It was suggested that Group Three sites represent areas where disturbance has been minimal and where site

Table 25 Kruskal-Wallis test statistics for six structural parameters from eight cluster groups (Wilkinson 1989). The data comes from 88 of 120 sites in the silvicultural study at ISA-Mao.

Structural Parameter	N	D.F.	Test Statistic	Probability
Mean height	88	7	19.14	0.008
Mean diameter	88	7	27.14	0.000
Total basal area	88	7	20.83	0.004
Stems per hectare	88	7	20.97	0.004
Trees per hectare	88	7	11.33	0.125
Mean stems per tree	88	7	25.70	0.001

Table 26 Mean values and rank means for structural characteristics within cluster groups and across all sites.

		Mean Height		Mean DKH		Mean basal area		Mean stems per ha		Mean trees per ha		Mean stems per tree	
	N	**Mean (m)**	*Rank mean*	**Mean (cm)**	*Rank mean*	**Mean (m^2 ha^{-1})**	*Rank mean*	**Mean**	*Rank mean*	**Mean**	*Rank mean*	**Mean**	*Rank mean*
Total	88	**4.5**	*44.5*	**5.8**	*44.5*	**9.0**	*44.5*	**3082**	*44.5*	**2292**	*44.5*	**1.37**	*44.5*
Group 3	18	**4.3**	*31.0*	**5.7**	*41.7*	**7.7**	*35.9*	**2728**	*43.0*	**2294**	*50.9*	**1.20**	*28.8*
Group 6	5	**4.5**	*44.1*	**5.0**	*23.0*	**6.3**	*24.4*	**2700**	*39.1*	**1700**	*30.0*	**1.55**	*62.4*
Group E	7	**4.5**	*45.9*	**5.3**	*31.7*	**6.3**	*22.6*	**2514**	*34.7*	**1771**	*30.6*	**1.42**	*58.1*
Group 5	8	**4.2**	*23.4*	**5.6**	*35.2*	**9.0**	*38.1*	**2875**	*40.5*	**2062**	*39.6*	**1.42**	*55.4*
Group 1	11	**4.7**	*55.4*	**7.0**	*68.8*	**12.3**	*65.5*	**2845**	*43.5*	**2209**	*42.5*	**1.36**	*37.4*
Group 7	14	**4.5**	*43.7*	**5.3**	*29.0*	**9.2**	*50.6*	**4464**	*72.1*	**2829**	*60.4*	**1.65**	*65.6*
Group D	14	**4.7**	*55.7*	**6.2**	*51.1*	**9.3**	*46.8*	**2671**	*36.3*	**2078**	*40.7*	**1.31**	*37.2*
Group 4	11	**4.8**	*57.0*	**6.6**	*60.7*	**10.5**	*54.5*	**2418**	*34.9*	**1955**	*39.5*	**1.24**	*35.1*

conditions are relatively drier than on other sites. Group Four sites, on the other hand, are represented as sites where favorable conditions for growth resulted in exceptional dominance by *P. brasiliensis*. In Figure 23, the distribution of height values for Group Three is consistently lower than the distribution of values for Group Four. Total basal area is also generally lower for Group Three than for Group Four. On average, Group Four carries 2.8 m^2 ha^{-1} more basal area than Group Three. Since total biomass is a function of basal area and height, these values suggest that Group Three sites carry considerably less biomass than sites representing Group Four. This relationship would be expected if Group Three sites represent areas with less favorable conditions for growth than Group Four sites.

The limited information on the distribution of *Phyllostylon brasiliensis* indicates the species is favored by disturbance. Sites dominated by *P. brasiliensis* would be expected to have structural characteristics indicative of such disturbance. Less basal area might be expected, as well as smaller diameters and more stems and total trees per ha. In fact, Group Four sites tend to have larger trees and fewer stems and trees per hectare than other sites. Cutting could also have resulted in more trees with multiple-stems, but Group Four sites had the second lowest number of stems per tree (Figure 23, Table 26). The structural characteristics of Group Four are not consistent with the suggestion that dominance by *P. brasiliensis* on these sites is indicative of disturbance. Differences between groups Three and Four are consistent with the suggestion that the two groupings of sites

represent opposite ends of an environmental gradient which affects relative site productivity.

The relationship between *P. brasiliensis* and *Pithecellobium circinale* on Group Seven sites is suggestive of disturbance. Structural characteristics are consistent with this interpretation. Group Seven sites have the second smallest diameters (5.3 cm), the most stems per tree (1.65) and the most stems per ha (4464). However, tree heights and total basal areas are intermediate between groups Three and Four. Therefore, total biomass may also be intermediate. The position of Group Seven sites in the ordinal procedures of the previous section suggest Group Seven sites represent conditions intermediate between groups Three and Four, but closest to Group Four. Relative biomass also places group Seven sites between groups Three and Four, but closest to Group Four. Groups Seven and Four may represent similar environmental conditions, with different disturbance histories. Cutting could have been more thorough on Group Seven sites resulting in more multiple stems, more stems per ha and smaller diameters. Group Seven may also represent sites with relatively poor site conditions which prevent *P. brasiliensis* from attaining the same dimensions as on Group Four sites. The interaction between *Pithecellobium circinale* and *Phyllostylon brasiliensis* on these sites may also be important. The weedy characteristics of *P. circinale* may indicate it as a fierce competitor for site resources. Disturbance may have allowed this species to dominate under particular site conditions and its removal may allow other species to make more expedient use of site resources.

In the ordinal procedures, the positions of groups Five and Six and Subgroup E were sometimes ambiguous with respect to the other groups. The structural characteristic of these groups are also somewhat ambiguous. Comparing groups Three and Five, Group Five sites have lower heights but more basal area. Site conditions on Group Five sites may be the same or slightly better than on Group Three sites. Mean heights and mean basal area values are about the same for Group Six and Subgroup E. Heights for these two groups are somewhat higher than for Group Three while basal areas are somewhat lower. Productivity for both groups would be expected to be less than on Group Five sites and about the same as Group Three.

Closely related based on species compositions, groups Five and Six and Subgroup E are not as closely related based on structural characteristics. Mean stems per tree are very similar among all three. However, Group Five has lower mean height values. Group Six, on the other hand, has lower mean diameters (DKH). Group Five has the most basal area and the most stems and trees. Of these three groups, Group Six is most clearly suggestive of disturbance, with smaller stems, less basal area and more multiple stems. However, differences among the three groups with respect to values for height, diameter and stems per tree are small relative to groups One and Four. Their values are also similar to Group Seven sites. Disturbance may have played an important role in the species distributions of all four groups.

Based on structural characteristics, the relationships between Group One and the other groups are not immediately apparent. If groups One and Three both represent drier site conditions, structural characteristics of the two groups would be expected to be similar. However, values for height and total basal area contrast sharply with Group Three sites. Values for Group One sites are not generally indicative of disturbance, either. Mean heights, diameters and basal area values are large, while mean stems per tree are relatively low. Overall, Group One sites are most similar to Group Four sites. These relationships are also consistent with the relative characteristics of the dominant species, *Bursera simaruba* which tended to be tall with large diameters and single stemmed. Both *B. simaruba* and *Phyllostylon brasiliensis* may represent residual components of former forest. Both species have relatively fast growth rates and may have increased their relative dominance as competition was removed. However, the specific gravity for *P. brasiliensis* is more than three times greater than for *B. simaruba*. The actual biomass indicated by basal area and height values is therefore proportionally greater for Group Four sites than for Group One sites. Relative site productivity is expected to be greater for Group Four.

Summary

Information on the ecological relationships of *A. scleroxyla* and *T. pallida* is very limited. The prevalent use of *A. scleroxyla*, *T. pallida* and *E. caribaeum* for charcoal production suggests that their dominance in Group Three sites is indicative of relatively undisturbed sites. The position of most Group Three sites

in a remote area of the forest is consistent with this interpretation. At the same time, the extreme slope angles and slope positions represented by these sites suggest particularly arid conditions. Mean heights tend to be low on these sites, as do values for total basal areas. Group Three sites are expected to have less productive site conditions than all other groups, representing the least productive end of the primary environmental gradient suggested by CA and CDA.

Implications of the known slope angles for some of the Group Four sites as well as the absence of Group Four sites on the ridges represented in Block Two suggest that dominance by *P. brasiliensis* is favored by shallow slopes and a position low in the topography of the ISA-Mao forest. The literature indicates that *P. brasiliensis* is indicative of disturbance. However, structural characteristics of Group Four sites indicate taller trees with larger diameters and greater total basal area. *P. brasiliensis* in Group Four sites may represent a residual component of former forest. Group Four sites are expected to have better site conditions than all of the groups, representing the most productive end of the primary environmental gradient suggested by CA and CDA. Subgroup D sites would be expected to have similar growth characteristics.

Structural characteristics of Group Seven do indicate disturbance. More over, both of the dominant characteristic species- *Phyllostylon brasiliensis* and *Pithecellobium circinale*- may be indicative of disturbed sites. Small in stature, thorny and composed of many small stems *P. circinale* is particularly suggestive of a species tolerant of harsh conditions. Present in smaller quantities in a number of other kinds of sites, excessive disturbance on Group Seven sites may have resulted in particular dominance by *P. circinale*. The number of small diameter stems on Group Seven sites may also indicate areas where disturbance favored regeneration of *P. brasiliensis*. The presence of *B. simaruba* as one of the minor characteristic species may indicate these sites have soil limitations. Total basal areas are intermediate between Group Three and Group Four and productivity is also expected to be intermediate.

Like Group Seven, structural characteristics of groups Five and Six and Subgroup E suggest disturbance. Mean heights are low and the number of multiple stems is high. *Caesalpinia coriaria*, *A. farnesiana* and *Prosopis juliflora* are the three species consistently associated with these groups. Of the three, the literature indicates *A. farnesiana* and *P. juliflora* are associated with disturbance. All three tend to have multiple stems and can be relatively fast growing. The literature also suggests they do best on sites with deep soils with no limitations for root growth. These sites may be disturbed areas of the forest with deep soils. Group Five sites have larger mean diameters than Group Six or Subgroup E. On these sites, *C. coriaria* may represent a residual component from the original forest. Group Five sites may be less disturbed than other areas. Based on low values for total basal area and small mean heights, productivity is expected to be less than groups Four and Seven, but higher than Group Three.

Of the two species characteristic of Group One, observations made in studies of the ISA-Mao forest suggest that *Bursera simaruba* is a residual component, dominating locally because other species were removed for charcoal. The other species characteristic of Groups One, *E. caribaeum*, may have been one of the these formerly dominant species. *E. caribaeum* has many local uses, including firewood and charcoal. Other studies suggest that both *B. simaruba* and *E. caribaeum* are tolerant of rocky, shallow soils which are highly alkaline. This suggests a contrast with groups Five and Six and Subgroup E which are dominated by species which may do best on soils without impediments to root growth. Slope angle relationships suggest that Group One sites are located on moderately steep slopes, which may represent relatively shallow soils. Structural characteristics of Group One are similar to Group Four, consisting of sites with tall trees, relatively large diameters and high total basal areas. These characteristics indicate growth conditions would also be similar to Group Four. However, *B. simaruba*'s low specific gravity indicates the biomass on Group One sites may not be particularly high, relative to Group Four sites. Group One sites are expected to have poor growth, intermediate between groups Three and Four and less than Group Seven.

Summary

Several different types of data have been used to examine differences between cluster groups. Based on analysis of the structural data and slope characteristics, the contrast between groups Three and Four is interpreted to represent differences in productivity. The structural characteristics of groups Five, Six and

Seven and Subgroup E are suggestive of disturbance. In these groups, species composition may be the result of an interaction between disturbance and environmental characteristics. Structural characteristics would indicate that groups One and Four should have similar levels of growth. However, the physiological characteristics of *Bursera simaruba* may be more indicative of drought adaptations than of high levels of productivity. Slope characteristics and species relationships suggest that Group One sites are intermediate between groups Three and Four.

The results of CA and CDA suggest a contrast between Group One sites on the one hand and groups Five, Six and E on the other. The underlying factor or factors which explain this relationship cannot be determined directly from the available data. However, the available literature indicates the contrast may be related to soil characteristics. The species dominating Group One may be tolerant of shallow, rocky soils, while the species dominating groups Five and Six and Subgroup E may do best on deep soils without impediments to root growth. Given this relationship, the prediction would be that growth would be higher on the sites without root impediments.

Growth and Mortality Within Cluster Groups

Measures of site productivity were used to examine differences in relative productivity between cluster groups. These measures of growth and mortality provided the final test for the scenarios presented based on ordinal procedures and site data. Group Three sites should be expected to show the lowest levels of growth, while sites dominated by *Phyllostylon brasiliensis* should be expected to show the highest levels. Both groups One and Five should show intermediate levels, which are closer to level represented by Group Three sites, if they do in fact represent areas with site characteristics which are more like those represented by Group Three. Group Seven sites should be expected to have a relatively better growth response than groups One, Three and Five if in fact Group Seven sites represent conditions similar to Group Four sites.

Assuming independence among the sites, the relationship between cluster group designation and growth and mortality was tested using the Kruskal-Wallis distribution free test of differences between rank means. In addition to the seven core site cluster groups, subgroups D and E were included to examine the relationship of sites theoretically representing intermediate areas along the species-site continuum. The groups were tested assuming the null hypothesis:

H_0: Group Three= Group Six= group E= Group Five, etc.

Table 27 lists the rank means for each parameters and the test statistic (H-statistic). An alpha level of 0.1 was used to test for significant differences. The equation for the H-statistic comes from Hollander and Wolfe (1973). See Appendix E for details of the test assumptions and the general equations.

Except for stem mortality, all of the parameters tested had at least two cluster groups with significantly different mean ranks. For the five parameters showing significant differences, a distribution-free test of differences between treatments was applied. Not all differences were of interest, so only fourteen contrasts were examined. The equation used assumes that all groups come from the same

Table 27 Rank means and calculated test statistics for growth and mortality parameters, using the Kruskal-Wallis distribution free test of differences between rank means. Eight cluster groups are tested for significant differences. The H-Statistic is the calculated test statistic to be compared with a Chi-square distribution. The alpha level was set at 0.1, with a Chi-square statistic of 12.02, assuming seven degrees of freedom (k-1, where k= the number of groups being tested).

Cluster group	N1	BARGRTH	NETGRTH	BARAVE	STEMMORT	BARMORT	N2	DKHDIF
Three	18	30.8	27.7	31.8	51.9	56.2	18	29.8
Six	5	35.0	32.8	51.2	45.3	56.0	5	44.0
E	7	58.7	66.3	57.9	36.2	25.6	7	51.9
Five	8	37.9	48.1	38.3	28.3	32.4	8	36.3
One	10	37.2	41.2	39.6	35.2	43.5	10	37.3
Seven	14	50.5	49.4	41.9	47.3	40.1	14	54.2
D	14	44.7	37.9	43.6	49.1	51.1	14	41.1
Four	11	62.2	62.2	63.3	44.2	35.0	10	62.4
H-Statistic	87	15.943	21.453	13.953	7.553	13.610	86	15.908

population (i.e. the null hypothesis) and is therefore conservative (Hollander and Wolfe 1973). Although basal area mortality was found to be significant, none of the differences between cluster groups examined exceeded the test for least significant differences. The results for the other four parameters are presented in Table 28. Figure 24 illustrates the means and standard deviations of the eight cluster groups across the four growth and two mortality parameters.

Groups Three and Four are significantly different across all four growth parameters, with Group Four sites showing higher levels of growth than Group Three, as expected based on previous analyses. These results support the proposition that groups Three and Four represent opposite ends of a species-site continuum which relates closely to fundamental differences in site factors associated with site productivity. More over, groups One, Five and Seven fall in between these two endpoints, which is also consistent with the model developed based on ordinal procedures and site data analyses (Figure 24).

Although the differences between groups One, Five and Seven are not statistically significant, the relative patterns between these groups show that growth was consistently higher in Group Seven sites than in sites of either Group One or Group Five (Table 27). Although not conclusive, this generally supports the association of Group Seven sites in proximity to Group Four sites in the ordinal procedures. Conversely, sites representing groups One and Five were generally

Table 28 Distribution free multiple comparisons for growth and mortality parameters found to have significant differences between treatment means using the Kruskal-Wallis distribution free test. Fourteen comparisons were examined. The test statistic is the critical value calculated using an alpha level of 0.1 with each test statistic based on the sample sizes of the treatments being compared. Values in each cell are differences between the two treatments being compared. Treatments with differences which are significant are underlined.

Treatment comparison	Test Statistic	BARGRTH	NETGRTH	BARAVE	DKHDIF
Three v/s E	32.5	-28.2	<u>-38.6</u>	-26.1	-22.0
Three v/s Five	31.0	-7.3	-20.5	-6.5	-6.4
Three v/s One	27.9	-6.6	-13.5	-7.8	-7.5
Three v/s Seven	26.0	-19.9	-21.7	-10.1	-24.4
Three v/s Four	27.9	<u>-31.6</u>	<u>-34.5</u>	<u>-31.5</u>	<u>-32.6</u>
Five v/s E	39.0	-20.8	-18.2	-19.6	-15.6
Five v/s Seven	33.8	-12.6	-1.2	-3.6	-18.0
Five v/s Four	35.3	-24.3	-14.1	-25.0	-26.2
One v/s E	35.3	-21.5	-25.1	-18.3	-14.6
One v/s Seven	29.4	-13.3	-8.2	-2.3	-16.9
One v/s Four	31.1	-25.0	-21.0	-23.7	-25.1
Seven v/s E	33.8	-8.2	-16.9	-16.0	2.4
Seven v/s Four	29.4	-11.7	-12.8	-21.4	-8.2
Four v/s E	35.3	3.5	-4.1	5.4	10.5

Figure 24 Growth and mortality response by cluster group in the ISA-Mao subtropical dry forest. Symbols represent averages of 100 m^2 sites within the same cluster group as designated based on four cluster techniques using relative basal area contributions of sixteen tree species. Bars represent plus and minus one standard deviation. The order of the groups is based on the first axis of a canonical discriminant analysis using 118 sites which represented thirteen cluster groups. Bars represent plus or minus one standard deviation. For Group Three, n=18, for Group Six, n=5, for group E, n=7, for group 5, n=8, for Group One, n=10, Group Seven, n=14, group D, n=14 and for Group Four, n=11, except for the parameter, mean DKH increment. For this parameter, Group Four is represented by only 10 sites. Growth estimates are based on diameter measurements taken at knee height in 1986 and 1992.

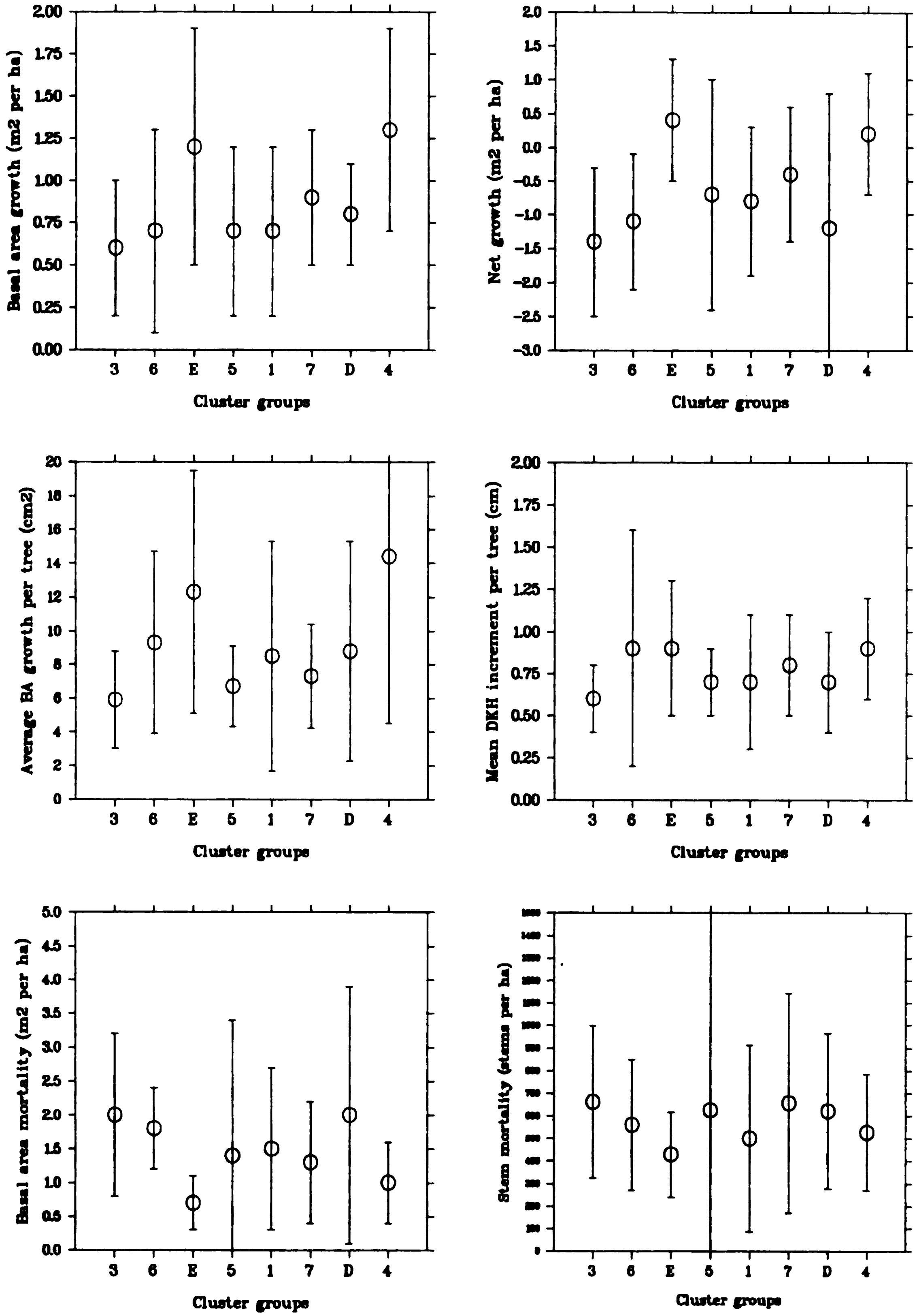
Basal area growth (m2 per ha)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
3 6 E 5 1 7 D 4
Cluster groups
Net growth (m2 per ha)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
3 6 E 5 1 7 D 4
Cluster groups
Average BA growth per tree (cm2)
20
18
16
14
12
10
8
6
4
2
0
3 6 E 5 1 7 D 4
Cluster groups
Mean DKH increment per tree (cm)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
3 6 E 5 1 7 D 4
Cluster groups
Basal area mortality (m2 per ha)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
3 6 E 5 1 7 D 4
Cluster groups
Stem mortality (stems per ha)
3 6 E 5 1 7 D 4
Cluster groups

Figure 24

less productive, which support their relative proximity to Group Three sites in the ordinal procedures.

On the other hand, subgroups D and E did not perform as expected. Subgroup D had lower mean values for basal area growth, net growth and mean DKH increment versus both groups Four and Seven. This was not predicted based on the close association of Subgroup D and Group Four sites. Based on species composition alone, sites in Subgroup D would be expected to have good growth rates if *P. brasiliensis* by itself indicates sites which are the most favorable for growth. The species characteristics which eliminated subgroup D sites from the Group Four core site classification may be related to site characteristics which distinguish Group Four and Subgroup D in terms of productivity.

Conversely, sites representing Subgroup E were considerably more productive than expected based on their close association with Group Five sites. Subgroup E sites had higher values for the four growth parameters than all other groups except groups Four and Seven. Again, based on species composition alone, sites in Subgroup E would be expected to have poor growth rates, if *Caesalpinia coriaria*, *A. farnesiana* and *Prosopis juliflora* indicate sites which are less favorable for growth. On the other hand, if these species are indicative of disturbance, a wide range of site qualities are possible, with a lack of root impediments being the possible unifying site factor among groups Five and Six and Subgroup E.

A contrast between Group One versus the association of groups Five and Six and Subgroup E might be expected given that *B. simaruba* and *E. caribaeum* may be indicative of rocky, shallow soils, while *C. coriaria*, *A. farnesiana* and *P. juliflora* may be indicative of deep soils. No such contrast is consistently apparent. Group Five sites in particular consistently shows about the same level of growth as Group One sites. However, as mentioned above, Subgroup E sites do not show a close relationship with groups Five and Six. These sites do show greater growth and lower mortality than Group One. Perhaps groups Five and Six represent areas with deep soils, but other site characteristics result in growth conditions which are roughly equivalent to those represented by Group One.

Summary

As expected based on the model of species-site relationships developed from ordinal procedures and the information available regarding species, site conditions and overstory structural characteristics, groups Three and Four contrast sharply in terms of growth as measured over the six years of the silvicultural study. Differences between these two groups are apparent in spite of effects related to different levels of thinning. Also expected were the intermediate positions of groups One, Five and Seven. Differences between these three groups were not statistically significant, but the trends across growth parameters indicate that Group Seven sites were generally more productive than the other two groups. This is also consistent with the model of species relationships based on the primary axes of the ordinal procedures which consistently placed Group Seven

sites closest to Group Four sites. It is also consistent with structural characteristics of these sites which indicated that Group Seven sites carried basal area similar to Group Four sites. On the other hand, subgroups D and E did not perform as expected. Subgroup D sites had considerably less growth than Group Four sites, and subgroup E sites had considerably better growth than Group Five sites. The growth responses of these two subgroups indicate a complex system which needs more study.

Nonparametric Analysis of Thinning Effects

Assuming independence among the sites, the effect of cutting level on growth and mortality was tested using the Kruskal-Wallis distribution-free test of differences between rank means. The same parameters examined in the previous section were tested for differences between five cutting levels. At a probability level of 0.1, average basal area increment, average diameter increment, stem mortality and basal area mortality were found to differ significantly between treatments (Table 29). For the five parameters found to have at least two treatments significantly different, rank mean differences were tested for significance (Table 30). See Appendix D for details of the test assumptions and the general equations. The means and standard deviations of the original values are plotted in Figure 25.

Sites cut at the second level (15-36%) had significantly higher net growth compared to control sites. These sites also had higher average diameter increment compared to sites cut at the first level (1-15%). Sites cut at the second level also had less stem and basal area mortality compared to control sites (Table 29, Figure 25). Sites cut at the third level (36-55%) showed greater average basal area increment per tree and greater average diameter increment per tree compared to control sites. These sites also had greater average diameter increment per tree than sites cut at the first level (1-15%). Sites cut at level three also had less stem mortality than control sites, although basal area mortality was not significantly different than sites cut at any other level (Table 29, Figure 25).

Table 29 Rank means and calculated test statistics for growth and mortality parameters, using the Kruskal-Wallis distribution free test of differences between rank means. Five levels of cutting were tested for significant differences: C= less than one percent of the basal area removed, 1= 1-15%, 2= 15-36%, 3= 36-55%, 4= 55-72%. H-Statistic is the calculated test statistic to be compared with a Chi-square distribution. A probability of 0.1 was used, with a Chi-square statistic of 7.779 assuming four degrees of freedom.

Cutlevel	N[1]	BARGRTH	NETGRTH	BARAVE	STEMMORT	BARMORT	N[2]	DKHDIF
C	32	55.3	44.7	44.7	74.1	71.5	32	46.3
1	19	62.1	51.7	51.7	65.2	63.9	19	39.9
2	22	67.3	74.5	65.7	50.2	42.8	21	68.9
3	25	56.1	60.1	67.2	47.1	52.4	25	69.5
4	15	40.6	59.3	60.2	36.6	45.7	15	60.3
H-Statistic	113	6.476	11.569	9.120	18.963	13.510	112	15.408

Table 30 Distribution free multiple comparisons for growth and mortality parameters found to have significant differences between treatment means using the Kruskal-Wallis distribution free test. See Table 29 for the treatments which were compared. The test statistic is the critical value calculated using an alpha level of 0.1 with each test statistic based on the sample sizes of the treatments being compared. Values in each cell are differences between the two treatments being compared. Differences between treatments which are significant are underlined.

Treatment Comparisons	Test Statistic[1]	NETGRTH	BARAVE	STEMMORT	BARMORT	Test Statistic[2]	DKHDIF
C-vs-1	24.2	-7.1	-7.0	8.9	7.6	24.0	6.3
C-vs-2	23.2	<u>-29.8</u>	-21.0	<u>23.9</u>	<u>28.7</u>	23.3	-22.7
C-vs-3	22.3	-15.4	<u>-22.5</u>	<u>27.1</u>	19.1	22.1	<u>-23.3</u>
C-vs-4	26.2	-14.6	-15.5	<u>37.6</u>	25.8	25.9	-14.0
1-vs-2	26.2	-22.7	-13.9	15.0	21.1	26.2	<u>-29.0</u>
1-vs-3	25.5	-8.3	-15.5	18.2	11.5	25.2	<u>-29.6</u>
1-vs-4	28.9	-7.5	-8.5	28.6	18.2	28.6	-20.3
2-vs-3	24.8	14.4	-1.5	3.1	-9.6	24.5	-0.6
2-vs-4	28.3	15.2	5.5	13.6	-2.9	28.0	8.6
3-vs-4	27.3	0.8	7.0	10.5	6.7	27.1	9.3

[1]Total N=113. For the variables NETGRTH, BARAVE, STEMMORT and BARMORT

[2]Total N=112. For the variable DKHDIF.

Figure 25 Growth and mortality responses to thinning in the subtropical dry forest of the Dominican Republic. Symbols represent averages of 100 m^2 sample plots within the same thinning level classification. Thinning levels are: 0= less than one percent of the basal area removed (n=32), 1= 1-15% (n=19), 2= 15-36% (n=22), 3= 36-55% (n=25), 4= 55-72% (n=15), 5= greater than 72% removal (n=5). Parameters are based on diameter measurements taken at 0.5 m above ground level taken in 1986 and 1992. Bars represent plus or minus one standard deviation.

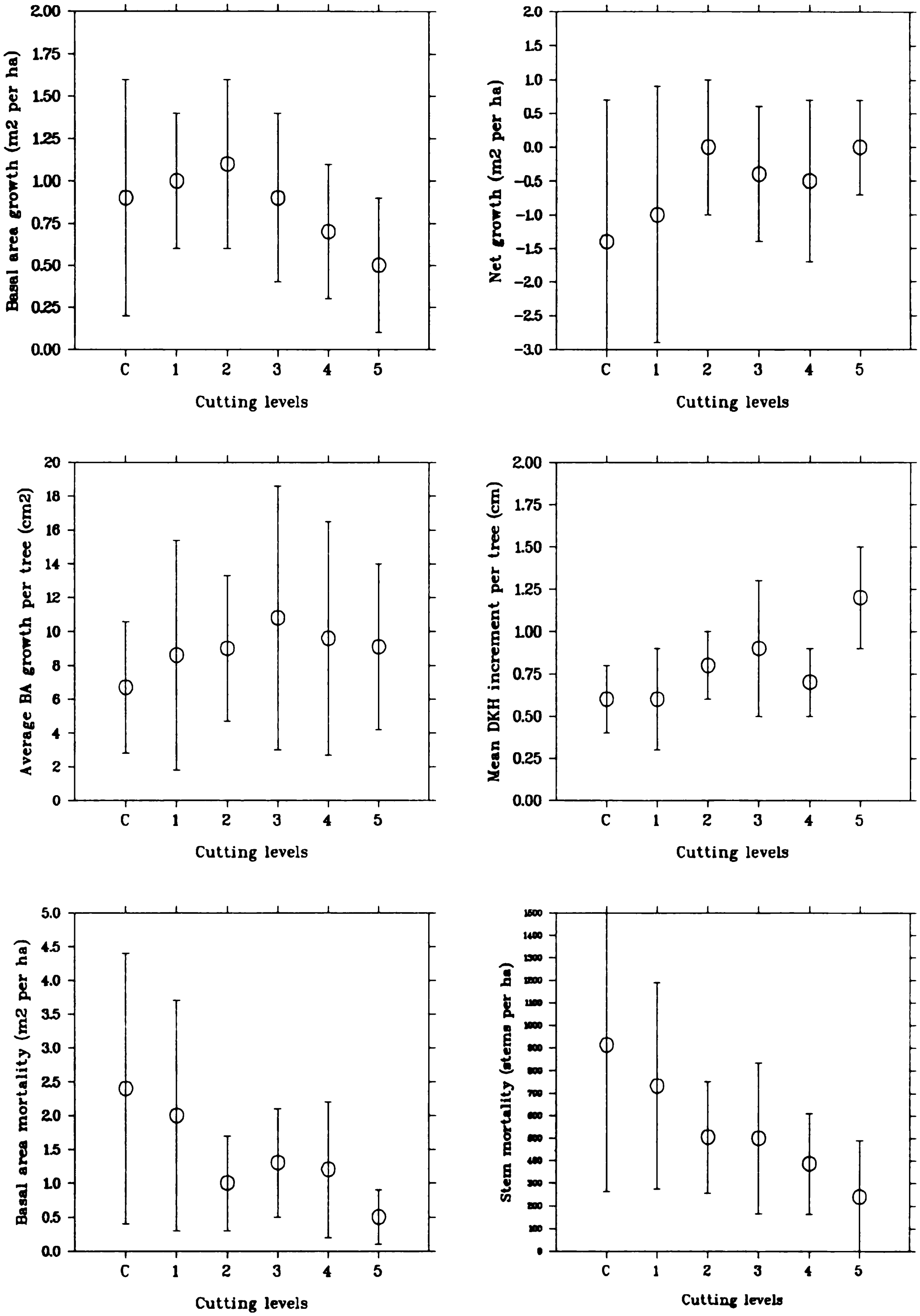
Basal area growth (m2 per ha)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
C
1
2
3
4
5
Cutting levels
Net growth (m2 per ha)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
Cutting levels
Average BA growth per tree (cm2)
20
18
16
14
12
10
8
6
4
2
0
Cutting levels
Mean DKH increment per tree (cm)
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Cutting levels
Basal area mortality (m2 per ha)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Cutting levels
Stem mortality (stems per ha)
Cutting levels

Figure 25

Although variability within treatments remained high after reassigning sites based on actual basal area removed (Figure 25), trends of the mean values within treatments suggest that in general, thinning succeeded in concentrating total basal area growth on fewer stems. For example, although total basal area growth per hectare was not significantly different between treatments based on nonparametric analyses, Figure 25 suggests that growth increased slightly on sites with 15-36% of the basal area removed and was not less than the control sites until the second highest rate of 55-72% removal. This implies that the growth potential of moderately thinned sites tended to remain constant relative to unthinned sites. Fewer stems, therefore, produced the same total growth. The same relationship is apparent for the parameters BARAVE and DKHDIF. Average basal increment and average diameter increment both tended to increase as thinning increased through the cutting level of 36-55% (Table 29, Figure 25). Trees within thinned sites were larger after six years than individuals in unthinned areas. The highest levels of thinning appear to have caused growth to decline.

Although growth tended to decrease at the highest levels of basal area removal, stem and basal area mortality tended to continue to decrease as thinning level increased. This suggests that even at the highest levels of thinning, stem removal eliminated competition which in the uncut sites resulted in higher mortality. Assuming that basal area lost from 1986 to 1992 was part of the natural processes of the dry forest, mortality may represent a harvestable quantity beyond the initial biomass removal in the original thinning. If biomass after six years is not

significantly less than uncut sites and average diameter is greater, it could be considered that the silvicultural thinning was successful. Based on these criteria, the cutting level of 15-36% basal area removal was the most successful. Sites cut at this level had the highest net growth (Table 29, Figure 25). These sites were essentially at equilibrium over the six years, with the same total biomass accumulating on fewer stems. On the other hand, sites subjected to 36-55% cutting appear to have had higher average basal area and diameter increments (Figure 25). However, based on rank means, the differences are very small between cutting levels two and three (Table 30). A moderate level of cutting appears to stimulate better growth in the ISA-Mao subtropical dry forest.

Summary

Based on nonparametric analyses, thinning did affect both growth and mortality in the forest. The growth response was generally positive for the lowest cutting levels, and increasingly negative for the two highest levels. Mortality, on the other hand, showed a linear decrease as cutting intensity increased. These results suggest that competition between trees in the dry forest is significant and growth rates can therefore be manipulated. However, a great deal of variability is evident in growth and mortality responses among sites within the same cutting level. This variability may well be associated with the patterns of species compositions and site characteristics observed in the data collected before thinning.

Summary

The goals of this study were to (1) determine whether patterns of species composition existed among the sampled sites in the unthinned forest of a silvicultural thinning study in the dry forest of the ISA-Mao Forestry Experimental Station, (2) examine the implications of species distribution with respect to disturbance history and underlying environmental gradients, and (3) explore the relationship of growth and mortality with respect to species composition and thinning level. An exploration of the data from the silvicultural study was considered necessary because initial analyses of the growth data had revealed extreme variability in the data, including among sites within the same thinning treatment.

Initial analyses focused on 45 sites representing a subset of the 120 sites in the silvicultural study. Basal area contributions of sixteen dry forest species prominent in the study sites were used to classify sites into relatively homogeneous groups, using a series of cluster analyses. Analyses of the entire data set resulted in similar groupings. Six major groups were formed based on analyses of the full data set. Numbered arbitrarily, Group One sites were found to be associated with the characteristic species *Bursera simaruba* and *Exostema caribaeum*. Group Three sites were found to have three characteristic species, *Acacia scleroxyla*, *E. caribaeum* and *Trichilia pallida*. Group Four sites were dominated by one species, *Phyllostylon brasiliensis*. Group Five was associated

with *Caesalpinia coriaria* and *A. farnesiana*. Group Six was associated with *A. farnesiana*, *C. coriaria* and *Prosopis juliflora*. Group Seven was associated with *P. brasiliensis*, *Pithecellobium circinale* and *B. simaruba*. Of the 120 sites examined in the second set of analyses, 67 were found to cluster consistently across four different procedures. These 67 sites were termed "core" sites.

Applied first to the core sites, then to all the sites, correspondence analysis (CA) was used to test the results of the cluster procedures. All of the groups formed from the cluster analyses were found repeated in CA. The species relationships implicit in the cluster techniques were also found to compare well with the results of CA. Commonly used as a tool for the ordination of sites, CA suggested a strong contrast between sites in groups Three and Four. A secondary contrast was suggested between Group One sites and sites representing groups Five and Six. Based on the results of CA used in other studies, these contrasts may be indicative of underlying environmental gradients.

Based on the results of the cluster analyses and the CA procedures, core sites were considered to represent samples of their respective cluster groups. These groups were submitted to canonical discriminant analysis (CDA) to examine their ordinal relationships. However, Group Six had to be eliminated because of apparent limitations related to sample size. Subsequently, the remaining five groups were submitted to CDA. Based on this CDA, each group plotted in a discrete portion of the graph and a contrast between groups Three and Four was

apparent. A second gradient was associated with the separation of Group One from the other groups, but this relationship did not appear to be directly related to the position of group Five.

Another CDA was applied to a data set partitioned into thirteen groups- six core site cluster groups and seven subgroups represented by the noncore sites. Results of this analysis suggested a continuum of groups, rather than a series of discrete positions, as expected given that noncore sites represented intermediate species compositions. Plotted along the first two axes, a curvilinear relationship was apparent. This effect is common for ordinal procedures applied to sites representing diverse habitats. The first axis suggested the same contrast between groups Three and Four noted previously. In this CDA procedure, the third axis was responsible for the separation of Group One from an association of groups Five and Six and the Subgroup E. Subgroup E consisted of sites closely associated with Group Five in the cluster analyses. The relative positions of the core site groups based on three axes were very similar to the relative positions of the groups based on three axes of CA applied to 67 sites.

To examine the implications of these ordinal relationships with respect to disturbance history and underlying environmental gradients, several different types of data examined. With respect to the contrast between groups Three and Four, species information suggested that *A. scleroxyla*, *E. caribaeum* and *T. pallida* may be indicative of relatively undisturbed sites, while *Phyllostylon brasiliensis* may be indicative of disturbed areas. However, observations of slope position and slope angle suggest a strong contrast based on site conditions, not disturbance. More over, the overstory structural data does not suggest that Group Four sites are highly disturbed. Group Three sites appear to be indicative of ridgetop sites with steep slopes which are relatively less productive. Group Four sites appear to represent areas located lower in the topography, with relatively slight slopes which are relatively more productive. As expected, growth and mortality parameters showed that Group Three had less growth and higher mortality than Group Four.

The structural characteristics of groups Five, Six and Seven and Subgroup E were suggestive of disturbance, which was consistent with the information available about the species dominant in these groups. However, species composition might also reflect an interaction between disturbance and environmental characteristics. For example, the literature indicated *C. coriaria*, *A. farnesiana* and *P. juliflora* are favored on sites without impediments for deep root extension. Structural characteristics suggested that groups Five and Six and Subgroup E represent less productive site conditions than Group Seven. All four of these groups suggested intermediate conditions between groups Three and Four. Growth and mortality parameters indicated productivity for Group Seven did tend to be higher than for groups Five and Six, but Subgroup E sites had relatively high growth rates and low mortality, similar to Group Four.

The literature suggests that the species characteristic of Group One, *B. simaruba* and *E. caribaeum*, are associated with rocky and shallow soils. Available information on slope angles for Group One sites suggested an association with moderately steep slopes, which may be indicative of shallow soils. Nevertheless, structural characteristics of Group One suggested that groups One and Four had similar site conditions. Both groups tended to carry relatively large amounts of basal area and were dominated by tall trees with large diameters. However, the physiological characteristics of *Bursera simaruba* may be more indicative of drought adaptations than of high levels of productivity. *B. simaruba* has a very low specific gravity and a large proportion of water in the green wood. Growth and mortality parameters indicated relative productivity on Group One sites was intermediate between groups Three and Four, and less than on Group Seven sites.

In the process of preparing the data for analysis, the target thinning levels were found to differ considerably from the actual stems and basal area removed. Therefore, nonparametric analyses were applied to growth and mortality parameters to examine the effects of actual basal area removal. In these analyses, thinning at a moderate level (15-36% removal) was generally found to have a positive effect on growth. Analysis of differences among the cluster groups did not take into account the effect of different levels of thinning. It would be reasonable to suggest that variability apparent within cluster groups may have been associated with different levels of thinning and, conversely, variability within cutting levels may have been associated with differences relating to species

composition and site conditions. Implications of the productivity gradient revealed using multivariate analyses suggest that thinning would have a more beneficial effect on "good" sites, where competition between individual trees is greatest. On "poor" sites, thinning would be predicted to have less effect, as environmental stress may be a more important limitation than competition between individual trees. The relatively high level of basal area and the extreme stem density in Group Seven indicate these sites might show a particluarly positive response to thinning.

Conclusions

Multivariate analyses had not previously been used to address questions of species-site relationships in subtropical dry forest. In this study, a series of MVA procedures were able to illustrate fundamental structures of species composition which were not previously understood. Limitations in available site data and in the literature describing the ecologies of species dominant in the forest restricted the interpretation of the structures apparent in the data. Nevertheless, the available data clearly suggested a productivity gradient apparently related to species composition and site characteristics.

Because virtually all of the dry forests of the world have been heavily affected by human intervention (Murphy and Lugo 1986a), it is important to emphasize that species relationships existed in the ISA-Mao forest in spite of disturbance, although disturbance has effected species distributions in a number of ways. Human intervention clearly makes analyses of forest dynamics more complicated. However, using MVA procedures, patterns apparent in the data can be simplified and, with additional information, these patterns can be understood and utilized to develop models of forest productivity which incorporate factors related to human disturbance as well as environmental gradients.

Recommendations

This study has resulted in many questions and ignored many others. Why such high rates of mortality existed in the silvicultural study has not been addressed. As mentioned previously, some of the mortality is related to cutting. Some "mortality" may be related to measurement error. Also, some of the trees may have been misplaced in the inventory. All of these factors would also impact growth estimates. Much of this information is available in the inventories from 1987 to 1991. Along with new inventories using more precise measurement techniques, studies of these other inventories would be a great addition to understanding the real effects of thinning in the dry forest, as well as add to the information about fundamental dynamics in the natural forest. In particular, reliable estimates of growth in the subtropical dry forest are necessary for determining sustainable harvest rates.

An important component of such studies would be the use of the biomass equations developed by Maxwell (1985). To make use of Maxwell's equations, only the measurement at knee height is necessary. In future inventories, it might be advisable to eliminate the measurements at breast height. Eliminating the breast height measurement would save time, allowing for greater accuracy in measuring the remaining parameters. For example, if the time limitation is reduced, knee height measurements could be taken with a diameter tape rather than calipers. Also, if possible, the diameters for each stem of trees with multiple

stems should be recorded together in subsequent inventories, so that the growth and mortality of individual stems can be analyzed. Because cacti clearly dominate some areas of the forest, some measure of cactus dominance should also be included in future inventories.

If quantitative data on slope positions, angles, aspects, soil depths and soil characteristics were available for each site, suggestions made in this study about underlying gradients and species distributions could be tested. The relative effectiveness of different levels of thinning could also be better understood. In Appendix M, a brief proposal is included for the study of soil-site interactions in the area of forest comprising the silvicultural study. Data from such a study would not only clarify the relationships between core cluster groups, they could potentially permit an integration of all the sites into one comprehensive system of classification which delineates the forest into relatively homogenous management units. Such a classification system would involve an iterative series of dynamic procedures, where classification leads to specific hypotheses, which result in a better understanding of the dry forest dynamics, resulting in better classifications. Multivariate methods represent an important tool in this process, helping to simplify relationships between variables which appear exceptionally complex.

Finally, I would like to emphasize that the ISA-Mao forest represents one of the few subtropical dry forests where systematic silvicultural techniques have been initiated. Despite the length of this study, it barely scratches the surface of the

pool of data collected in the forest since the forest was donated to ISA in 1978. Some of the studies initiated in the forest were concluded and have been analyzed and summarized sufficiently by the professors and students in ISA's department of natural resources. Nevertheless, many of the data have never been thoroughly analyzed. Although there are undoubtedly many limitations in some of the data sets, the results of this study show that the available numbers have the potential for illustrating fundamental relationships directly relevant to appropriate management of the forest. Resources for an institution such as ISA are always limited. This is a fact of institutional life. However, it is to be hoped that the fundamental importance of the research at the ISA-Mao Forestry Experimental Station is never underestimated due to lack of interest in an "unsexy" resource.

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APPENDICES

APPENDIX A

Actual basal area and stems removed and assigned cutting levels

APPENDIX A

OBS	ID	BLOCK	SUBPLOT	CLUSTOT	TRTMT	CUTLEVEL	PERBARCT	PERTRKCT
1	101	01	01	BG	C	C	0.0	0.0
2	102	01	02	7	C	1	1.3	3.0
3	103	01	03	BG	C	C	0.0	0.0
4	104	01	04	D	C	C	0.0	0.0
5	105	01	05	BD	C	C	0.0	0.0
6	106	01	06	BD	40	3	46.5	47.2
7	107	01	07	C	40	3	50.7	40.7
8	108	01	08	BG	40	3	48.1	35.7
9	109	01	09	4	40	3	52.8	44.4
10	110	01	10	5	40	C	0.7	2.0
11	111	01	11	D	20	1	1.6	7.4
12	112	01	12	4	20	1	3.1	8.7
13	113	01	13	D	20	2	18.3	21.4
14	114	01	14	D	20	1	10.7	21.1
15	115	01	15	FG	20	2	16.5	12.5
16	116	01	16	BG	60	4	69.2	54.1
17	117	01	17	D	60	4	65.9	61.4
18	118	01	18	1	60	4	63.4	51.4
19	119	01	19	5	60	4	61.1	54.3
20	120	01	20	3	60	4	67.0	56.5
21	121	01	21	E	80	3	47.9	54.2
22	122	01	22	D	80	2	30.0	65.0
23	123	01	23	EH	80	3	51.5	65.5
24	124	01	24	6	80	3	49.0	63.6
25	125	01	25	E	80	4	56.9	70.8
26	126	01	26	1	C	1	4.3	2.2
27	127	01	27	6	C	C	0.0	0.0
28	128	01	28	E	C	1	9.8	12.0
29	129	01	29	G	C	C	0.0	0.0
30	130	01	30	E	C	C	0.0	0.0
31	201	02	01	3	60	3	53.9	46.4
32	202	02	02	3	60	4	58.6	64.0
33	203	02	03	3	60	2	31.9	36.7
34	204	02	04	BG	60	3	53.1	53.8
35	205	02	05	3	60	3	48.6	61.1
36	206	02	06	E	C	C	0.0	0.0
37	207	02	07	3	C	C	0.0	0.0
38	208	02	08	3	C	1	2.1	4.0
39	209	02	09	3	C	C	0.0	0.0
40	210	02	10	3	C	C	0.0	0.0
41	211	02	11	3	20	1	3.9	3.3
42	212	02	12	3	20	C	0.0	0.0
43	213	02	13	1	20	C	0.0	0.0
44	214	02	14	X	20	C	0.0	0.0
45	215	02	15	C	20	C	0.0	0.0
46	216	02	16	1	40	4	62.8	43.5
47	217	02	17	3	40	3	43.2	47.8
48	218	02	18	1	40	5	83.6	69.7
49	219	02	19	C	40	4	70.8	57.1
50	220	02	20	7	40	3	51.4	53.7
51	221	02	21	E	C	C	0.0	0.0
52	222	02	22	FG	C	C	0.0	0.0
53	223	02	23	3	C	1	8.9	10.3
54	224	02	24	3	C	C	0.0	0.0
55	225	02	25	3	C	C	0.0	0.0
56	226	02	26	3	80	4	66.6	65.4
57	227	02	27	1	80	3	52.0	63.6
58	228	02	28	7	80	5	79.2	85.2
59	229	02	29	3	80	4	58.3	78.9
60	230	02	30	1	80	4	66.3	30.8
61	301	03	01	7	C	C	0.5	2.3
62	302	03	02	1	C	1	1.6	8.7
63	303	03	03	D	C	1	2.5	4.8
64	304	03	04	4	C	C	0.0	0.0
65	305	03	05	D	C	C	0.0	0.0
66	306	03	06	7	40	2	31.1	57.8
67	307	03	07	6	40	2	34.6	42.2
68	308	03	08	5	40	2	19.1	47.6
69	309	03	09	5	40	2	19.7	29.4
70	310	03	10	G	40	3	39.9	55.8
71	311	03	11	E	20	2	24.2	18.5
72	312	03	12	D	20	2	27.3	28.9
73	313	03	13	B	20	2	15.9	44.4
74	314	03	14	7	20	2	26.3	39.3
75	315	03	15	7	20	3	54.8	45.9

OBS	ID	BLOCK	SUBPLOT	CLUSTOT	TRTMT	CUTLEVEL	PERBARCT	PERTRKCT
76	316	03	16	G	C	1	8.3	6.5
77	317	03	17	G	C	C	0.0	0.0
78	318	03	18	BG	C	1	7.6	25.0
79	319	03	19	G	C	1	1.1	2.3
80	320	03	20	5	C	C	0.0	0.0
81	321	03	21	1	80	4	67.4	82.6
82	322	03	22	BG	80	3	38.8	78.6
83	323	03	23	7	80	2	24.3	32.3
84	324	03	24	BG	80	4	63.5	81.8
85	325	03	25	4	80	2	35.3	40.0
86	326	03	26	7	60	2	35.7	40.8
87	327	03	27	4	60	2	27.3	40.9
88	328	03	28	7	60	2	30.0	35.9
89	329	03	29	4	60	2	31.3	38.5
90	330	03	30	FH	60	2	34.2	48.1
91	401	04	01	4	C	1	1.9	5.0
92	402	04	02	4	C	C	0.0	0.0
93	403	04	03	D	C	1	1.1	5.0
94	404	04	04	4	C	C	0.0	0.0
95	405	04	05	D	C	C	0.0	0.0
96	406	04	06	3	80	5	85.3	87.5
97	407	04	07	4	80	3	47.8	75.0
98	408	04	08	B	80	3	52.7	73.7
99	409	04	09	7	80	5	72.5	78.8
100	410	04	10	5	80	4	62.7	79.1
101	411	04	11	BG	20	2	23.7	27.1
102	412	04	12	X	20	2	35.2	37.8
103	413	04	13	D	20	2	31.3	41.1
104	414	04	14	G	20	3	46.8	42.9
105	415	04	15	B	20	1	12.3	13.0
106	416	04	16	D	40	1	10.9	27.3
107	417	04	17	7	40	4	59.9	60.8
108	418	04	18	4	40	5	80.0	35.3
109	419	04	19	7	40	3	45.9	51.9
110	420	04	20	D	40	2	34.5	36.0
111	421	04	21	1	60	3	49.4	71.1
112	422	04	22	7	60	3	51.5	60.3
113	423	04	23	6	60	3	42.5	57.9
114	424	04	24	A	60	3	41.4	47.8
115	425	04	25	G	60	3	41.4	42.1
116	426	04	26	6	C	C	0.0	0.0
117	427	04	27	5	C	C	0.0	0.0
118	428	04	28	G	C	C	0.0	0.0
119	429	04	29	1	C	C	0.0	0.0
120	430	04	30	5	C	1	3.4	4.0

APPENDIX B

Structural characteristics of 120 silvicultural sites

APPENDIX B

OBS	ID	BLOCK	SUBPLOT	CLUSTOT	ALTINI	DKHDIF	BARPRE	TRUNKINI	TREEINI	AVESTEM
1	101	01	01	BG	4.3	0.9	7.0	2700.0	2600.0	1.0
2	102	01	02	7	3.7	0.4	6.1	3300.0	2200.0	1.5
3	103	01	03	BG	4.3	0.8	14.9	3900.0	3700.0	1.1
4	104	01	04	D	4.7	0.3	5.9	2200.0	2100.0	1.0
5	105	01	05	BD	4.5	0.5	12.3	5800.0	5700.0	1.0
6	106	01	06	BD	4.8	0.7	11.6	5300.0	4000.0	1.3
7	107	01	07	C	4.3	1.3	6.4	2700.0	2200.0	1.2
8	108	01	08	BG	5.2	0.9	16.2	4200.0	3900.0	1.1
9	109	01	09	4	5.4	0.9	18.0	2700.0	2200.0	1.2
10	110	01	10	5	4.7	0.9	11.6	5100.0	3500.0	1.5
11	111	01	11	D	5.1	0.7	18.6	2700.0	2300.0	1.2
12	112	01	12	4	4.9	0.4	10.8	2300.0	1700.0	1.4
13	113	01	13	D	5.0	0.7	12.4	2800.0	2700.0	1.0
14	114	01	14	D	5.2	0.5	11.3	1900.0	1600.0	1.2
15	115	01	15	FG	3.9	1.2	5.6	2400.0	1900.0	1.3
16	116	01	16	BG	4.5	0.8	10.2	3700.0	3100.0	1.2
17	117	01	17	D	4.7	1.0	12.8	4400.0	3900.0	1.1
18	118	01	18	1	4.7	0.6	17.9	3700.0	3500.0	1.1
19	119	01	19	5	4.0	0.7	6.6	3500.0	2600.0	1.3
20	120	01	20	3	4.3	0.6	9.2	4600.0	3700.0	1.2
21	121	01	21	E	4.9	1.4	5.6	2400.0	1700.0	1.4
22	122	01	22	D	5.1	0.8	10.3	2000.0	1400.0	1.4
23	123	01	23	EH	5.4	0.7	8.3	2900.0	2600.0	1.1
24	124	01	24	6	4.9	1.0	4.9	1100.0	1000.0	1.1
25	125	01	25	E	5.1	1.2	6.2	2400.0	1500.0	1.6
26	126	01	26	1	5.3	0.3	14.8	4600.0	4400.0	1.0
27	127	01	27	6	5.3	0.4	5.8	2500.0	1400.0	1.8
28	128	01	28	E	4.3	0.6	4.9	2500.0	1900.0	1.3
29	129	01	29	G	4.3	0.8	4.7	3300.0	2900.0	1.1
30	130	01	30	E	4.7	0.7	9.6	4300.0	2900.0	1.5
31	201	02	01	3	4.2	0.4	7.6	2800.0	2400.0	1.2
32	202	02	02	3	4.8	0.6	8.8	2500.0	2300.0	1.1
33	203	02	03	3	5.5	0.6	11.5	3000.0	2200.0	1.4
34	204	02	04	BG	4.5	0.7	8.7	3900.0	3300.0	1.2
35	205	02	05	3	4.6	0.9	9.5	3600.0	3000.0	1.2
36	206	02	06	E	3.9	0.5	4.9	1500.0	1100.0	1.4
37	207	02	07	3	3.5	0.8	8.5	1700.0	1600.0	1.1
38	208	02	08	3	4.4	0.4	8.0	2500.0	2200.0	1.1
39	209	02	09	3	4.3	0.6	5.7	1900.0	1800.0	1.1
40	210	02	10	3	4.4	0.3	7.7	2700.0	2300.0	1.2
41	211	02	11	3	4.4	0.5	6.9	3000.0	2700.0	1.1
42	212	02	12	3	4.3	0.4	5.7	2000.0	1800.0	1.1
43	213	02	13	1	5.0	0.7	12.8	2000.0	1800.0	1.1
44	214	02	14	X	4.2	0.6	7.7	3000.0	2000.0	1.5
45	215	02	15	C	4.8	0.3	6.8	1900.0	1700.0	1.1
46	216	02	16	1	5.4	0.6	13.5	2300.0	2100.0	1.1
47	217	02	17	3	3.7	0.4	5.6	2300.0	1500.0	1.5
48	218	02	18	1	4.8	1.0	13.2	3300.0	1500.0	2.2
49	219	02	19	C	4.4	0.7	8.0	3500.0	2600.0	1.3
50	220	02	20	7	4.6	0.6	8.5	4100.0	3300.0	1.2
51	221	02	21	E	3.9	1.1	6.5	1800.0	1200.0	1.5
52	222	02	22	FG	4.7	0.5	4.3	2000.0	1300.0	1.5
53	223	02	23	3	4.3	0.5	6.7	2900.0	1800.0	1.6
54	224	02	24	3	4.3	0.5	7.8	3000.0	2800.0	1.1
55	225	02	25	3	4.5	0.6	10.3	2600.0	2600.0	1.0
56	226	02	26	3	4.1	0.3	4.6	2600.0	2200.0	1.2
57	227	02	27	1	4.1	0.6	8.5	3300.0	1600.0	2.1
58	228	02	28	7	4.5	1.3	3.9	2700.0	1200.0	2.2
59	229	02	29	3	4.2	0.5	8.9	3800.0	3000.0	1.3
60	230	02	30	1	4.5	.	5.3	1300.0	1000.0	1.3
61	301	03	01	7	4.7	0.5	10.1	4400.0	3100.0	1.4
62	302	03	02	1	4.5	1.7	8.9	2300.0	2000.0	1.1
63	303	03	03	D	4.7	0.7	5.8	2100.0	1900.0	1.1
64	304	03	04	4	5.0	0.6	12.4	3200.0	2500.0	1.3
65	305	03	05	D	4.8	0.3	6.4	2100.0	2000.0	1.1
66	306	03	06	7	4.4	0.9	10.3	4500.0	1900.0	2.4
67	307	03	07	6	4.3	0.6	8.7	4500.0	2500.0	1.8
68	308	03	08	5	4.5	.	5.4	2100.0	1300.0	1.6
69	309	03	09	5	4.3	0.6	7.6	1700.0	1100.0	1.5
70	310	03	10	G	4.2	1.0	7.4	4300.0	1700.0	2.5
71	311	03	11	E	5.0	0.6	6.4	2700.0	2100.0	1.3
72	312	03	12	D	5.0	0.5	10.9	3800.0	2900.0	1.3
73	313	03	13	B	4.7	0.9	11.5	3600.0	2800.0	1.3

OBS	ID	BLOCK	SUBPLOT	CLUSTOT	ALTINI	DKHDIF	BARPRE	TRUNKINI	TREEINI	AVESTEM
74	314	03	14	7	4.6	1.1	8.3	2800.0	2000.0	1.4
75	315	03	15	7	4.8	1.1	10.9	3700.0	2100.0	1.8
76	316	03	16	G	4.8	0.5	5.3	3100.0	1900.0	1.6
77	317	03	17	G	4.5	0.6	14.0	3100.0	2200.0	1.4
78	318	03	18	BG	4.5	0.7	10.2	2800.0	2000.0	1.4
79	319	03	19	G	4.5	0.6	8.8	4300.0	2100.0	2.0
80	320	03	20	5	4.2	0.5	7.3	1500.0	1300.0	1.2
81	321	03	21	1	4.7	0.6	16.9	2300.0	2000.0	1.1
82	322	03	22	BG	4.6	0.9	16.2	2800.0	2500.0	1.1
83	323	03	23	7	4.3	0.8	7.3	3100.0	2200.0	1.4
84	324	03	24	BG	4.8	0.8	15.5	3300.0	2400.0	1.4
85	325	03	25	4	4.6	1.2	16.5	3500.0	2700.0	1.3
86	326	03	26	7	4.7	0.7	10.2	4900.0	3100.0	1.6
87	327	03	27	4	4.9	0.7	8.0	2200.0	2000.0	1.1
88	328	03	28	7	5.2	0.8	9.7	3900.0	2200.0	1.8
89	329	03	29	4	5.1	1.0	11.3	2600.0	2300.0	1.1
90	330	03	30	FH	5.1	.	7.9	2700.0	2000.0	1.4
91	401	04	01	4	4.5	0.6	4.6	2000.0	1700.0	1.2
92	402	04	02	4	4.2	1.0	6.0	1100.0	1000.0	1.1
93	403	04	03	D	4.7	0.8	5.1	2000.0	1400.0	1.4
94	404	04	04	4	4.6	0.7	9.2	2500.0	2200.0	1.1
95	405	04	05	D	4.3	1.2	3.8	1100.0	1000.0	1.1
96	406	04	06	3	4.2	1.0	5.6	1600.0	1400.0	1.1
97	407	04	07	4	4.4	1.0	7.3	2800.0	2000.0	1.4
98	408	04	08	B	4.3	0.9	9.8	3800.0	2300.0	1.7
99	409	04	09	7	4.3	1.2	9.8	5200.0	3700.0	1.4
100	410	04	10	5	3.9	0.7	9.7	4300.0	3300.0	1.3
101	411	04	11	BG	4.4	0.7	7.6	4800.0	2900.0	1.7
102	412	04	12	X	3.8	0.6	6.4	3700.0	3000.0	1.2
103	413	04	13	D	4.5	0.7	11.8	5600.0	3100.0	1.8
104	414	04	14	G	3.8	0.4	8.9	4200.0	2500.0	1.7
105	415	04	15	B	4.6	0.7	5.8	2300.0	1800.0	1.3
106	416	04	16	D	4.3	0.2	9.5	2200.0	1100.0	2.0
107	417	04	17	7	4.1	0.8	14.6	7900.0	5500.0	1.4
108	418	04	18	4	4.7	1.7	11.0	1700.0	1200.0	1.4
109	419	04	19	7	4.7	0.8	9.5	5200.0	4200.0	1.2
110	420	04	20	D	4.2	0.7	5.6	2500.0	1700.0	1.5
111	421	04	21	1	4.9	0.4	13.8	3800.0	2400.0	1.6
112	422	04	22	7	4.6	0.5	9.7	6800.0	2900.0	2.3
113	423	04	23	6	4.5	2.1	9.1	3800.0	2600.0	1.5
114	424	04	24	A	4.0	1.2	7.5	2300.0	2100.0	1.1
115	425	04	25	G	4.3	0.4	6.4	3800.0	2600.0	1.5
116	426	04	26	6	3.7	0.4	3.0	1600.0	1000.0	1.6
117	427	04	27	5	4.2	0.8	8.3	2300.0	1300.0	1.8
118	428	04	28	G	4.3	0.6	5.6	2700.0	1600.0	1.7
119	429	04	29	1	4.1	0.4	9.1	2400.0	2000.0	1.2
120	430	04	30	5	4.1	0.4	7.1	2500.0	2100.0	1.2

APPENDIX C

Site characteristics data from the forty original control sites

APPENDIX C

OBS	ID	GROUP	POSITION	SLOPE	CANOPY	HERB	SOIL	STONY
1	101	BG	lowridge	slight	5	2.0	siltclay	none
2	102	7	midslope	slight	3	3.0	siltclay	very
3	103	BG	midslope	slight	5	3.0	siltclay	none
4	104	D	midslope	slight	3	0.5	siltclay	none
5	105	BD	lowridge	slight	5	4.0	siltclay	very
6	126	1	midslope	moderate	5	4.0	sandycla	very
7	127	6	midslope	slight	5	4.0	sandycla	very
8	128	E	toe	slight	4	2.0	sandysil	none
9	129	G	midslope	slight	4	2.0	sandycla	very
10	130	E	midslope	slight	4	4.0	siltclay	very
11	206	E	highridg	steep	3	2.0	rockycla	very
12	207	3	shoulder	steep	3	2.0	sandycla	none
13	208	3	midslope	verystee	4	3.0	sandycla	very
14	209	3	midslope	verystee	3	4.0	rockycla	very
15	210	3	shoulder	steep	3	3.0	sandycla	none
16	221	E	shoulder	moderate	5	3.0	sandycla	some
17	222	FG	highridg	slight	2	4.0	claysand	none
18	223	3	midslope	steep	2	2.0	sandycla	some
19	224	3	midslope	steep	4	5.0	sandycla	some
20	225	3	midslope	steep	5	4.0	siltysan	very
21	301	7	midslope	slight	5	4.0	claysilt	none
22	302	1	shoulder	moderate	3	3.0	siltclay	none
23	303	D	midslope	moderate	5	3.0	claysilt	some
24	304	4	toe	slight	5	5.0	sandycla	very
25	305	D	midslope	moderate	4	3.0	siltclay	none
26	316	G	shoulder	slight	4	4.0	sandycla	none
27	317	G	lowridge	none	4	4.0	sandycla	none
28	318	BG	shoulder	slight	5	5.0	claysand	none
29	319	G	toe	slight	3	3.0	sandycla	none
30	320	5	toe	slight	5	5.0	sandycla	none
31	401	4	lowridge	slight	3	1.0	sandycla	some
32	402	4	midslope	slight	4	4.0	siltclay	none
33	403	D	plain	none	5	5.0	siltclay	none
34	404	4	toe	slight	4	3.0	siltclay	none
35	405	D	plain	none	3	1.0	siltclay	none
36	426	6	midslope	moderate	5	1.0	claysilt	none
37	427	5	shoulder	moderate	5	5.0		some
38	428	G	shoulder	moderate	4	1.0	siltclay	none
39	429	1	shoulder	moderate	3	2.0	siltclay	some
40	430	5	midslope	moderate	5	1.0	claysilt	none

APPENDIX D

Ground vegetation data and CRUZALL data from the forty original control sites

APPENDIX D

OBS	ID	GROUP	HERB	INDEX	TREES	CRUZALL
1	101	BG	B.pingui	0.5	GUATAP	2
2	101	BG	Herb	0.5	BAITOA	2
3	101	BG	Agave	2.0	QUINA	1
4	101	BG		.	CAFETAN	1
5	101	BG		.	ALMACIG	3
6	101	BG		.	CAYUCO	3
7	102	7		.	CAYUCO	2
8	102	7		.	PABURR	1
9	102	7	Agave	3.0	CINAZO	3
10	102	7	B.pingui	2.0	BAITOA	2
11	103	BG		.	PABURR	1
12	103	BG		.	ALMACIG	1
13	103	BG	C.cariba	0.5	GUATAP	2
14	103	BG	Agave	3.0	BAITOA	3
15	103	BG	B.pingui	2.0	FRIJOL	5
16	104	D	B.pingui	0.5	BAITOA	2
17	104	D	Herb	0.5	GUATAP	1
18	104	D		.	FRIJOL	1
19	105	BD		.	ALMACIG	1
20	105	BD	Agave	4.0	GUATAP	2
21	105	BD	B.pingui	1.0	BAITOA	1
22	105	BD		.	FRIJOL	3
23	126	1		.	CANDEL	1
24	126	1		.	GUAYAC	1
25	126	1		.	ALMACIG	1
26	126	1	Agave	4.0	CAYUCO	2
27	126	1		.	BAITOA	4
28	127	6		.	OJPALO	1
29	127	6	Agave	3.0	CAYUCO	6
30	128	E		.	CAMBRON	2
31	128	E	B.pingui	1.0	GUATAP	2
32	128	E	Agave	2.0	CAYUCO	9
33	128	E		.	MOSTAZO	1
34	129	G	B.pingui	1.0	BRUCON	1
35	129	G		.	CINAZO	1
36	129	G		.	FRIJOL	1
37	129	G		.	OJPALO	1
38	129	G	Agave	2.0	BAITOA	3
39	129	G		.	CAYUCO	1
40	130	E		.	CAMBRON	3
41	130	E		.	CAYUCO	8
42	130	E		.	BAITOA	3
43	130	E	Agave	4.0	GUATAP	1
44	206	E	C.cariba	0.5	ALPARGAT	1
45	206	E	Herb	1.0		.
46	206	E	L.hystri	0.5	GUATAP	1
47	206	E	A.gracil	2.0	CAYUCO	6
48	207	3		.	FRIJOL	1
49	207	3		.	CAYUCO	1
50	207	3	Agave	2.0	QUINA	1
51	208	3	Gramal	2.0	PAAMAR	1
52	208	3		.	CAYUCO	2
53	208	3	Agave	2.0	GUATAP	3
54	208	3	Herb	1.0	ALMACIG	1
55	208	3		.	CANDEL	1
56	209	3		.	CANDEL	2
57	209	3	A.gracil	4.0	CAYUCO	4
58	209	3	Herb	1.0	FRIJOL	1
59	210	3		.	QUINA	2
60	210	3		.	GUAYAC	1
61	210	3	L.hystri	0.5	CAYUCO	3
62	210	3	Agave	1.0	CANDEL	11
63	210	3	A.gracil	3.0	FRIJOL	3
64	221	E	A.gracil	2.0	CANDEL	1
65	221	E		.	CAYUCO	1
66	221	E		.	SANGRE	1
67	221	E	C.cariba	0.5	TABACU	1
68	221	E	Gramal	2.0	GUATAP	2
69	222	FG	C.cariba	0.5	GUATAP	4
70	222	FG		.	ALMACIG	1
71	222	FG		.	AROMA	1

OBS	ID	GROUP	HERB	INDEX	TREES	CRUZALL
72	222	FG	Gramal	4.0	ALPARGAT	1
73	223	3	A.gracil	2.0	CAYUCO	2
74	223	3	C.cariba	0.5	CANDEL	2
75	223	3	Herb	0.5	CINAZO	2
76	224	3	Agave	5.0	SANGRE	2
77	224	3	A.gracil	3.0	UNYA	1
78	224	3		.	QUINA	1
79	225	3	Gramax	3.0	CAYUCO	1
80	225	3		.	CANDEL	2
81	225	3	Agave	2.0	PABURR	2
82	225	3	A.gracil	2.0	GUATAP	1
83	301	7	Herb	2.0	CAYUCO	1
84	301	7		.	CAFETAN	2
85	301	7	Gramal	2.0	BAITOA	2
86	301	7	Frucraea	3.0	ALMACIG	1
87	302	1		.	ALAMCIG	2
88	302	1		.	QUINA	1
89	302	1		.	FRIJOL	1
90	302	1	Gramal	3.0	BAITOA	1
91	302	1	Herb	2.0	CAYUCO	2
92	302	1		.	CAFETAN	1
93	303	D	Herb	3.0	CAYUCO	1
94	303	D	C.cariba	0.5	ALMACIG	2
95	303	D	Gramal	1.0	QUINA	1
96	303	D		.	BRUCON	1
97	303	D	Frucraea	2.0	FRIJOL	1
98	304	4	C.cariba	1.0	CAYUCO	1
99	304	4		.	FRIJOL	1
100	304	4	Gramal	5.0	BAITOA	3
101	305	D		.	QUINA	1
102	305	D	C.cariba	0.5	BAITOA	2
103	305	D	Gramal	3.0	CAYUCO	3
104	305	D	Herb	2.0	GUAYAC	1
105	316	G	C.cariba	3.0	FRIJOL	1
106	316	G	Herb	3.0	CAYUCO	6
107	316	G		.	CAMBRON	4
108	317	G		.	ALPARGAT	1
109	317	G		.	CAYUCO	1
110	317	G		.	CAMBRON	1
111	317	G	Cactil	0.5	FRIJOL	1
112	317	G	C.cariba	3.0	BAITOA	3
113	317	G	Herb	2.0	CAFETAN	1
114	318	BG	Herb	2.0	FRIJOL	1
115	318	BG		.	UVERO	2
116	318	BG		.	CAYUCO	2
117	318	BG	C.cariba	5.0	BAITOA	7
118	319	G	C.cariba	2.0	CINAZO	1
119	319	G	Herb	2.0	CAYUCO	9
120	319	G		.	BAITOA	2
121	319	G		.	CAMBRON	1
122	319	G	L.hystri	2.0	UVERO	1
123	320	5	Herb	3.0	BAITOA	3
124	320	5	C.cariba	4.0	GUATAP	2
125	320	5		.	FRIJOL	1
126	320	5	L.hystri	0.5	CAMBRON	1
127	401	4	Herb	2.0	CAYUCO	3
128	401	4		.	UVERO	1
129	401	4		.	MOSTAZO	1
130	401	4		.	BAITOA	4
131	401	4		.	ALPARGAT	1
132	401	4	C.cariba	0.5	BRUCON	1
133	402	4	C.cariba	0.5	CAYUCO	11
134	402	4	Herb	4.0	BAITOA	4
135	402	4		.	GUAYAC	1
136	402	4		.	BRUCON	1
137	403	D	Herb	5.0	CAYUCO	3
138	403	D	Cactil	0.5	BAITOA	3
139	403	D		.	ALPARGAT	1
140	403	D		.	GUATAP	1
141	403	D	L.hystri	0.5	FRIJOL	1
142	404	4	Cactil	0.5	GUATAP	1
143	404	4	Herb	3.0	BAITOA	5
144	404	4	L.hystri	0.5		.
145	404	4	C.cariba	1.0	CAYUCO	2
146	405	D	Cactil	0.5	CAMBRON	1
147	405	D	Herb	1.0	CAYUCO	3

OBS	ID	GROUP	HERB	INDEX	TREES	CRUZALL
148	405	D		.	AROMA	1
149	405	D		.	ALPARGAT	1
150	405	D	C.cariba	0.5	BAITOA	3
151	426	6	Herb	1.0	GUATAP	1
152	426	6	A.gracil	1.0	UVERO	2
153	427	5		.	SANGRE	1
154	427	5		.	MOSTAZO	1
155	427	5	Herb	5.0	GUATAP	4
156	427	5		.	CINAZO	1
157	428	G	C.cariba	1.0	CAYUCO	3
158	428	G	Gramax	0.5	SANGRE	1
159	428	G	Herb	1.0	BAITOA	4
160	429	1		.	CAYUCO	1
161	429	1		.	QUINA	1
162	429	1	A.gracil	2.0	ALMACIG	2
163	429	1		.	PABURR	1
164	430	5	L.hystri	0.5	CAFETAN	2
165	430	5	C.cariba	0.5	GUATAP	2
166	430	5	Frucraea	2.0	CINAZO	1
167	430	5	Herb	0.5	GUACON	1

APPENDIX E

Growth and mortality parameters for 120 sites

APPENDIX E

OBS	ID	BLOCK	SUBPLOT	CUTLEVEL	CLUSTOT	BARGRTH	BARAVE	DKHDIF	BARMORT	TRUNKMRT	NETGRTH
1	101	01	01	C	BG	1.4	7.1	0.9	1.1	600.0	0.3
2	102	01	02	1	7	0.7	3.1	0.4	0.1	100.0	0.6
3	103	01	03	C	BG	3.7	12.8	0.8	3.7	1000.0	-0.0
4	104	01	04	C	D	0.5	4.2	0.3	2.8	900.0	-2.3
5	105	01	05	C	BD	1.2	3.0	0.5	3.2	1800.0	-2.0
6	106	01	06	3	BD	1.5	9.8	0.7	2.8	1000.0	-1.3
7	107	01	07	3	C	1.5	11.3	1.3	0.1	100.0	1.4
8	108	01	08	3	BG	1.4	7.2	0.9	2.8	700.0	-1.4
9	109	01	09	3	4	1.0	9.7	0.9	0.6	300.0	0.3
10	110	01	10	C	5	1.7	8.9	0.9	6.2	3100.0	-4.5
11	111	01	11	1	D	0.9	6.1	0.7	2.4	1100.0	-1.6
12	112	01	12	1	4	1.0	9.2	0.4	0.6	500.0	0.4
13	113	01	13	2	D	1.2	6.3	0.7	0.5	300.0	0.7
14	114	01	14	1	D	0.5	4.0	0.5	3.0	300.0	-2.5
15	115	01	15	2	FG	1.5	9.5	1.2	0.5	200.0	1.0
16	116	01	16	4	BG	0.8	7.2	0.8	0.5	300.0	0.3
17	117	01	17	4	D	1.4	9.2	1.0	0.3	100.0	1.1
18	118	01	18	4	1	0.9	6.0	0.6	1.4	300.0	-0.5
19	119	01	19	4	5	0.9	6.9	0.7	0.2	200.0	0.7
20	120	01	20	4	3	0.6	3.9	0.6	0.7	500.0	-0.1
21	121	01	21	3	E	1.2	23.3	1.4	1.0	500.0	0.2
22	122	01	22	2	D	0.5	10.5	0.8	0.1	100.0	0.5
23	123	01	23	3	EH	0.8	13.7	0.7	2.4	300.0	-1.6
24	124	01	24	3	6	0.2	9.4	1.0	1.3	200.0	-1.1
25	125	01	25	4	E	0.4	18.5	1.2	0.9	500.0	-0.6
26	126	01	26	1	1	1.1	2.6	0.3	0.6	200.0	0.4
27	127	01	27	C	6	0.2	1.8	0.4	2.7	500.0	-2.5
28	128	01	28	1	E	2.0	12.6	0.6	0.7	300.0	1.3
29	129	01	29	C	G	1.4	5.9	0.8	0.9	700.0	0.5
30	130	01	30	C	E	1.7	6.6	0.7	0.6	700.0	1.1
31	201	02	01	3	3	0.2	3.5	0.4	1.8	800.0	-1.6
32	202	02	02	4	3	0.1	4.5	0.6	3.2	600.0	-3.0
33	203	02	03	2	3	0.7	9.6	0.6	2.8	800.0	-2.2
34	204	02	04	3	BG	1.2	9.8	0.7	0.3	200.0	0.9
35	205	02	05	3	3	1.0	11.6	0.9	1.0	400.0	0.0
36	206	02	06	C	E	0.3	3.4	0.5	1.3	400.0	-1.0
37	207	02	07	C	3	1.0	10.0	0.8	4.6	700.0	-3.6
38	208	02	08	1	3	0.3	2.6	0.4	2.7	1100.0	-2.4
39	209	02	09	C	3	0.5	4.2	0.6	1.5	600.0	-1.0
40	210	02	10	C	3	0.4	2.1	0.3	1.8	600.0	-1.4
41	211	02	11	1	3	1.0	5.3	0.5	2.3	1000.0	-1.3
42	212	02	12	C	3	0.5	3.5	0.4	1.1	500.0	-0.6
43	213	02	13	C	1	0.8	5.5	0.7	3.6	400.0	-2.7
44	214	02	14	C	X	0.6	4.8	0.6	3.8	1200.0	-3.2
45	215	02	15	C	C	0.4	6.3	0.3	4.1	1100.0	-3.7
46	216	02	16	4	1	0.5	6.3	0.6	2.6	400.0	-2.1
47	217	02	17	3	3	0.2	4.1	0.4	1.4	400.0	-1.1
48	218	02	18	5	1	0.4	7.4	1.0	0.7	400.0	-0.2
49	219	02	19	4	C	0.4	5.4	0.7	1.0	500.0	-0.5
50	220	02	20	3	7	0.6	5.3	0.6	1.9	600.0	-1.3
51	221	02	21	C	E	1.6	14.7	1.1	0.2	100.0	1.4
52	222	02	22	C	FG	0.2	4.1	0.5	2.4	1100.0	-2.1
53	223	02	23	1	3	0.7	8.7	0.5	3.1	1400.0	-2.4
54	224	02	24	C	3	1.2	7.0	0.5	3.7	1200.0	-2.5
55	225	02	25	C	3	1.3	6.1	0.6	1.5	500.0	-0.2
56	226	02	26	4	3	0.4	10.1	0.3	0.4	300.0	-0.0
57	227	02	27	3	1	0.3	5.2	0.6	0.8	400.0	-0.5
58	228	02	28	5	7	0.2	6.8	1.3	0.1	100.0	0.1
59	229	02	29	4	3	0.3	6.7	0.5	1.4	400.0	-1.2
60	230	02	30	4	1	.	.	.	1.8	900.0	.
61	301	03	01	C	7	0.9	3.8	0.5	2.4	1500.0	-1.5
62	302	03	02	1	1	1.9	24.0	1.7	2.4	1100.0	-0.5
63	303	03	03	1	D	0.7	5.5	0.7	3.3	900.0	-2.6
64	304	03	04	C	4	1.1	4.8	0.6	0.8	600.0	0.2
65	305	03	05	C	D	0.3	2.5	0.3	2.1	800.0	-1.7
66	306	03	06	2	7	1.4	10.6	0.9	0.3	300.0	1.1
67	307	03	07	2	6	1.0	7.5	0.6	1.9	800.0	-0.9
68	308	03	08	2	5	0.5	8.2	.	0.2	200.0	0.3
69	309	03	09	2	5	0.3	3.3	0.6	0.3	300.0	-0.1
70	310	03	10	3	G	1.8	16.4	1.0	0.7	300.0	1.1
71	311	03	11	2	E	1.1	6.7	0.6	0.5	500.0	0.7
72	312	03	12	2	D	0.6	4.0	0.5	1.2	700.0	-0.5
73	313	03	13	2	B	1.7	12.7	0.9	1.1	500.0	0.6
74	314	03	14	2	7	1.3	12.7	1.1	0.5	400.0	0.8

OBS	ID	BLOCK	SUBPLOT	CUTLEVEL	CLUSTOT	BARGRTH	BARAVE	DKHDIF	BARMORT	TRUNKMRT	NETGRTH
75	315	03	15	3	7	0.7	8.6	1.1	2.8	1100.0	-2.1
76	316	03	16	1	G	1.1	6.7	0.5	0.7	600.0	0.4
77	317	03	17	C	G	0.5	5.1	0.6	9.8	2600.0	-9.4
78	318	03	18	1	BG	1.5	9.4	0.7	0.6	500.0	1.0
79	319	03	19	1	G	0.8	5.4	0.6	3.3	1700.0	-2.5
80	320	03	20	C	5	0.9	8.8	0.5	0.8	300.0	0.0
81	321	03	21	4	1	0.5	16.9	0.6	0.2	100.0	0.3
82	322	03	22	3	BG	1.0	16.7	0.9	0.0	0.0	1.0
83	323	03	23	2	7	0.9	7.2	0.8	1.3	400.0	-0.4
84	324	03	24	4	BG	1.2	29.3	0.8	0.5	300.0	0.6
85	325	03	25	2	4	2.8	23.0	1.2	1.0	700.0	1.7
86	326	03	26	2	7	1.3	7.6	0.7	1.1	500.0	0.2
87	327	03	27	2	4	0.5	6.3	0.7	1.4	500.0	-0.9
88	328	03	28	2	7	0.6	5.4	0.8	1.6	1000.0	-0.9
89	329	03	29	2	4	0.9	15.3	1.0	2.5	900.0	-1.6
90	330	03	30	2	FH	.	.	.	5.2	1400.0	.
91	401	04	01	1	4	0.9	6.9	0.6	1.0	500.0	-0.1
92	402	04	02	C	4	1.5	16.8	1.0	0.3	100.0	1.3
93	403	04	03	1	D	1.0	11.3	0.8	1.8	600.0	-0.8
94	404	04	04	C	4	1.8	11.5	0.7	1.4	900.0	0.5
95	405	04	05	C	D	0.7	14.1	1.2	0.9	500.0	-0.1
96	406	04	06	5	3	0.1	3.1	1.0	0.7	100.0	-0.7
97	407	04	07	3	4	1.6	39.6	1.0	0.7	200.0	0.9
98	408	04	08	3	B	0.3	5.6	0.9	1.4	400.0	-1.0
99	409	04	09	5	7	1.1	12.2	1.2	0.0	0.0	1.1
100	410	04	10	4	5	0.3	5.6	0.7	2.3	300.0	-2.0
101	411	04	11	2	BG	1.5	7.3	0.7	1.1	600.0	0.4
102	412	04	12	2	X	1.3	7.5	0.6	0.4	200.0	1.0
103	413	04	13	2	D	1.3	5.9	0.7	0.9	500.0	0.5
104	414	04	14	3	G	0.3	2.9	0.4	1.9	800.0	-1.6
105	415	04	15	1	B	0.9	8.5	0.7	1.1	700.0	-0.1
106	416	04	16	1	D	0.8	27.9	0.2	7.7	1200.0	-6.8
107	417	04	17	4	7	1.4	7.1	0.8	2.2	1000.0	-0.9
108	418	04	18	5	4	0.8	15.7	1.7	1.0	600.0	-0.2
109	419	04	19	3	7	1.5	9.1	0.8	1.7	800.0	-0.2
110	420	04	20	2	D	0.8	11.6	0.7	1.8	700.0	-1.0
111	421	04	21	3	1	0.6	8.8	0.4	0.4	300.0	0.2
112	422	04	22	3	7	0.3	3.2	0.5	1.8	1400.0	-1.5
113	423	04	23	3	6	1.5	16.9	2.1	1.3	400.0	0.2
114	424	04	24	3	A	0.7	11.6	1.2	1.9	600.0	-1.3
115	425	04	25	3	G	0.8	5.8	0.4	0.3	300.0	0.5
116	426	04	26	C	6	0.5	10.7	0.4	1.6	900.0	-1.0
117	427	04	27	C	5	0.7	8.9	0.8	0.7	500.0	-0.0
118	428	04	28	C	G	0.5	4.6	0.6	1.9	1400.0	-1.3
119	429	04	29	C	1	0.3	2.6	0.4	2.4	1400.0	-2.1
120	430	04	30	1	5	0.6	3.1	0.4	0.6	100.0	-0.1

APPENDIX F

Nonparametric analysis of growth and mortality:

Assumptions and Calculations

APPENDIX F

(I) Assumptions and equations for Kruskal-Wallis distribution-free test.[1]

A1: The basic model is:

$$X_{ij} = \mu + \tau_j + e_{ij}\,, \qquad i = 1,\ldots, n_j, \quad j = 1, \ldots, k,$$

Where μ is the overall mean, τ is the effect of treatment j, and $\sum_{j=1}^{k} \tau_j = 0$.

A2. The e's (error variables) are mutually independent.
A3. Each e comes from the same continuous population.

To test

$$H_0: \tau_1 = \tau_2 = \ldots = \tau_k,$$

(1) Rank all values from lowest to highest.

(2) Determine the H statistic, where the H statistic is calculated as:

$$H = \left(\frac{12}{N(N+1)} \sum_{n=1}^{k} \frac{R_j^2}{n_j} \right) - 3\,(N+1)$$

Where:

N = the total sample size,
R_j = the sum of the ranks for treatment j,
n_j = the sample size for treatment j,
k = total number of treatments.

(3) Reject H_0 if $H \geq \chi^2$ (k-1, α) and
Accept H_0 if $H < \chi^2$ (k-1, α),

where α represents the approximate probability assuming a Chi-square distribution with (k-1) degrees of freedom.

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[1]Taken from Hollander and Wolfe (1973), pp 114-120.

(II) Calculations of *H*-statistic for test of differences in growth and mortatlity between cluster groups (N=87).

Cluster group	n	BARGRTH (rank sums)	NETGRTH (rank sums)	BARAVE (rank sums)	STEMMORT (rank sums)	BARMORT (rank sums)	N	DKHDIF (rank sums)
Three	18	550.0	498.0	572.0	933.5	1012.0	18	537.0
Six	5	175.0	164.0	256.0	226.5	280.0	5	220.0
E	7	411.0	464.0	405.0	253.5	179.0	7	363.0
Five	8	303.0	385.0	306.0	226.5	259.0	8	290.0
One	10	372.0	412.0	396.0	351.5	435.0	10	373.0
Seven	14	707.0	691.0	586.0	662.0	562.0	14	759.0
D	14	626.0	530.0	611.0	688.0	716.0	14	575.0
Four	11	684.0	684.0	696.0	486.5	385.0	10	624.0

	BARGRTH	NETGRTH	BARAVE	STEMMORT	BARMORT	DKHDIF
$\left(\frac{12}{N(N+1)}\right)$	0.0015674	0.0015674	0.0015674	0.0015674	0.0015674	0.0016038
$\left(\sum_{a=1}^{k} \frac{R_j^2}{n_j}\right)$	178603.65848	182118.73149	177334.22136	173251.12165	177115.37103	172652.35714
3 (N +1)	264.00000	264.00000	264.00000	264.00000	264.00000	261.00000
H-statistic	15.43361	21.452897	13.953656	7.5538055	13.610631	12.899839

(III) Calculations of H-statistic for test of differences in growth and mortatlity between cutting levels (N=113).

Cutting level	n	BARGRTH (rank sums)	NETGRTH (rank sums)	BARAVE (rank sums)	STEMMORT (rank sums)	BARMORT (rank sums)	N	DKHDIF (rank sums)
Control	32	1770.0	1429.0	1430.0	2372.0	2288.0	32	1480.0
One	19	1179.0	983.0	983.0	1239.0	1215.0	19	759.0
Two	22	1480.0	1638.0	1445.0	1104.5	942.0	21	1447.0
Three	25	1403.0	1502.0	1680.0	1176.5	1310.0	25	1738.0
Four	15	609.0	889.0	903.0	548.5	686.0	15	904.0

	BARGRTH	NETGRTH	BARAVE	STEMMORT	BARMORT	DKHDIF
$\left(\frac{12}{N(N+1)}\right)$	0.0009315	0.0009315	0.0009315	0.0009315	0.0009315	0.0009482
$\left(\sum_{i=1}^{k} \frac{R_j^2}{n_j}\right)$	374088.57399	379555.86916	376927.26806	387494.16922	381639.84657	369250.01566
3 (N +1)	342.0	342.00000	342.00000	342.00000	342.00000	339.00000
H-statistic	6.4756162	11.5685786	9.1199516	18.9633621	13.5098710	11.5685786

(IV) General equation used for distribution-free multiple comparisons based on Kruskal-Wallis rank sums: an approximation valid for unequal sample sizes (Hollander and Wolfe 1973).

To decide if $\tau_u \neq \tau_v$, determine if:

$$|R_{\cdot u} - R_{\cdot v}| \geq z_{(\alpha / [k(k-1)])} \left[\frac{N(N+1)}{12} \right]^{1/2} \left[\left(\frac{1}{n_u} + \frac{1}{n_v} \right) \right]^{1/2}.$$

Where:

$\lvert R_{\cdot u} - R_{\cdot v} \rvert$	is the difference between the rank mean of "treatment" *u* and the rank mean of "treatment" *v*.
$z_{(\alpha / [k(k-1)])}$	is the *z*-value associated with the upper-tail area of a normal curve, based on a pre-determined probability level, and the number of groups being examined.[2]
n_u	is the number of samples for "treatment" *u*.
n_v	is the number of samples for "treatment" *v*.

[2]Taken from Table 2, Appendix A in Ott (1988).

(V) Calculation of test-statistics for multiple comparisons of cluster groups.

Comparison	$z_{(\alpha / [k(k-1)])}$[3]	$\left[\frac{N(N+1)}{12}\right]^{1/2}$	$\left[\left(\frac{1}{n_u}+\frac{1}{n_v}\right)\right]^{1/2}$	Test statistic
Three v/s six	2.92	25.2587	0.5055	37.283356722
Three v/s E	2.92	25.2587	0.4454	32.8506569416
Three v/s 5	2.92	25.2587	0.4249	31.3386711596
Three v/s one	2.92	25.2587	0.3944	29.0891313376
Three v/s seven	2.92	25.2587	0.3563	26.2790504452
Three v/s D	2.92	25.2587	0.3563	26.2790504452
Three v/s four	2.92	25.2587	0.3827	28.2261931108
Six v/s E	2.92	25.2587	0.5855	43.183789042
Six v/s five	2.92	25.2587	0.5701	42.0479558204
Six v/s one	2.92	25.2587	0.5477	40.3958347708
Six v/s seven	2.92	25.2587	0.5210	38.426565484
Sex v/s D	2.92	25.2587	0.5210	38.426565484
Six v/s four	2.92	25.2587	0.5394	39.7836649176
E v/s five	2.92	25.2587	0.5175	38.16842157
E v/s one	2.92	25.2587	0.4928	36.3466630912
E v/s seven	2.92	25.2587	0.4629	34.1413765116
E v/s D	2.92	25.2587	0.4629	34.1413765116
E v/s four	2.92	25.2587	0.4835	35.660737834
Five v/s one	2.92	25.2587	0.4743	34.9821881172
Five v/s seven	2.92	25.2587	0.4432	32.6883950528
Five v/s D	2.92	25.2587	0.4432	32.6883950528
Five v/s four	2.92	25.2587	0.4647	34.2741362388
One v/s seven	2.92	25.2587	0.4140	30.534737256
One v/s D	2.92	25.2587	0.4140	30.534737256
One v/s four	2.92	25.2587	0.4369	32.2237360076
Seven v/s D	2.92	25.2587	0.3780	27.879542712
Seven v/s four	2.92	25.2587	0.4029	29.7160522716
D v/s four	2.92	25.2587	0.4029	29.7160522716

[3] 0.00179, where α was set at 0.1 and k(k-1)=56.

(VI) Calculations of test statistics for multiple-comparisons of cutting levels.

Comparison of cutting levels	$z_{(\alpha / [k(k-1)])}$[4]	$[\frac{N(N+1)}{12}]^{1/2}$	$[(\frac{1}{n_u} + \frac{1}{n_v})]^{1/2}$	Test statistic
Control v/s one	2.575	32.4756	0.2896	24.217704432
Control v/s two	2.575	32.4756	0.2769	23.155671123
Contorl v/s three	2.575	32.4756	0.2669	22.319424423
Control v/s four	2.575	32.4756	0.3129	26.166159243
One v/s two	2.575	32.4756	0.3131	26.182884177
One v/s three	2.575	32.4756	0.3043	25.446987081
One v/s four	2.575	32.4756	0.3454	28.883961018
Two v/s three	2.575	32.4756	0.2960	24.75290232
Two v/s four	2.575	32.4756	0.3380	28.26513846
Three v/s four	2.575	32.4756	0.3266	27.311817222

[4] 0.005 where α was set at 0.1 and $k(k-1)=20$.

APPENDIX G

Results of hierarchical cluster analyses

APPENDIX G

(I) Results of SAS analyses using 45 sites and 16 species

Ward's Minimum Variance Cluster Analysis

2 observation(s) trimmed with estimated density 6.576241E-28 or less.

Eigenvalues of the Covariance Matrix

	Eigenvalue	Difference	Proportion	Cumulative
1	871.347	511.868	0.456237	0.45624
2	359.479	103.516	0.188223	0.64446
3	255.962	126.921	0.134022	0.77848
4	129.042	63.536	0.067566	0.84605
5	65.506	8.488	0.034299	0.88035
6	57.018	15.078	0.029855	0.91020
7	41.940	1.682	0.021960	0.93216
8	40.257	13.815	0.021079	0.95324
9	26.442	5.334	0.013845	0.96709
10	21.108	4.954	0.011052	0.97814
11	16.155	6.164	0.008459	0.98660
12	9.990	4.411	0.005231	0.99183
13	5.579	1.604	0.002921	0.99475
14	3.975	0.353	0.002081	0.99683
15	3.622	1.190	0.001896	0.99873
16	2.432	.	0.001273	1.00000

Root-Mean-Square Total-Sample Standard Deviation = 10.92547
Root-Mean-Square Distance Between Observations = 61.80378

Ward's Minimum Variance Cluster Analysis

Number of Clusters	Clusters Joined		Frequency of New Cluster	Semipartial R-Squared	R-Squared	Tie
42	401	402	2	0.000963	0.999037	
41	304	404	2	0.001024	0.998013	
40	207	210	2	0.001202	0.996811	
39	209	223	2	0.001477	0.995334	
38	129	428	2	0.001772	0.993561	
37	208	212	2	0.001821	0.991741	
36	126	213	2	0.001826	0.989915	
35	CL41	CL42	4	0.002325	0.987590	
34	302	429	2	0.002408	0.985182	
33	303	305	2	0.002746	0.982436	
32	206	215	2	0.002878	0.979558	
31	130	316	2	0.003595	0.975964	
30	110	430	2	0.003610	0.972353	
29	128	320	2	0.003838	0.968515	
28	104	105	2	0.003876	0.964639	
27	317	319	2	0.004008	0.960631	
26	CL33	405	3	0.004301	0.956330	
25	CL39	225	3	0.004404	0.951927	
24	CL28	403	3	0.004919	0.947008	
23	CL38	CL27	4	0.005408	0.941600	
22	CL32	221	3	0.005775	0.935825	
21	102	301	2	0.006696	0.929130	
20	222	224	2	0.006775	0.922355	
19	101	CL30	3	0.007419	0.914936	
18	CL37	CL25	5	0.007445	0.907491	
17	CL21	318	3	0.009631	0.897860	
16	CL29	427	3	0.009714	0.888146	
15	CL19	214	4	0.011422	0.876724	
14	CL24	CL35	7	0.011738	0.864986	
13	CL23	CL31	6	0.013481	0.851505	
12	CL40	CL18	7	0.015566	0.835939	
11	CL36	CL34	4	0.017648	0.818291	
10	CL15	CL22	7	0.018550	0.799742	
9	CL17	CL26	6	0.020807	0.778934	
8	CL10	103	8	0.024323	0.754611	
7	CL8	CL16	11	0.032049	0.722562	
6	CL9	CL13	12	0.034288	0.688274	
5	CL12	CL20	9	0.034369	0.653905	
4	CL6	CL11	16	0.086081	0.567824	
3	CL7	CL4	27	0.130356	0.437467	
2	CL3	CL5	36	0.173705	0.263763	
1	CL2	CL14	43	0.263763	0.000000	

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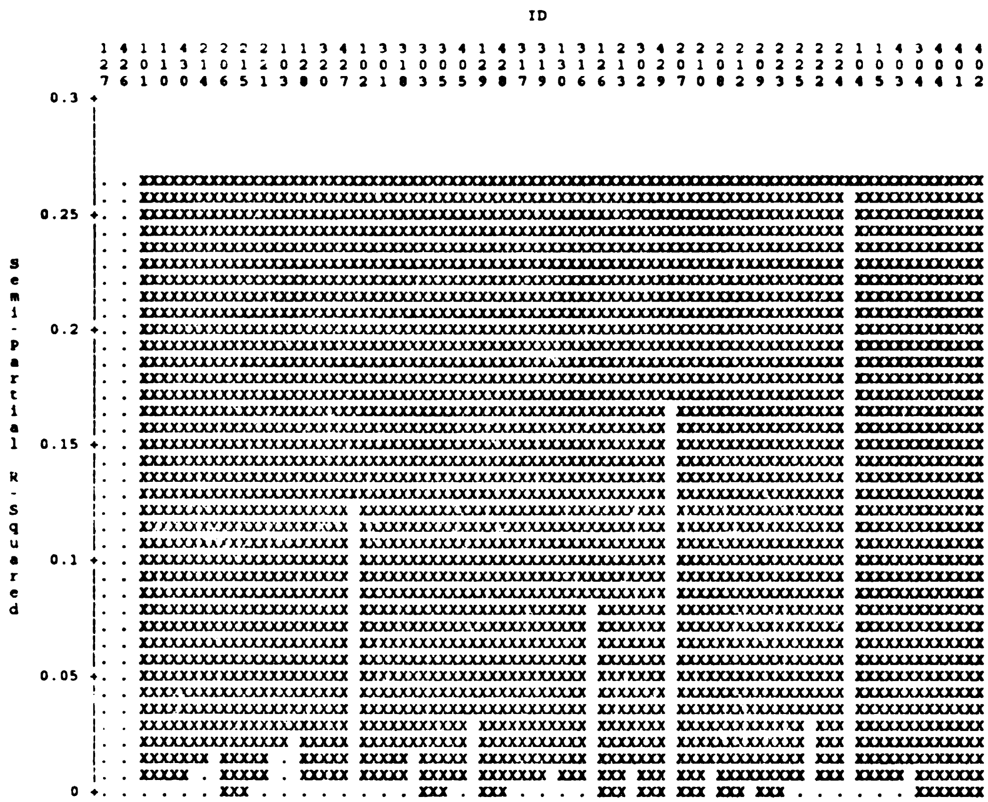
Ward's Minimum Variance Cluster Analysis



Flexible-Beta Cluster Analysis

Eigenvalues of the Covariance Matrix

	Eigenvalue	Difference	Proportion	Cumulative
1	837.729	492.534	0.425315	0.42532
2	345.195	80.584	0.175256	0.60057
3	264.611	115.046	0.134343	0.73491
4	149.565	60.853	0.075934	0.81085
5	88.712	27.822	0.045039	0.85589
6	60.890	2.637	0.030914	0.88680
7	58.253	18.296	0.029575	0.91638
8	39.957	4.635	0.020286	0.93666
9	35.322	9.300	0.017933	0.95459
10	26.022	6.564	0.013211	0.96781
11	19.458	1.365	0.009879	0.97768
12	18.093	3.678	0.009186	0.98687
13	14.415	9.211	0.007319	0.99419
14	5.204	1.422	0.002642	0.99683
15	3.782	1.324	0.001920	0.99875
16	2.458	.	0.001248	1.00000

Beta = -0.25

Root-Mean-Square Total-Sample Standard Deviation = 11.09523
Mean Distance Between Observations = 59.86433

Flexible-Beta Cluster Analysis

Number of Clusters	Clusters Joined		Frequency of New Cluster	Normalized Flexible Distance	Tie
44	401	402	2	0.207675	
43	304	404	2	0.214093	
42	207	210	2	0.231930	
41	209	223	2	0.257167	
40	129	428	2	0.281676	
39	208	212	2	0.285489	
38	126	213	2	0.285871	
37	CL43	CL44	4	0.302795	
36	302	429	2	0.328336	
35	303	305	2	0.350597	
34	206	215	2	0.358919	
33	130	316	2	0.401146	
32	110	430	2	0.402006	
31	128	320	2	0.414509	
30	104	105	2	0.416573	
29	317	319	2	0.423571	
28	CL35	405	3	0.434201	
27	CL41	225	3	0.442452	
26	CL30	403	3	0.466544	
25	CL40	CL29	4	0.477776	
24	CL34	221	3	0.501193	
23	CL39	CL27	5	0.523151	
22	102	301	2	0.547476	
21	222	224	2	0.550704	
20	101	CL32	3	0.571936	
19	CL31	427	3	0.639743	
18	CL26	CL37	7	0.651031	
17	CL22	318	3	0.651550	
16	CL20	214	4	0.695780	
15	CL25	CL33	6	0.723903	
14	127	426	2	0.752431	
13	CL42	CL23	7	0.786435	
12	CL16	CL24	7	0.843440	
11	CL38	CL36	4	0.865587	
10	CL17	CL28	6	0.918513	
9	CL12	CL19	10	1.084151	
8	CL10	103	7	1.120361	
7	CL13	CL21	9	1.134807	
6	CL8	CL15	13	1.155165	
5	CL6	CL14	15	1.714345	
4	CL5	CL11	19	1.882564	
3	CL9	CL7	19	1.962854	
2	CL3	CL4	38	2.172582	
1	CL2	CL18	45	3.877186	

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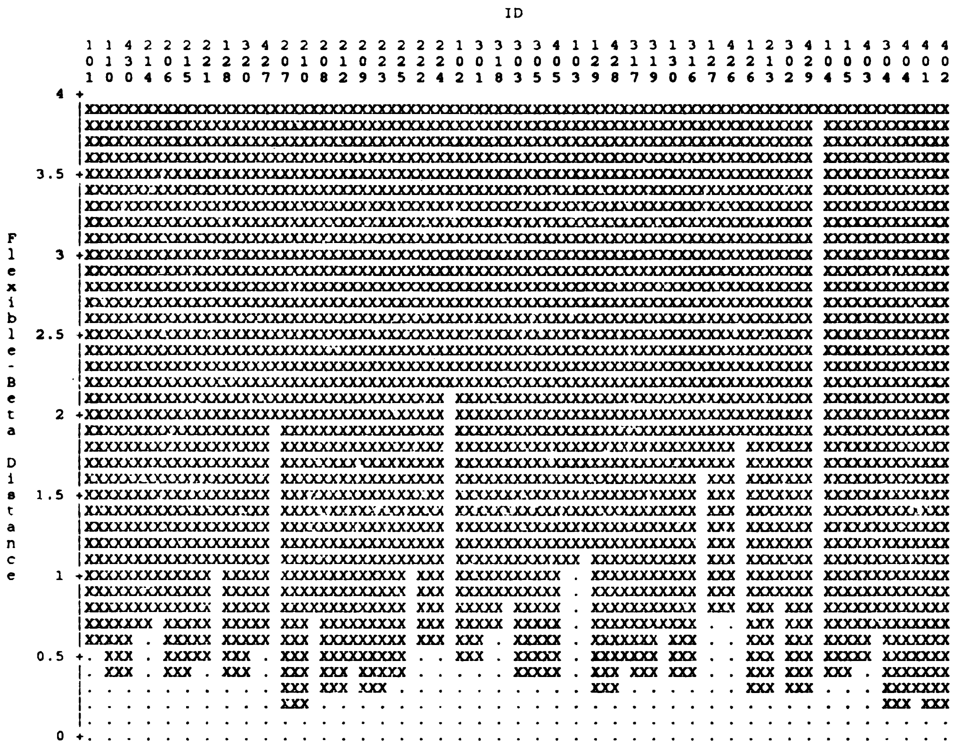
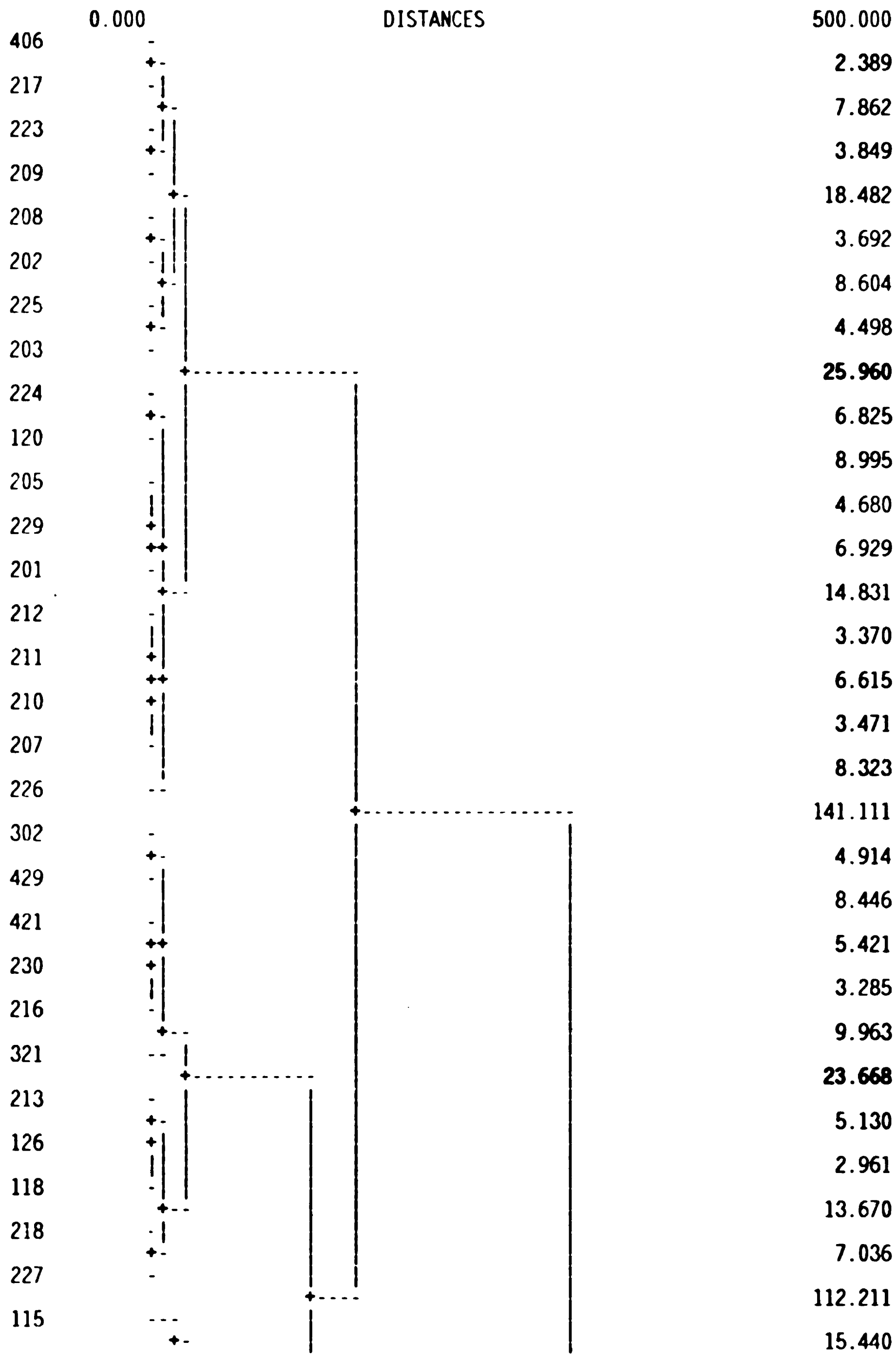
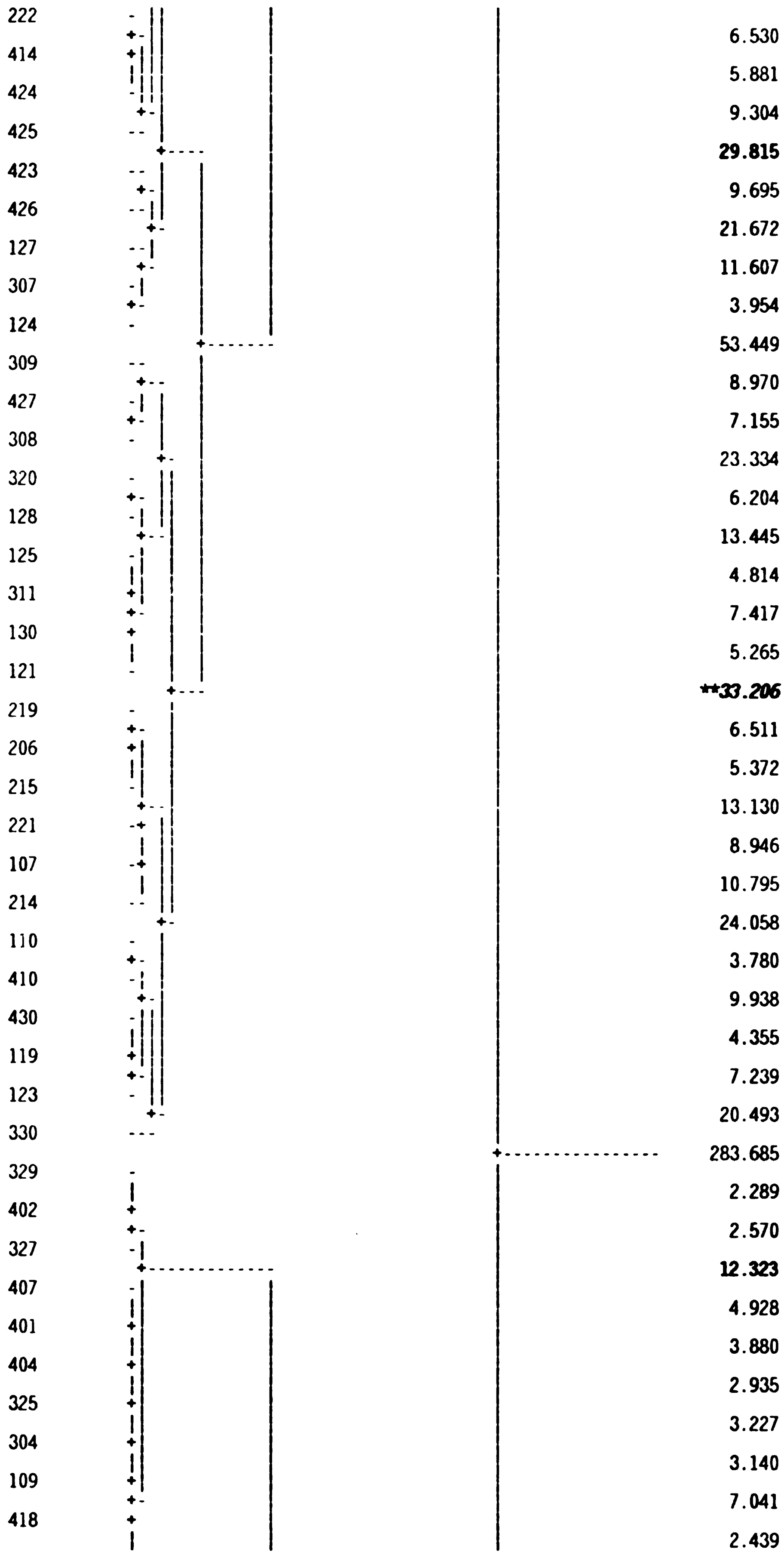
Flexible-Beta Cluster Analysis



(II) A representative dendogram from SYSTAT (Willkinson 1989) of Ward Minimum Variance hierarchical cluster analysis using 16 species and 120 sites (Distance metric is Euclidean distance)

> **(1) Numbers in bold along the right margin represent points above which cuts were made to form clusters used in these anayses.**
>
> **(2) Numbers in *italics* represent range between which cuts can be made without affecting the clusters formed.**

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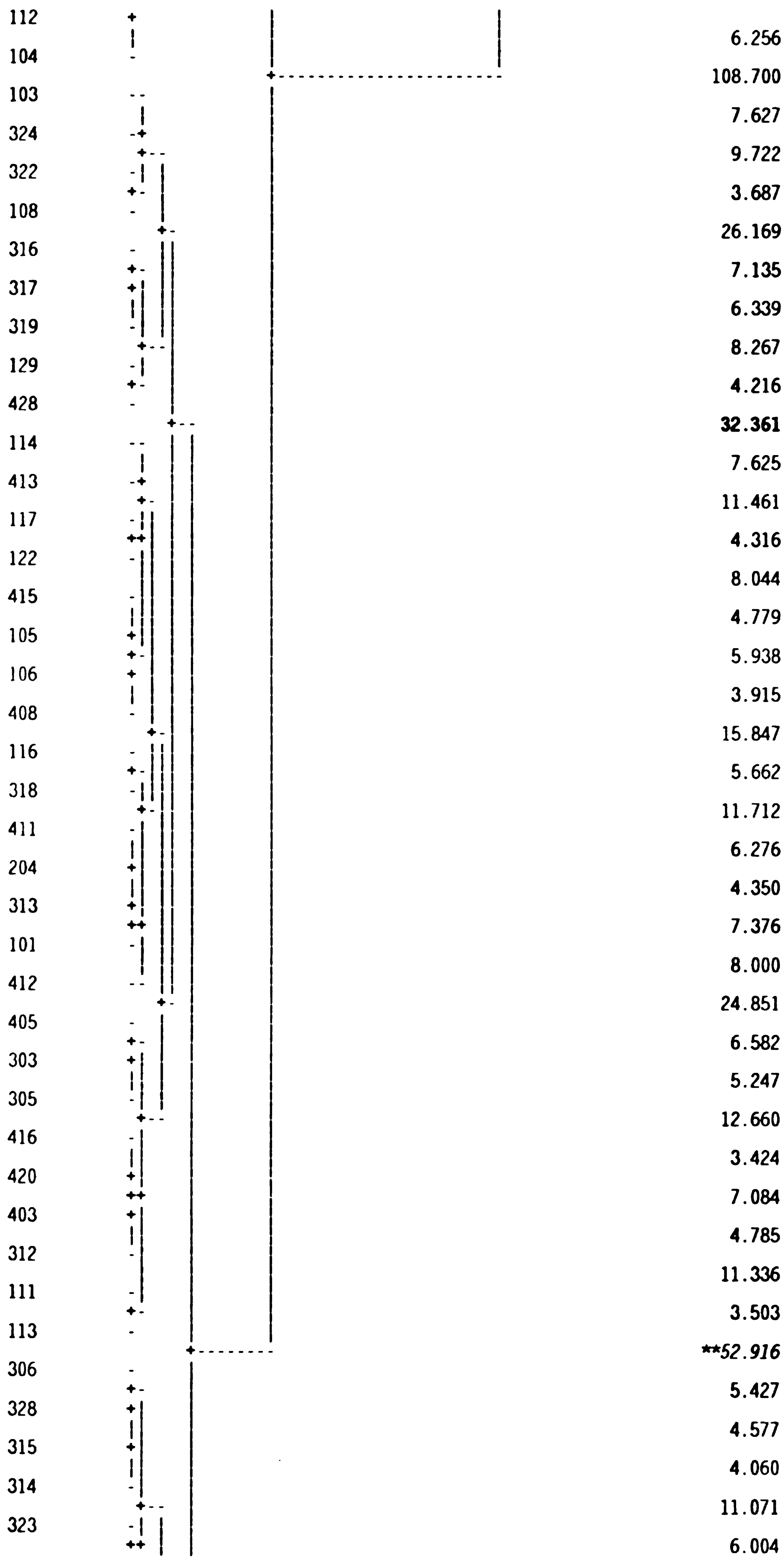
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122
415
105
106
408
116
318
411
204
313
101
412
405
303
305
416
420
403
312
111
113
306
328
315
314
323
6.256
108.700
7.627
9.722
3.687
26.169
7.135
6.339
8.267
4.216
32.361
7.625
11.461
4.316
8.044
4.779
5.938
3.915
15.847
5.662
11.712
6.276
4.350
7.376
8.000
24.851
6.582
5.247
12.660
3.424
7.084
4.785
11.336
3.503
**52.916
5.427
4.577
4.060
11.071
6.004

```
301          -|  |   |
              |  |   |          9.791
419          -|  |   |
             ||  |   |          2.942
220          +|  |   |
             ++  |   |          7.170
102          -|  |   |
              |  |   |          7.993
326          -|  |   |
             +-  |   |          6.280
417          +   |   |
             |   |   |          3.861
409          -   |   |
                 +---          24.719
310          --  |
              +--               9.692
422          -|
             +-                 7.431
228          -
```

APPENDIX H

CA scores from the initial analyses

APPENDIX H

(I) Results of CA procedure using 16 spp and 45 control sites

Inertia and Chi-Square Decomposition

Singular Values	Principal Inertias	Chi-Squares	Percents	4 8 12 16 20
				----+----+----+----+----+---
0.74884	0.56076	18057.8	20.09%	*************************
0.64634	0.41776	13452.7	14.97%	*******************
0.58767	0.34535	11121.1	12.37%	***************
0.54936	0.30179	9718.45	10.81%	**************
0.52025	0.27066	8715.84	9.70%	************
0.43015	0.18503	5958.39	6.63%	********
0.38322	0.14685	4729.05	5.26%	*******
0.37732	0.14237	4584.54	5.10%	******
0.35765	0.12792	4119.17	4.58%	******
0.30456	0.09276	2986.94	3.32%	****
0.26560	0.07055	2271.74	2.53%	***
0.21461	0.04606	1483.12	1.65%	**
0.20860	0.04351	1401.23	1.56%	**
0.14512	0.02106	678.134	0.75%	*
0.13766	0.01895	610.264	0.68%	*
	-------	-------		
	2.79137	89888.5	(Degrees of Freedom = 660)	

Row Coordinates

Initial Cluster	Dim1	Dim2	Dim3	Dim4	Dim5
E	0.25645	0.17066	-0.32319	0.18267	-0.12134
2	-0.37605	0.06933	0.08047	-0.02055	0.00858
E	-0.47621	0.84573	-0.63961	-0.98061	1.53217
4	-0.62433	0.09146	-0.60617	0.09867	-0.19591
4	-0.49200	0.15941	-0.54789	-0.26004	0.37219
5	-0.15239	0.71643	0.02711	-0.40482	-0.21836
1	-0.04472	-1.10449	0.03361	-0.34342	0.09354
6	-0.71684	0.25991	2.68092	0.99846	0.41781
5	-0.40090	0.85033	0.84126	-0.66813	-0.40234
2	-0.80051	0.33305	-0.04088	0.24647	-0.58549
E	-0.48935	0.69570	0.18412	-0.21784	-0.87595
5	0.59322	0.48021	0.13670	-0.16221	-0.10379
3	1.21486	-0.09139	-0.31252	0.54294	0.09081
3	1.31127	0.29722	-0.09957	0.13755	-0.06839
3	1.69132	-0.02796	-0.27072	0.62149	0.07562
3	1.00455	-0.07136	-0.16507	0.28272	0.22056
3	1.52630	0.03987	-0.15777	0.35280	0.03283
1	0.29725	-1.09604	-0.08093	-0.36278	-0.01267
E	0.55592	0.02586	-0.14769	0.06299	-0.26848
E	1.05656	0.41676	0.08694	-0.08217	-0.07256
5	0.89242	0.73995	0.17893	-0.38337	-0.27322
C	0.11663	0.10969	1.13394	0.21805	-0.36208
3	1.50015	0.03844	-0.13161	0.61567	0.03347
3	1.19521	0.18329	0.07528	0.27236	0.03265
3	1.37057	0.33639	-0.18428	0.21036	0.07575
A	-0.13788	-0.82608	0.06665	-0.08357	-0.14741
1	-0.01033	-1.78102	0.68310	-0.95068	-0.01402
D	-0.38995	-0.50331	0.07026	0.15342	-0.14228
4	-0.78280	-0.19215	-0.58186	0.64956	0.04884
D	-0.43808	-0.11229	-0.42699	0.15573	0.00142
B	-0.59207	0.35161	-0.06725	0.07911	-0.68186
B	-0.81920	0.02746	-0.38988	0.37970	-0.66589
B	-0.55064	-0.19053	-0.07661	0.89956	1.07098
2	-0.70890	-0.01670	0.31698	0.45917	-0.40670
5	-0.18024	0.90966	0.33029	-1.01913	-0.29548
4	-0.82572	-0.15845	-0.62511	0.39793	-0.29453
4	-0.77042	-0.16581	-0.47447	0.37549	-0.31906
4	-0.82579	0.10409	-0.60336	0.31225	0.00458
4	-0.82313	-0.10623	-0.76474	0.49221	-0.28971
D	-0.73927	-0.03215	0.10233	0.05951	-0.32543
6	-0.85733	0.25071	2.53169	1.86927	2.06418
5	0.12959	1.06064	0.81184	-0.82579	-0.27518
2	-0.57374	0.38791	0.03106	0.28823	-1.10554
1	0.12588	-1.39240	0.51088	-0.94400	0.11463
5	-0.26752	0.47494	0.65022	-0.17764	-0.00126

Squared Cosines for the Row Points

Initial Cluster	Dim1	Dim2	Dim3	Dim4	Dim5
E	0.121895	0.053985	0.193607	0.061851	0.027288
2	0.037348	0.001270	0.001710	0.000112	0.000019
E	0.043622	0.137583	0.078691	0.184967	0.451556
4	0.292232	0.006271	0.275484	0.007300	0.028774
4	0.260176	0.027313	0.322644	0.072681	0.148894
5	0.014409	0.318459	0.000456	0.101682	0.029585
1	0.001319	0.804458	0.000745	0.077774	0.005770
6	0.045815	0.006023	0.640807	0.088884	0.015564
5	0.050141	0.225573	0.220789	0.139263	0.050500
2	0.193378	0.033473	0.000504	0.018332	0.103447
E	0.104569	0.211356	0.014804	0.020723	0.335065
5	0.242180	0.158693	0.012860	0.018108	0.007414
3	0.533589	0.003019	0.035311	0.106574	0.002981
3	0.832327	0.042763	0.004800	0.009159	0.002264
3	0.773460	0.000211	0.019817	0.104437	0.001546
3	0.505397	0.002550	0.013646	0.040031	0.024364
3	0.856098	0.000584	0.009147	0.045741	0.000396
1	0.047040	0.639530	0.003487	0.070064	0.000086
E	0.066777	0.000144	0.004713	0.000857	0.015575
E	0.675076	0.105039	0.004570	0.004083	0.003184
5	0.364999	0.250929	0.014674	0.067357	0.034211
C	0.003410	0.003016	0.322338	0.011919	0.032865
3	0.679379	0.000446	0.005229	0.114431	0.000338
3	0.323562	0.007610	0.001283	0.016802	0.000241
3	0.641059	0.038616	0.011589	0.015101	0.001958
A	0.008379	0.300757	0.001958	0.003078	0.009577
1	0.000022	0.657163	0.096673	0.187243	0.000041
D	0.146671	0.244342	0.004761	0.022704	0.019526
4	0.353447	0.021295	0.195278	0.243363	0.001376
D	0.176016	0.011565	0.167220	0.022244	0.000002
B	0.262000	0.092399	0.003380	0.004677	0.347489
B	0.380681	0.000428	0.086228	0.081783	0.251529
B	0.074237	0.008888	0.001437	0.198128	0.280833
2	0.234062	0.000130	0.046798	0.098201	0.077039
5	0.011034	0.281046	0.037052	0.352758	0.029653
4	0.364448	0.013421	0.208873	0.084642	0.046370
4	0.376243	0.017427	0.142702	0.089375	0.064530
4	0.438367	0.006965	0.234018	0.062678	0.000014
4	0.329360	0.005486	0.284291	0.117772	0.040800
D	0.288096	0.000545	0.005520	0.001867	0.055826
6	0.042207	0.003609	0.368047	0.200645	0.244668
5	0.004616	0.309184	0.181143	0.187418	0.020812
2	0.073048	0.033391	0.000214	0.018435	0.271219
1	0.004427	0.541614	0.072912	0.248949	0.003671
5	0.050802	0.160119	0.300105	0.022401	0.000001

Column Coordinates

SPP	Dim1	Dim2	Dim3	Dim4	Dim5
BAITOA	-0.64751	-0.09654	-0.52948	0.27285	-0.10024
GUATAP	0.18347	0.89923	0.20313	-0.67279	-0.20331
QUINA	0.91565	-0.22913	-0.02498	0.26708	0.12002
BRUCON	-0.35065	-0.30758	0.69758	-0.17921	-0.30229
CANDEL	1.50245	0.05203	-0.22326	0.38988	0.04921
CINAZO	-0.33323	-0.10646	0.38357	0.50467	0.08685
ALMACIG	0.04775	-1.79284	0.36747	-0.92150	0.07227
GUAYAC	-0.14923	-0.16994	-0.08538	0.32251	-0.01798
CAMBRON	-0.78852	0.49899	0.27155	0.16054	-1.10840
AROMA	-0.64761	0.48774	2.92878	1.05265	0.81068
MOSTAZO	-0.40126	0.63284	0.14250	-1.14442	0.47697
SANGRE	0.47063	0.54359	0.51308	-0.18447	-0.36413
FRIJOL	-0.50004	0.74157	-0.74959	-0.78795	1.96452
CAFETAN	-0.03519	-0.40502	-0.07454	0.11894	-0.25299
PAAMAR	1.24094	0.03821	-0.06563	0.20114	-0.14269
UVERO	-0.80588	-0.24154	0.61297	1.53512	1.55014

Squared Cosines for the Column Points

SPP	Dim1	Dim2	Dim3	Dim4	Dim5
BAITOA	0.473890	0.010533	0.316874	0.084146	0.011357
GUATAP	0.019172	0.460578	0.023501	0.257825	0.023544
QUINA	0.433445	0.027141	0.000323	0.036877	0.007446
BRUCON	0.071424	0.054955	0.282665	0.018656	0.053081
CANDEL	0.834639	0.001001	0.018430	0.056202	0.000895
CINAZO	0.045191	0.004612	0.059877	0.103652	0.003070
ALMACIG	0.000526	0.740974	0.031129	0.195751	0.001204
GUAYAC	0.014741	0.019117	0.004825	0.068852	0.000214
CAMBRON	0.148934	0.059642	0.017663	0.006174	0.294275
AROMA	0.032947	0.018688	0.673861	0.087050	0.051629
MOSTAZO	0.040095	0.099729	0.005057	0.326140	0.056654
SANGRE	0.034375	0.045859	0.040856	0.005281	0.020578
FRIJOL	0.035676	0.078463	0.080170	0.088586	0.550654
CAFETAN	0.000248	0.032897	0.001114	0.002837	0.012836
PAAMAR	0.456610	0.000433	0.001277	0.011996	0.006037
UVERO	0.061234	0.005501	0.035427	0.222196	0.226567

(II) CA scores from the analysis using 16 spp and 30 core sites

```
                      Inertia and Chi-Square Decomposition

Singular  Principal Chi-
Values    Inertias  Squares Percents    5    10   15   20   25
                                    ----+----+----+----+----+---
0.77763   0.60471     13319  25.90% **************************
0.66993   0.44881   9885.31  19.22% *******************
0.62099   0.38562   8493.59  16.52% *****************
0.49850   0.24850   5473.38  10.64% ***********
0.36962   0.13662   3009.19   5.85% ******
0.32383   0.10487   2309.78   4.49% ****
0.31414   0.09868   2173.53   4.23% ****
0.29566   0.08741   1925.31   3.74% ****
0.24682   0.06092   1341.78   2.61% ***
0.21163   0.04479   986.445   1.92% **
0.19412   0.03768   829.966   1.61% **
0.16594   0.02754   606.485   1.18% *
0.15726   0.02473    544.73   1.06% *
0.11476   0.01317   290.097   0.56% *
0.10361   0.01074   236.461   0.46%
          -------   -------
          2.33479   51425.1 (Degrees of Freedom = 435)
```

ID$	CLUSTER$	DIM1	DIM2	DIM3	SUMCO12	SUMCO123	SQUCOS1	SQUCOS2	SQUCOS3
102	2	-0.448	0.255	0.048	0.070	0.070	0.053	0.017	0.001
104	4	-0.797	0.138	-0.453	0.485	0.636	0.471	0.014	0.152
105	4	-0.594	0.078	-0.304	0.237	0.298	0.233	0.004	0.061
110	5	-0.226	0.868	0.223	0.527	0.560	0.034	0.494	0.032
126	1	-0.221	-0.905	0.397	0.743	0.878	0.042	0.701	0.135
128	5	-0.331	1.136	1.005	0.355	0.611	0.028	0.327	0.256
129	2	-0.876	0.310	-0.327	0.192	0.216	0.171	0.021	0.024
206	5	0.537	0.554	0.128	0.447	0.459	0.217	0.230	0.012
207	3	1.009	-0.277	-0.597	0.496	0.658	0.461	0.035	0.162
208	3	1.134	0.222	-0.232	0.760	0.790	0.732	0.028	0.031
209	3	1.428	-0.260	-0.666	0.740	0.896	0.716	0.024	0.156
210	3	0.856	-0.246	-0.346	0.471	0.542	0.435	0.036	0.071
212	3	1.326	-0.114	-0.419	0.807	0.887	0.801	0.006	0.080
213	1	0.061	-0.911	0.323	0.573	0.645	0.003	0.571	0.072
221	5	0.762	0.792	0.232	0.654	0.683	0.314	0.340	0.029
223	3	1.255	-0.119	-0.606	0.611	0.753	0.606	0.005	0.141
224	3	1.043	0.063	-0.351	0.317	0.352	0.315	0.001	0.036
225	3	1.130	0.165	-0.365	0.608	0.670	0.595	0.013	0.062
302	1	-0.112	-1.367	1.338	0.478	0.932	0.003	0.474	0.455
304	4	-0.964	-0.168	-0.734	0.477	0.746	0.463	0.014	0.269
319	2	-0.776	0.121	0.028	0.203	0.203	0.198	0.005	0.000
320	5	-0.167	1.152	0.931	0.445	0.730	0.009	0.436	0.285
401	4	-1.010	-0.142	-0.633	0.538	0.745	0.527	0.010	0.207
402	4	-0.935	-0.134	-0.505	0.541	0.696	0.530	0.011	0.154
403	4	-0.953	0.016	-0.713	0.440	0.687	0.440	0.000	0.246
404	4	-1.033	-0.124	-0.808	0.513	0.822	0.506	0.007	0.309
427	5	0.158	1.357	0.950	0.537	0.796	0.007	0.530	0.259
428	2	-0.714	0.414	-0.299	0.126	0.142	0.094	0.032	0.017
429	1	0.050	-1.051	1.172	0.384	0.861	0.001	0.383	0.476
430	5	-0.234	0.796	0.584	0.293	0.438	0.023	0.270	0.145
SP	BA	-0.845	-0.114	-0.560	0.640	0.916	0.629	0.011	0.276
SP	GU	0.190	1.101	0.574	0.657	0.830	0.019	0.638	0.174
SP	QU	0.940	-0.336	-0.207	0.512	0.534	0.454	0.058	0.022
SP	BR	-0.298	-0.123	0.781	0.058	0.398	0.049	0.008	0.340
SP	CA	1.262	-0.150	-0.502	0.797	0.921	0.786	0.011	0.124
SP	CI	-0.288	0.141	-0.136	0.034	0.040	0.027	0.006	0.006
SP	AL	-0.104	-1.467	1.150	0.600	0.968	0.003	0.597	0.367
SP	GY	-0.274	-0.198	-0.202	0.095	0.128	0.062	0.032	0.034
SP	CM	-0.894	0.550	-0.020	0.192	0.192	0.139	0.053	0.000
SP	AR	-0.209	1.213	1.099	0.247	0.444	0.007	0.240	0.197
SP	MO	-0.290	0.860	1.153	0.176	0.460	0.018	0.158	0.284
SP	SA	0.363	0.671	0.171	0.131	0.138	0.030	0.102	0.007
SP	FR	-0.331	0.003	-0.526	0.022	0.078	0.022	0.000	0.056
SP	CF	-0.180	0.050	0.323	0.011	0.042	0.010	0.001	0.032
SP	PA	1.232	0.000	-0.381	0.534	0.585	0.534	0.000	0.051
SP	UV	-0.885	-0.287	-0.263	0.154	0.166	0.139	0.015	0.012

APPENDIX I

CDA scores from the initial analyses

APPENDIX I

(I) CDA scores from analysis of 16 spp and 43 sites

Canonical Discriminant Analysis

43 Observations	42 DF Total
16 Variables	38 DF Within Classes
5 Classes	4 DF Between Classes

Class Level Information

CLUSTEMP	Frequency	Weight	Proportion
1	4	4.0000	0.093023
2	8	8.0000	0.186047
3	10	10.0000	0.232558
4	10	10.0000	0.232558
5	11	11.0000	0.255814

Multivariate Statistics and F Approximations

S=4 M=5.5 N=10.5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.00015391	12.1413	64	92.31694	0.0001
Pillai's Trace	3.43378835	9.8548	64	104	0.0001
Hotelling-Lawley Trace	40.92173632	13.7471	64	86	0.0001
Roy's Greatest Root	21.11946598	34.3191	16	26	0.0001

NOTE: F Statistic for Roy's Greatest Root is an upper bound.

	Canonical Correlation	Adjusted Canonical Correlation	Approx Standard Error	Squared Canonical Correlation
1	0.977134	0.965886	0.006976	0.954791
2	0.958511	0.942672	0.012538	0.918743
3	0.927586	0.907639	0.021538	0.860416
4	0.836564	0.796772	0.046316	0.699839

Eigenvalues of INV(E)*H
= CanRsq/(1-CanRsq)

	Eigenvalue	Difference	Proportion	Cumulative
1	21.1195	9.8129	0.5161	0.5161
2	11.3066	5.1425	0.2763	0.7924
3	6.1641	3.8326	0.1506	0.9430
4	2.3315	.	0.0570	1.0000

Test of H0: The canonical correlations in the current row and all that follow are zero

	Likelihood Ratio	Approx F	Num DF	Den DF	Pr > F
1	0.00015391	12.1413	64	92.31694	0.0001
2	0.00340450	9.2461	45	72.07848	0.0001
3	0.04189779	6.9383	28	50	0.0001
4	0.30016099	4.6631	13	26	0.0004

OBS	ID	CLUSINI	CLUSTEMP	CAN1	CAN2	CAN3	CAN4
1	101	E	5	-2.1356	0.02905	-0.32766	0.52405
2	102	2	2	-0.5228	2.47778	-3.56876	-2.44013
3	103	E	5	-2.8857	0.60001	-0.05177	2.58331
4	104	4	4	1.1229	4.06835	2.75282	1.17133
5	105	4	4	0.9988	2.28029	1.42393	1.34887
6	110	5	5	-2.3890	0.99846	-1.89097	2.11183
7	126	1	1	11.5606	-1.01991	0.02857	0.81812
8	128	5	5	-2.4271	-1.08899	-0.79220	2.61604
9	129	2	2	-1.5452	1.75917	-4.23943	-2.67998
10	130	E	5	-2.0679	1.15122	-3.09086	0.95046
11	206	5	5	-4.0018	-1.62957	-0.67164	1.27822
12	207	3	3	-2.0905	-4.95521	2.60447	-1.31058
13	208	3	3	-2.4861	-4.66582	2.04372	0.59420
14	209	3	3	-0.9913	-6.04420	2.01173	-1.75806
15	210	3	3	-2.2267	-4.16199	2.18819	-1.09098
16	212	3	3	-1.1001	-5.55769	2.69351	-0.98119
17	213	1	1	11.0864	-2.30445	-0.36167	1.25990
18	214	E	5	-4.2270	0.17260	-2.20957	1.01794
19	215	C	3	-2.7427	-3.52391	0.92716	0.60085
20	221	5	5	-2.6393	-2.24376	-0.55343	1.60180
21	222	C	3	-0.9253	-3.90421	1.25242	-0.85568
22	223	3	3	-1.3665	-5.21334	2.01110	-2.26749
23	224	3	3	-2.2199	-3.85482	1.21887	-2.30827
24	225	3	3	-1.8233	-4.75346	-0.41204	-0.23283
25	301	B	2	1.7931	2.22571	-2.97753	-0.08312
26	302	1	1	15.3105	-2.27851	-1.87488	0.90617
27	303	D	4	0.7271	2.46527	2.21357	-0.02202
28	304	4	4	1.2026	4.76197	3.30812	-0.55185
29	305	D	4	-0.6147	3.01469	2.51210	-0.18806
30	316	B	2	-1.0193	2.53706	-2.10787	-0.07185
31	317	B	2	-1.3426	2.11524	-3.22204	-2.17809
32	318	B	2	-0.2914	1.61349	-4.03920	-2.52406
33	319	2	2	-1.7553	2.98602	-4.13910	-2.91397
34	320	5	5	-2.9456	1.22737	-2.78296	3.36948
35	401	4	4	1.2733	5.61366	5.04467	-0.43851
36	402	4	4	0.9295	5.21744	3.71237	-0.62137
37	403	4	4	-0.2705	4.28377	1.30441	-0.96047
38	404	4	4	1.7185	4.60263	3.45992	-0.14172
39	405	D	4	-0.0046	4.08403	4.11448	-0.60862
40	427	5	5	-4.4973	-0.98757	-1.00121	4.38827
41	428	2	2	-0.6954	0.18684	-3.05238	-2.55963
42	429	1	1	13.0957	-2.70298	-2.18804	0.50130
43	430	5	5	-4.5688	0.41827	-1.27093	2.14643

(II) CDA scores from analysis of 16 spp and 30 core sites

Canonical Discriminant Analysis

30 Observations	29 DF Total
16 Variables	25 DF Within Classes
5 Classes	4 DF Between Classes

Class Level Information

CLUSINI	Frequency	Weight	Proportion
1	4	4.0000	0.133333
2	4	4.0000	0.133333
3	8	8.0000	0.266667
4	7	7.0000	0.233333
5	7	7.0000	0.233333

Multivariate Statistics and F Approximations

S=4   M=5.5   N=4

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.00000293	16.1211	64	41.42423	0.0001
Pillai's Trace	3.74007736	11.6912	64	52	0.0001
Hotelling-Lawley Trace	176.55852938	23.4492	64	34	0.0001
Roy's Greatest Root	132.75869213	107.8664	16	13	0.0001

NOTE: F Statistic for Roy's Greatest Root is an upper bound.

	Canonical Correlation	Adjusted Canonical Correlation	Approx Standard Error	Squared Canonical Correlation
1	0.996255	0.993955	0.001388	0.992524
2	0.980087	0.967797	0.007322	0.960571
3	0.964889	0.950178	0.012811	0.931010
4	0.925188	0.901485	0.026745	0.855973

Eigenvalues of INV(E)*H
= CanRsq/(1-CanRsq)

	Eigenvalue	Difference	Proportion	Cumulative
1	132.7587	108.3968	0.7519	0.7519
2	24.3619	10.8670	0.1380	0.8899
3	13.4948	7.5517	0.0764	0.9663
4	5.9431	.	0.0337	1.0000

Test of H0: The canonical correlations in the current row and all that follow are zero

	Likelihood Ratio	Approx F	Num DF	Den DF	Pr > F
1	0.00000293	16.1211	64	41.42423	0.0001
2	0.00039179	9.6828	45	33.45879	0.0001
3	0.00993644	7.7417	28	24	0.0001
4	0.14402715	5.9431	13	13	0.0015

OBS	ID	CLUSINI	CAN1	CAN2	CAN3	CAN4
1	102	2	-5.7318	0.96066	-4.73807	-3.29251
2	104	4	3.5366	6.85705	1.40729	1.23832
3	105	4	4.7931	6.07486	3.77552	0.50796
4	110	5	-7.7223	2.29747	-3.46619	2.25516
5	126	1	23.2065	-1.91667	-0.67711	0.59456
6	128	5	-8.6493	0.45477	-2.16883	3.38070
7	129	2	-5.0583	1.80242	-5.79960	-4.36042
8	206	5	-9.5420	-0.54357	-2.01576	2.94455
9	207	3	-4.9508	-5.34835	4.47364	-0.74634
10	208	3	-5.0305	-4.14571	3.15657	1.25197
11	209	3	-6.2952	-5.63284	4.55897	-1.74836
12	210	3	-4.8376	-4.06394	5.20120	-0.76039
13	212	3	-5.8222	-4.22148	4.02973	0.03826
14	213	1	23.6176	-4.42719	-0.70861	0.48129
15	221	5	-7.9461	-1.29034	-0.87146	2.20407
16	223	3	-4.0350	-5.20395	3.74403	-1.50507
17	224	3	-5.9668	-4.25557	2.62514	-2.64425
18	225	3	-6.8301	-4.76921	2.19553	-0.54162
19	302	1	26.4906	-4.75849	-3.25674	1.06375
20	304	4	5.7136	6.52958	2.00115	-0.52046
21	319	2	-6.6745	0.07478	-5.95695	-4.41419
22	320	5	-7.7475	0.56963	-3.33428	2.96502
23	401	4	4.2505	8.71183	3.59516	-0.14628
24	402	4	2.9232	7.36280	2.79155	-0.95546
25	403	4	3.5044	7.57275	1.35829	-1.48071
26	404	4	5.4936	7.25337	2.41519	-0.93892
27	427	5	-8.9052	0.16356	-2.64428	5.79967
28	428	2	-5.9857	-0.74407	-5.81517	-4.37020
29	429	1	22.8452	-5.40218	-3.14574	0.68234
30	430	5	-8.6442	0.03805	-2.73015	3.01754

APPENDIX J

SAS output for correspondence analyses using the full data set

APPENDIX J

(I) Results for CA procedure using 120 sites

```
                 The Correspondence Analysis Procedure

                   Inertia and Chi-Square Decomposition

Singular  Principal Chi-
Values    Inertias  Squares Percents    4    8   12   16   20
                                    ----+----+----+----+----+---
0.72040   0.51897     51676  18.53% ***********************
0.64242   0.41270   41094.2  14.74% ******************
0.54279   0.29463   29336.9  10.52% *************
0.48965   0.23975   23873.1   8.56% ***********
0.46161   0.21309   21217.7   7.61% **********
0.43402   0.18838   18757.2   6.73% ********
0.39142   0.15321   15255.7   5.47% *******
0.38930   0.15156   15091.1   5.41% *******
0.36991   0.13683   13624.9   4.89% ******
0.35335   0.12486   12432.7   4.46% ******
0.31169   0.09715   9673.44   3.47% ****
0.29424   0.08658    8620.7   3.09% ****
0.29361   0.08621   8584.13   3.08% ****
0.22374   0.05006   4984.62   1.79% **
0.21527   0.04634   4614.38   1.65% **
          -------   -------
          2.80031    278837 (Degrees of Freedom = 1785)
```

Row Coordinates

ID	CLUSTOT	Dim1	Dim2	Dim3	Dim4	Dim5
101	BG	0.43163	0.27358	-0.33312	-0.15254	0.02828
102	7	-0.19395	-0.18542	-0.11556	-0.00969	-0.39745
103	BG	-0.42118	0.05908	-0.41291	-0.66495	1.88205
104	D	-0.54903	0.08763	-0.47192	-0.32549	-0.00895
105	BD	-0.41642	-0.07573	-0.36459	-0.37405	0.58449
106	BD	-0.05228	0.22884	-0.25152	-0.32067	0.11704
107	C	0.64376	0.52167	0.04652	-0.35816	0.47349
108	BG	-0.45925	-0.69233	-0.35924	-0.27186	1.07220
109	4	-0.71448	-0.07493	-0.70822	-0.16849	-0.00282
110	5	-0.08710	0.72944	0.27822	-0.49958	0.36060
111	D	-0.57776	-0.44804	-0.31009	-0.13218	-0.04780
112	4	-0.68414	0.10133	-0.45457	0.05246	-0.19871
113	D	-0.40751	-0.72444	0.00528	-0.16856	-0.08456
114	D	-0.55920	0.48857	0.20069	0.61287	-0.28630
115	FG	-0.43452	0.58874	0.40676	-0.02174	0.24049
116	BG	-0.49153	0.16973	-0.18173	1.19299	0.60053
117	D	-0.31853	0.02370	-0.54242	-0.24672	-0.04779
118	1	0.18570	-0.85590	0.38954	-0.18397	0.18243
119	5	-0.01727	0.68771	0.47190	-0.28395	-0.05875
120	3	1.22479	0.17633	-0.39466	0.12286	-0.13166
121	E	-0.50971	1.21021	0.93885	0.14172	0.02009
122	D	-0.47568	0.24818	-0.15824	-0.29513	0.04201
123	EH	-0.16765	0.65561	0.40600	-0.38988	-0.29659
124	6	-0.57228	1.51896	1.49767	0.38121	-0.29523
125	E	-0.34336	1.54192	1.34373	-0.27966	0.05409
126	1	0.10710	-0.89983	0.32896	0.09851	0.04874
127	6	-0.55476	0.92820	1.13698	0.78009	-0.89233
128	E	-0.29627	1.05819	0.91875	-0.50580	0.04454
129	G	-0.67610	0.54734	0.17699	-0.22368	-0.15107
130	E	-0.41169	1.02953	0.60498	-0.55466	-0.02124
201	3	1.61044	0.15229	-0.47112	0.22149	-0.36987
202	3	1.63111	0.48616	-0.18726	-0.04127	0.18734
203	3	1.22323	0.50039	-0.31958	-0.17474	0.07652
204	BG	-0.11034	0.14636	-0.38828	-0.21047	0.02627
205	3	1.04486	0.33910	-0.21205	-0.04587	0.03810
206	E	0.75170	0.56184	0.23794	-0.23142	0.14305
207	3	1.55832	0.09283	-0.54760	0.26754	-0.03071
208	3	1.55681	0.41990	-0.22730	-0.05731	0.06326
209	3	2.07149	0.16996	-0.66667	0.25011	-0.07123
210	3	1.31210	0.07076	-0.40919	0.16896	0.10613
211	3	1.83460	0.17787	-0.38264	0.25225	-0.03430
212	3	1.83707	0.18822	-0.37898	0.15186	-0.02544
213	1	0.47998	-0.88505	0.22346	-0.10981	-0.00067
214	X	0.59097	0.11799	-0.28502	-0.08533	-0.28142

ID	CLUSTOT	Dim1	Dim2	Dim3	Dim4	Dim5
215	C	1.26719	0.52941	0.04477	-0.15276	0.13068
216	1	0.76232	-1.49308	0.93485	-0.04764	0.03158
217	3	2.11251	0.25047	-0.68455	0.20107	-0.09220
218	1	-0.00360	-0.79549	0.54152	-0.13242	-0.14583
219	C	0.82919	0.46855	0.32404	0.07697	0.08690
220	7	-0.00965	-0.40694	-0.17092	0.10262	-0.52312
221	E	1.07045	0.77635	0.19739	-0.43173	0.21884
222	FG	0.30402	0.38513	0.71779	0.32079	-0.48192
223	3	1.87159	0.14729	-0.59814	0.25310	-0.25509
224	3	1.49372	0.03395	-0.31292	0.29879	-0.12478
225	3	1.70874	0.48702	-0.42355	-0.10805	0.24714
226	3	1.20087	-0.30240	-0.23342	0.26241	0.01258
227	1	0.19456	-0.51875	0.72108	-0.07542	-0.24720
228	7	0.07679	-0.13285	0.13093	0.51832	-0.95202
229	3	1.48467	0.23104	-0.33520	0.16914	-0.07581
230	1	0.54545	-1.27545	1.21556	0.04320	0.09578
301	7	-0.06407	-0.66300	0.06018	0.05945	-0.51839
302	1	0.14231	-1.37171	1.07755	-0.06531	-0.17210
303	D	-0.27381	-0.26011	-0.16379	0.06783	-0.46149
304	4	-0.68046	-0.12436	-0.70007	0.33508	-0.14008
305	D	-0.31698	-0.10822	-0.54214	-0.06281	-0.15074
306	7	-0.38694	-0.18308	-0.40738	-0.00368	-0.43141
307	6	-0.44434	1.34336	1.34902	0.44223	-0.20595
308	5	-0.13542	1.18129	0.97403	-0.26750	0.22006
309	5	0.12247	1.31346	0.96740	-1.00118	0.70606
310	G	-0.31504	0.59789	0.52151	-0.10964	-0.48001
311	E	-0.33171	1.40224	1.05487	-0.63442	0.08259
312	D	-0.58851	0.03159	-0.37974	0.04414	-0.30924
313	B	-0.39403	0.17896	-0.25642	0.21557	0.00224
314	7	-0.36579	0.03478	-0.26892	-0.03735	-0.20330
315	7	-0.54010	-0.24015	-0.21201	0.39624	-0.30097
316	G	-0.49315	0.62478	0.17304	-0.36326	-0.17151
317	G	-0.73807	0.27104	-0.29157	-0.16875	-0.42489
318	BG	-0.39581	-0.09836	-0.30544	1.58783	0.72514
319	G	-0.57400	0.42954	0.15788	0.44854	-0.38961
320	5	-0.10807	0.89869	0.65343	-0.75805	0.32538
321	1	-0.09412	-1.63220	0.87781	-0.21097	0.17118
322	BG	-0.36169	-0.61951	-0.18951	-0.36184	1.20319
323	7	-0.42638	-0.14599	-0.37761	0.12610	-0.85874
324	BG	-0.57990	0.02577	-0.41896	0.14553	0.98039
325	4	-0.68675	-0.09639	-0.73667	-0.09279	-0.34678
326	7	-0.15959	-0.37726	0.03167	-0.02401	-0.15444
327	4	-0.62523	-0.09516	-0.69176	-0.10527	-0.44631
328	7	-0.38504	-0.04688	0.01303	0.28481	-0.56572
329	4	-0.63391	-0.06960	-0.61295	-0.09492	-0.45904
330	FH	-0.25022	0.30271	0.20360	-0.12881	-0.83608
401	4	-0.73407	-0.06430	-0.72081	-0.13567	-0.36359
402	4	-0.66746	-0.01397	-0.60036	-0.12319	-0.37928
403	D	-0.72834	0.03090	-0.53309	-0.18474	0.06585
404	4	-0.73029	-0.03432	-0.73216	-0.15537	-0.21260
405	D	-0.62053	0.18662	-0.18998	-0.12574	-0.50048
406	3	2.09843	0.30624	-0.73588	0.15706	-0.03051
407	4	-0.76075	-0.14934	-0.86834	-0.16193	-0.21065
408	B	-0.42562	0.49701	0.05307	-0.25254	-0.05348
409	7	0.21689	-0.42437	-0.17885	0.17637	-0.44581
410	5	0.13542	0.52166	0.11768	-0.40977	0.15524
411	BG	-0.43636	-0.00378	-0.38913	-0.24448	0.51255
412	X	0.00499	0.16977	-0.11490	-0.15824	-0.08639
413	D	-0.14142	-0.08491	-0.25286	-0.12806	-0.11644
414	G	0.55076	-0.41461	0.47171	0.08621	-0.32870
415	B	-0.41552	0.25800	-0.10108	-0.24555	-0.05668
416	D	-0.78360	0.41099	-0.09545	0.05990	-0.19662
417	7	-0.12346	-0.57771	0.05591	0.49061	-0.21254
418	4	-0.75459	0.21078	-0.32701	0.09284	-0.33300
419	7	0.03805	-0.33605	-0.20773	0.06973	-0.56554
420	D	-0.73859	0.15851	-0.37227	0.17334	-0.06177
421	1	0.18465	-1.73143	1.29511	-0.06254	0.09417
422	7	-0.18628	-0.09254	-0.00183	0.15848	-0.80857
423	6	-0.36301	0.57356	0.49086	3.46165	1.20385
424	A	0.50471	-0.32461	0.66600	0.23213	-0.20639
425	G	0.05399	-0.19361	0.23488	0.05175	-0.51626
426	6	-0.68146	0.93459	1.01053	2.96183	0.92565
427	5	0.21005	1.05354	0.85956	-0.58243	0.30450
428	G	-0.43225	0.70748	0.30732	-0.17075	-0.40004
429	1	0.30495	-1.19757	0.94979	-0.05666	-0.05199
430	5	-0.17820	0.59422	0.41763	-0.19876	-0.10558

Squared Cosines for the Row Points

CLUSTOT	Dim1	Dim2	Dim3	Dim4	Dim5
BG	0.254643	0.102299	0.151672	0.031804	0.001093
7	0.015155	0.013852	0.005380	0.000038	0.063642
BG	0.031381	0.000617	0.030162	0.078220	0.626621
D	0.268899	0.006850	0.198673	0.094510	0.000071
BD	0.198305	0.006558	0.152012	0.160008	0.390694
BD	0.004095	0.078466	0.094791	0.154078	0.020524
C	0.116566	0.076544	0.000609	0.036080	0.063058
BG	0.083017	0.188665	0.050795	0.029091	0.452498
4	0.421574	0.004637	0.414224	0.023446	0.000007
5	0.003819	0.267862	0.038968	0.125643	0.065462
D	0.388563	0.233670	0.111928	0.020337	0.002660
4	0.374262	0.008211	0.165231	0.002201	0.031575
D	0.157522	0.497820	0.000026	0.026951	0.006782
D	0.115014	0.087795	0.014814	0.138151	0.030148
FG	0.021293	0.039091	0.018659	0.000053	0.006522
BG	0.079372	0.009465	0.010850	0.467562	0.118478
D	0.077261	0.000428	0.224042	0.046350	0.001739
1	0.028526	0.605988	0.125526	0.027999	0.027530
5	0.000168	0.266766	0.125608	0.045479	0.001947
3	0.359374	0.007449	0.037314	0.003616	0.004153
E	0.075219	0.424035	0.255197	0.005815	0.000117
D	0.164611	0.044809	0.018215	0.063367	0.001284
EH	0.009596	0.146752	0.056280	0.051899	0.030033
6	0.039034	0.274984	0.267331	0.017320	0.010388
E	0.022959	0.463003	0.351625	0.015230	0.000570
1	0.010110	0.713640	0.095378	0.008552	0.002094
6	0.038678	0.108275	0.162462	0.076478	0.100067
E	0.024904	0.317711	0.239499	0.072587	0.000563
G	0.114486	0.075031	0.007846	0.012531	0.005716
E	0.054868	0.343134	0.118485	0.099595	0.000146
3	0.614589	0.005496	0.052597	0.011625	0.032418
3	0.789996	0.070181	0.010412	0.000506	0.010421
3	0.519439	0.086922	0.035456	0.010600	0.002033
BG	0.023391	0.041154	0.289647	0.085104	0.001326
3	0.753925	0.079411	0.031052	0.001453	0.001002
E	0.270516	0.151125	0.027105	0.025640	0.009796
3	0.583096	0.002069	0.072003	0.017188	0.000226
3	0.724789	0.052726	0.015450	0.000982	0.001197
3	0.784427	0.005281	0.081246	0.011435	0.000928
3	0.564536	0.001642	0.054905	0.009361	0.003693
3	0.752896	0.007077	0.032752	0.014234	0.000263
3	0.784495	0.008235	0.033387	0.005361	0.000150
1	0.140132	0.476466	0.030373	0.007334	0.000000
X	0.048640	0.001939	0.011314	0.001014	0.011030
C	0.604272	0.105471	0.000754	0.008781	0.006427
1	0.140975	0.540796	0.212007	0.000551	0.000242
3	0.720303	0.010126	0.075636	0.006526	0.001372
1	0.000010	0.485019	0.224761	0.013441	0.016300
C	0.260462	0.083164	0.039777	0.002244	0.002861

Squared Cosines for the Row Points, continued.

CLUSTOT	Dim1	Dim2	Dim3	Dim4	Dim5
7	0.000048	0.084910	0.014979	0.005400	0.140312
E	0.383780	0.201867	0.013050	0.062426	0.016040
FG	0.024142	0.038741	0.134574	0.026879	0.060662
3	0.753179	0.004665	0.076927	0.013774	0.013992
3	0.474707	0.000245	0.020833	0.018994	0.003313
3	0.681651	0.055374	0.041882	0.002726	0.014259
3	0.385745	0.024460	0.014574	0.018419	0.000042
1	0.017993	0.127907	0.247144	0.002704	0.029046
7	0.000817	0.002445	0.002375	0.037221	0.125570
3	0.753058	0.018237	0.038385	0.009774	0.001963
1	0.077548	0.424022	0.385136	0.000487	0.002391
7	0.001538	0.164729	0.001357	0.001324	0.100707
1	0.005103	0.474087	0.292558	0.001075	0.007463
D	0.069840	0.063026	0.024992	0.004286	0.198397
4	0.330266	0.011032	0.349583	0.080088	0.013997
D	0.098620	0.011496	0.288486	0.003873	0.022304
7	0.078867	0.017655	0.087422	0.000007	0.098040
6	0.033862	0.309503	0.312116	0.033541	0.007275
5	0.004692	0.356986	0.242709	0.018306	0.012389
5	0.002623	0.301663	0.163644	0.175270	0.087170
G	0.042827	0.154255	0.117360	0.005187	0.099423
E	0.020893	0.373357	0.211291	0.076425	0.001295
D	0.442534	0.001275	0.184253	0.002489	0.122189
B	0.219358	0.045246	0.092893	0.065655	0.000007
7	0.224287	0.002028	0.121220	0.002339	0.069283
7	0.318752	0.063022	0.049115	0.171569	0.098982
G	0.155179	0.249069	0.019106	0.084196	0.018770
G	0.270302	0.036452	0.042183	0.014130	0.089580
BG	0.041459	0.002560	0.024687	0.667172	0.139148
G	0.143004	0.080081	0.010818	0.087321	0.065884
5	0.003500	0.242018	0.127946	0.172198	0.031726
1	0.002292	0.689254	0.199360	0.011516	0.007581
BG	0.047409	0.139088	0.013016	0.047449	0.524635
7	0.042331	0.004963	0.033201	0.003702	0.171708
BG	0.131608	0.000260	0.068694	0.008288	0.376154
4	0.287521	0.005663	0.330835	0.005248	0.073311
7	0.017348	0.096945	0.000683	0.000393	0.016247
4	0.239545	0.005549	0.293245	0.006791	0.122065
7	0.110236	0.001634	0.000126	0.060315	0.237961
4	0.248411	0.002994	0.232256	0.005570	0.130261
FH	0.008268	0.012101	0.005474	0.002191	0.092315
4	0.345540	0.002651	0.333169	0.011803	0.084768
4	0.340897	0.000149	0.275798	0.011613	0.110075
D	0.392349	0.000706	0.210188	0.025241	0.003207
4	0.323493	0.000714	0.325145	0.014642	0.027416
D	0.207054	0.018727	0.019408	0.008501	0.134689
3	0.603549	0.012854	0.074222	0.003381	0.000128
4	0.303605	0.011700	0.395559	0.013755	0.023279
B	0.222891	0.303932	0.003465	0.078467	0.003520
7	0.035895	0.137413	0.024408	0.023736	0.151653
5	0.017205	0.255294	0.012991	0.157526	0.022610
BG	0.117290	0.000009	0.093274	0.036819	0.161827
X	0.000024	0.027610	0.012648	0.023989	0.007149
D	0.007437	0.002681	0.023776	0.006098	0.005042
G	0.045312	0.025678	0.033237	0.001110	0.016139
B	0.182466	0.070348	0.010798	0.063720	0.003395
D	0.331009	0.091060	0.004911	0.001935	0.020840
7	0.012482	0.273300	0.002560	0.197103	0.036992
4	0.358029	0.027935	0.067238	0.005419	0.069723
7	0.000741	0.057802	0.022086	0.002489	0.163703
D	0.375652	0.017302	0.095432	0.020690	0.002627
1	0.006890	0.605791	0.338942	0.000790	0.001792
7	0.009798	0.002418	0.000001	0.007092	0.184610
6	0.008378	0.020916	0.015319	0.761883	0.092144
A	0.107411	0.044430	0.187028	0.022720	0.017962
G	0.000843	0.010844	0.015959	0.000775	0.077100
6	0.033117	0.062290	0.072824	0.625594	0.061103
5	0.010909	0.274435	0.182678	0.083872	0.022926
G	0.033657	0.090165	0.017013	0.005252	0.028829
1	0.030298	0.467271	0.293916	0.001046	0.000881
5	0.023472	0.260983	0.128915	0.029198	0.008239

Column Coordinates

	Dim1	Dim2	Dim3	Dim4	Dim5
BAITOA	-0.56384	-0.10253	-0.49623	-0.07037	-0.11147
GUATAP	0.18460	0.90909	0.55724	-0.53777	0.38805
QUINA	1.09298	-0.11399	-0.03999	0.30760	-0.02810
BRUCON	-0.22444	0.12772	0.11704	0.00604	-0.57602
CANDEL	1.80517	0.22466	-0.50362	0.08321	0.01039
CINAZO	-0.13180	-0.17965	0.07417	0.23815	-0.62416
ALMACIG	0.14041	-1.55519	0.95526	-0.12015	0.10163
GUAYAC	-0.00637	0.07627	-0.09924	-0.03131	0.15656
CAMBRON	-0.66983	1.07432	0.70235	-0.22569	-0.24760
AROMA	-0.51687	1.10830	1.18540	0.79231	-0.31697
MOSTAZO	-0.24821	0.04676	0.15847	-0.36396	0.24936
SANGRE	0.63465	0.08007	0.10695	0.12011	-0.24428
FRIJOL	-0.47974	-0.32453	-0.57014	-0.37222	1.92636
CAFETAN	-0.16019	-0.21453	-0.33177	0.15248	-0.44451
PAAMAR	1.13969	-0.14438	-0.25484	0.08697	-0.39823
UVERO	-0.60374	0.30815	0.17169	3.01672	1.13411

Squared Cosines for the Column Points

	Dim1	Dim2	Dim3	Dim4	Dim5
BAITOA	0.465889	0.015406	0.360868	0.007256	0.018211
GUATAP	0.016497	0.400115	0.150335	0.140013	0.072903
QUINA	0.458279	0.004985	0.000613	0.036296	0.000303
BRUCON	0.018269	0.005916	0.004968	0.000013	0.120335
CANDEL	0.825918	0.012792	0.064283	0.001755	0.000027
CINAZO	0.006910	0.012837	0.002188	0.022559	0.154951
ALMACIG	0.005678	0.696494	0.262778	0.004157	0.002975
GUAYAC	0.000020	0.002858	0.004839	0.000482	0.012045
CAMBRON	0.093362	0.240164	0.102647	0.010599	0.012757
AROMA	0.040020	0.184003	0.210496	0.094037	0.015051
MOSTAZO	0.018402	0.000653	0.007501	0.039569	0.018573
SANGRE	0.072604	0.001156	0.002062	0.002600	0.010756
FRIJOL	0.036181	0.016557	0.051102	0.021781	0.583374
CAFETAN	0.004412	0.007913	0.018923	0.003997	0.033970
PAAMAR	0.223710	0.003590	0.011185	0.001303	0.027313
UVERO	0.030209	0.007870	0.002443	0.754239	0.106599

(II) Results of CA procedure for 67 core sites.

The Correspondence Analysis Procedure

Inertia and Chi-Square Decomposition

Singular Values	Principal Inertias	Chi-Squares	Percents	4 8 12 16 20 ----+----+----+----+----+---
0.75483	0.56976	32661.9	20.78%	**************************
0.68434	0.46832	26846.7	17.08%	*********************
0.61642	0.37998	21782.3	13.86%	*****************
0.56887	0.32361	18551.4	11.80%	***************
0.46979	0.22070	12651.8	8.05%	**********
0.43505	0.18927	10849.8	6.90%	*********
0.34491	0.11896	6819.62	4.34%	*****
0.30906	0.09552	5475.75	3.48%	****
0.29361	0.08621	4941.86	3.14%	****
0.27560	0.07596	4354.31	2.77%	***
0.25540	0.06523	3739.31	2.38%	***
0.23938	0.05730	3284.78	2.09%	***
0.19638	0.03857	2210.82	1.41%	**
0.17325	0.03002	1720.73	1.09%	*
0.15150	0.02295	1315.82	0.84%	*
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	2.74235	157207	(Degrees of Freedom = 990)	

Row Coordinates

CLUSTOT	ID	Dim1	Dim2	Dim3	Dim4	Dim5
1	118	-0.00955	-0.58550	0.42091	-0.20944	-0.09184
1	126	-0.12839	-0.60424	0.38635	0.13021	-0.07725
1	213	0.16309	-0.66852	0.24699	-0.05803	0.08211
1	216	0.43354	-1.09950	0.96011	-0.09051	0.23366
1	218	-0.17026	-0.48114	0.48194	-0.28288	-0.11205
1	227	0.08573	-0.23325	0.63850	-0.38428	-0.18915
1	230	0.28906	-0.76371	1.16490	-0.10770	0.43648
1	302	-0.07570	-0.94572	1.01496	-0.14754	0.17292
1	321	-0.31354	-1.13066	0.90124	-0.21509	0.05764
1	421	-0.01300	-1.16448	1.35905	-0.23497	-0.02342
1	429	0.10857	-0.84191	0.94990	-0.20575	0.09043
3	120	1.03161	0.07481	-0.47345	0.18625	-0.06162
3	201	1.17770	-0.10902	-0.47617	0.35842	0.33260
3	202	1.35532	0.37947	-0.21997	-0.06203	-0.10646
3	203	0.94292	0.41156	-0.35029	-0.17048	-0.15501
3	205	0.85023	0.27457	-0.27423	-0.05190	-0.14319
3	207	1.16812	-0.10912	-0.51948	0.36146	0.23536
3	208	1.23710	0.29386	-0.24300	-0.05943	-0.05377
3	209	1.57742	-0.12871	-0.60263	0.43299	0.38292
3	210	1.00571	-0.08215	-0.37822	0.28254	0.18369
3	211	1.45571	-0.02343	-0.37423	0.30527	0.21120
3	212	1.42479	-0.00767	-0.35687	0.22809	0.21161
3	217	1.66752	-0.02366	-0.65884	0.39918	0.28311
3	223	1.41579	-0.11180	-0.56404	0.37133	0.34158
3	224	1.26807	-0.09248	-0.36416	0.34404	0.11358
3	225	1.37173	0.31760	-0.40062	0.00619	0.00663
3	226	0.87140	-0.38175	-0.15371	0.30147	0.22479
3	229	1.19439	0.07564	-0.36093	0.18082	0.07695
3	406	1.65100	0.01883	-0.70025	0.38213	0.27078
4	109	-0.86641	-0.04843	-0.74485	-0.00997	0.01969
4	112	-0.85398	0.21004	-0.52549	0.06410	0.09605
4	304	-0.88700	-0.02956	-0.60732	0.43816	-0.29593
4	325	-0.90598	-0.09296	-0.78730	-0.00441	-0.06621
4	327	-0.84058	-0.12109	-0.77015	0.02216	-0.11703
4	329	-0.82294	-0.09509	-0.70409	0.00985	-0.13017
4	401	-0.94030	-0.06516	-0.80946	-0.00703	-0.06948
4	402	-0.85360	-0.02231	-0.70965	-0.01823	-0.03100
4	404	-0.92478	-0.02450	-0.81978	-0.02658	-0.02290
4	407	-0.97168	-0.14608	-0.89072	-0.02536	-0.20312
4	418	-0.95332	0.34189	-0.49857	0.07460	0.52855
5	110	-0.02966	0.95623	0.11855	-0.72534	-0.80171
5	119	0.02708	0.87489	0.22350	-0.54861	-0.37644
5	308	-0.06735	1.58897	0.65491	-0.75355	0.02279
5	309	0.33165	1.63924	0.70319	-1.44791	-1.08508
5	320	-0.00730	1.10162	0.50271	-1.11882	-0.74662

CLUSTOT	ID	Dim1	Dim2	Dim3	Dim4	Dim5
5	410	0.08696	0.62994	-0.03013	-0.55387	-0.47789
5	427	0.38755	1.35712	0.57491	-0.99234	-0.80138
5	430	-0.20484	0.79142	0.26653	-0.53675	-0.19822
6	124	-0.62390	2.05629	0.91200	-0.18856	2.11940
6	127	-0.70393	1.32018	0.68619	0.26116	1.99420
6	307	-0.47456	1.85668	0.91084	-0.12104	1.48963
6	423	-0.37275	1.35931	1.48458	3.42398	-1.48834
6	426	-0.70279	1.78636	1.52875	2.70999	0.50831
7	102	-0.26907	-0.12583	-0.14763	-0.19406	-0.28495
7	220	-0.25456	-0.37681	-0.20946	0.04039	0.09563
7	228	-0.11480	-0.09703	0.02961	0.11007	0.36982
7	301	-0.32862	-0.52667	0.05961	-0.03358	0.01836
7	306	-0.56463	-0.18822	-0.36866	-0.11381	-0.11924
7	314	-0.48433	0.07088	-0.31821	-0.09358	-0.06587
7	315	-0.71910	-0.08136	-0.15162	0.38603	-0.16356
7	323	-0.64916	-0.17176	-0.41865	0.01979	-0.05873
7	326	-0.28572	-0.25635	-0.00277	-0.12018	-0.08366
7	328	-0.59460	0.10245	-0.11942	0.09870	0.51968
7	409	-0.06306	-0.36059	-0.16606	0.10829	0.05580
7	417	-0.33798	-0.33754	0.17233	0.43278	-0.19295
7	419	-0.21018	-0.32694	-0.26559	0.04089	0.04884
7	422	-0.33821	-0.10682	-0.05926	-0.11680	0.00249

Squared Cosines for the Row Points

CLUSTOT	ID	Dim1	Dim2	Dim3	Dim4	Dim5
1	118	0.000101	0.380278	0.196535	0.048661	0.009357
1	126	0.022970	0.508759	0.207994	0.023626	0.008316
1	213	0.026630	0.447471	0.061078	0.003372	0.006750
1	216	0.069827	0.449105	0.342453	0.003044	0.020283
1	218	0.035110	0.280361	0.281294	0.096916	0.015206
1	227	0.004850	0.035900	0.269003	0.097438	0.023608
1	230	0.032698	0.228250	0.531045	0.004539	0.074556
1	302	0.001897	0.296003	0.340933	0.007204	0.009896
1	321	0.036968	0.480718	0.305428	0.017397	0.001249
1	421	0.000048	0.383458	0.522310	0.015612	0.000155
1	429	0.004942	0.297191	0.378321	0.017749	0.003429
3	120	0.273966	0.001441	0.057706	0.008930	0.000978
3	201	0.451270	0.003867	0.073770	0.041798	0.035993
3	202	0.774668	0.060727	0.020406	0.001623	0.004779
3	203	0.457479	0.087154	0.063134	0.014955	0.012364
3	205	0.684119	0.071346	0.071168	0.002549	0.019403
3	207	0.475818	0.004152	0.094104	0.045560	0.019317
3	208	0.648225	0.036576	0.025011	0.001496	0.001225
3	209	0.696876	0.004640	0.101708	0.052508	0.041065
3	210	0.432985	0.002889	0.061236	0.034172	0.014445
3	211	0.684204	0.000177	0.045218	0.030088	0.014402
3	212	0.706170	0.000020	0.044302	0.018097	0.015577
3	217	0.668505	0.000135	0.104359	0.038310	0.019270
3	223	0.675159	0.004210	0.107157	0.046443	0.039300
3	224	0.376737	0.002004	0.031070	0.027730	0.003023
3	225	0.657612	0.035253	0.056092	0.000013	0.000015
3	226	0.244590	0.046941	0.007610	0.029274	0.016276
3	229	0.691458	0.002773	0.063143	0.015848	0.002870
3	406	0.558763	0.000073	0.100518	0.029933	0.015030
4	109	0.387075	0.001209	0.286079	0.000051	0.000200
4	112	0.471763	0.028539	0.178629	0.002658	0.005967
4	304	0.472865	0.000525	0.221685	0.115388	0.052634
4	325	0.427085	0.004497	0.322523	0.000010	0.002281
4	327	0.367178	0.007620	0.308232	0.000255	0.007118
4	329	0.349605	0.004668	0.255915	0.000050	0.008747
4	401	0.468484	0.002250	0.347178	0.000026	0.002558
4	402	0.443259	0.000303	0.306365	0.000202	0.000585
4	404	0.413785	0.000290	0.325159	0.000342	0.000254
4	407	0.419442	0.009480	0.352459	0.000286	0.018329
4	418	0.487711	0.062728	0.133393	0.002987	0.149921
5	110	0.000369	0.383380	0.005893	0.220595	0.269490
5	119	0.000350	0.365218	0.023834	0.143608	0.067614
5	308	0.001068	0.594680	0.101021	0.133743	0.000122
5	309	0.015913	0.388750	0.071536	0.303297	0.170336
5	320	0.000011	0.251985	0.052475	0.259916	0.115748
5	410	0.005832	0.306040	0.000700	0.236593	0.176136
5	427	0.031967	0.391992	0.070345	0.209586	0.136682
5	430	0.026514	0.395781	0.044889	0.182044	0.024829
6	124	0.036225	0.393494	0.077403	0.003309	0.418018

Squared Cosines for the Row Points

CLUSTOT	ID	Dim1	Dim2	Dim3	Dim4	Dim5
6	127	0.062724	0.220619	0.059603	0.008634	0.503404
6	307	0.032279	0.494092	0.118911	0.002100	0.318047
6	423	0.007626	0.101412	0.120965	0.643450	0.121579
6	426	0.032313	0.208768	0.152897	0.480466	0.016904
7	102	0.025364	0.005547	0.007636	0.013193	0.028447
7	220	0.045566	0.099840	0.030851	0.001147	0.006431
7	228	0.002437	0.001742	0.000162	0.002241	0.025297
7	301	0.044367	0.113963	0.001460	0.000463	0.000139
7	306	0.165070	0.018344	0.070373	0.006707	0.007362
7	314	0.295592	0.006330	0.127599	0.011035	0.005467
7	315	0.528880	0.006770	0.023513	0.152409	0.027361
7	323	0.097554	0.006829	0.040572	0.000091	0.000798
7	326	0.057941	0.046643	0.000005	0.010251	0.004968
7	328	0.308918	0.009171	0.012461	0.008512	0.235975
7	409	0.004459	0.145793	0.030922	0.013149	0.003492
7	417	0.122137	0.121818	0.031752	0.200260	0.039807
7	419	0.030055	0.072720	0.047988	0.001138	0.001623
7	422	0.036858	0.003677	0.001132	0.004396	0.000002

Column Coordinates

	Dim1	Dim2	Dim3	Dim4	Dim5
BAITOA	-0.75871	-0.10614	-0.58704	0.00834	-0.08103
GUATAP	0.38224	1.22211	0.46429	-0.89780	-0.67425
QUINA	0.93595	-0.21690	-0.05447	0.28870	0.13064
BRUCON	-0.32752	0.06082	-0.03086	0.00212	0.00280
CANDEL	1.44834	-0.00962	-0.50599	0.26426	0.20542
CINAZO	-0.27052	-0.17187	0.02939	-0.02048	0.09137
ALMACIG	-0.05023	-1.12994	1.10007	-0.19873	0.07895
GUAYAC	0.00458	0.00739	-0.15668	-0.01151	-0.11976
CAMBRON	-0.74461	1.31874	0.26207	-0.37944	1.21710
AROMA	-0.66398	1.76458	0.94701	0.39401	1.79346
MOSTAZO	-0.21224	0.05114	0.46847	-0.70201	-0.52171
SANGRE	0.84921	0.18514	-0.12109	0.05726	-0.27840
FRIJOL	-0.09950	-0.23029	-0.21268	0.17046	0.04873
CAFETAN	-0.44235	-0.25635	-0.24422	0.05378	-0.08577
PAAMAR	0.73573	-0.36386	-0.27409	0.19095	0.27344
UVERO	-0.60472	1.18832	1.47103	3.63996	-1.50560

Squared Cosines for the Column Points

	Dim1	Dim2	Dim3	Dim4	Dim5
BAITOA	0.571487	0.011184	0.342128	0.000069	0.006518
GUATAP	0.045704	0.467208	0.067433	0.252144	0.142210
QUINA	0.436963	0.023467	0.001480	0.041576	0.008513
BRUCON	0.054082	0.001865	0.000480	0.000002	0.000004
CANDEL	0.788742	0.000035	0.096266	0.026257	0.015867
CINAZO	0.036123	0.014582	0.000426	0.000207	0.004121
ALMACIG	0.000956	0.483964	0.458716	0.014970	0.002363
GUAYAC	0.000013	0.000035	0.015607	0.000084	0.009119
CAMBRON	0.091538	0.287115	0.011339	0.023770	0.244561
AROMA	0.054746	0.386658	0.111366	0.019278	0.399417
MOSTAZO	0.010016	0.000581	0.048795	0.109571	0.060515
SANGRE	0.148330	0.007050	0.003016	0.000674	0.015943
FRIJOL	0.002627	0.014073	0.012003	0.007710	0.000630
CAFETAN	0.032760	0.011002	0.009985	0.000484	0.001232
PAAMAR	0.142381	0.034825	0.019761	0.009591	0.019668
UVERO	0.018696	0.072196	0.110634	0.677392	0.115896

APPENDIX K

Results of CDA procedures using the full data set

APPENDIX K

(I) The results of the CDA procdure using 16 spp and 118 sites representing 13 groups.

Canonical Discriminant Analysis

118 Observations	117 DF Total
16 Variables	105 DF Within Classes
13 Classes	12 DF Between Classes

Class Level Information

CLUSTOT	Frequency	Weight	Proportion
1	12	12.0000	0.101695
3	18	18.0000	0.152542
4	11	11.0000	0.093220
5	8	8.0000	0.067797
6	5	5.0000	0.042373
7	14	14.0000	0.118644
B	5	5.0000	0.042373
BG	9	9.0000	0.076271
C	3	3.0000	0.025424
D	14	14.0000	0.118644
E	8	8.0000	0.067797
F	3	3.0000	0.025424
G	8	8.0000	0.067797

Multivariate Statistics and F Approximations

S=12 M=1.5 N=44

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.00001118	10.5143	192	895.1545	0.0001
Pillai's Trace	5.74286224	5.7937	192	1212	0.0001
Hotelling-Lawley Trace	34.93521466	16.0423	192	1058	0.0001
Roy's Greatest Root	14.37501015	90.7423	16	101	0.0001

NOTE: F Statistic for Roy's Greatest Root is an upper bound.

	Canonical Correlation	Adjusted Canonical Correlation	Approx Standard Error	Squared Canonical Correlation
1	0.966933	0.958459	0.006013	0.934959
2	0.935468	0.917721	0.011547	0.875101
3	0.918217	0.904816	0.014503	0.843122
4	0.854955	0.816981	0.024874	0.730948
5	0.828280	0.805344	0.029025	0.686048
6	0.783755	0.763512	0.035661	0.614272
7	0.698087	0.668289	0.047397	0.487325
8	0.555300	0.504569	0.063942	0.308358
9	0.319294	.	0.083025	0.101948
10	0.313328	.	0.083374	0.098175
11	0.239786	0.230256	0.087134	0.057497
12	0.071483	-.140496	0.091978	0.005110

Eigenvalues of INV(E)*H
= CanRsq/(1-CanRsq)

	Eigenvalue	Difference	Proportion	Cumulative
1	14.3750	7.3685	0.4115	0.4115
2	7.0065	1.6321	0.2006	0.6120
3	5.3744	2.6576	0.1538	0.7659
4	2.7168	0.5316	0.0778	0.8436
5	2.1852	0.5927	0.0625	0.9062
6	1.5925	0.6419	0.0456	0.9518
7	0.9506	0.5047	0.0272	0.9790
8	0.4458	0.3323	0.0128	0.9917
9	0.1135	0.0047	0.0032	0.9950
10	0.1089	0.0479	0.0031	0.9981
11	0.0610	0.0559	0.0017	0.9999
12	0.0051	.	0.0001	1.0000

Test of H0: The canonical correlations in the current row and all that follow are zero

	Likelihood Ratio	Approx F	Num DF	Den DF	Pr > F
1	0.00001118	10.5143	192	895.1545	0.0001
2	0.00017191	8.2849	165	834.2959	0.0001
3	0.00137642	6.7941	140	772.1261	0.0001
4	0.00877378	5.3568	117	708.5608	0.0001
5	0.03260998	4.4388	96	643.4827	0.0001
6	0.10386917	3.4397	77	576.723	0.0001
7	0.26928065	2.4094	60	508.0294	0.0001
8	0.52524640	1.5035	45	437.0074	0.0226
9	0.75941907	0.8789	32	363.0013	0.6598
10	0.84562968	0.8156	21	284.8247	0.7001
11	0.93768675	0.5449	12	200	0.8833
12	0.99489018	0.1037	5	101	0.9912

OBS	ID	CLUSTOT	CAN1	CAN2	CAN3	CAN4
1	101	BG	-0.81675	1.59491	1.12975	0.82675
2	102	7	2.23279	-0.39849	-1.45107	1.07361
3	103	BG	-0.29055	0.02542	2.93572	-1.15631
4	104	D	5.16966	1.31896	1.46726	0.98382
5	105	B	2.91590	0.65693	1.19883	0.23706
6	106	B	1.82592	0.78350	1.40704	1.21870
7	107	C	-3.85375	-0.44050	1.16974	0.69985
8	108	BG	2.01636	0.60849	-0.60862	-1.33142
9	109	4	5.45245	2.86356	1.00867	-0.02502
10	110	5	0.42812	-2.82172	2.22634	2.36623
11	111	D	4.55815	0.99600	-0.89856	-0.09456
12	112	4	5.94578	2.34513	1.59064	-1.00132
13	113	D	4.54877	0.58781	-2.47918	-0.32854
14	114	D	3.39850	0.12827	2.31842	-3.59205
15	115	F	-2.16297	-2.03379	0.03519	1.97341
16	116	BG	2.01409	-1.10302	1.47642	-1.20781
17	117	D	3.98185	2.50642	0.97690	0.28687
18	118	1	0.47929	-0.39825	-3.73584	-0.24577
19	119	5	-0.90904	-3.18427	1.99944	1.70196
20	120	3	-3.93646	4.26763	0.17003	0.40928
21	121	E	-1.91788	-3.51949	2.34992	-0.31494
22	122	D	4.06589	0.48365	1.55282	0.17490
23	123	E	-1.44054	-2.83532	1.46490	2.39514
24	124	6	-1.95166	-4.89756	3.42061	-4.96191
25	125	E	-3.50649	-5.23798	2.86136	0.40453
26	126	1	0.94854	-0.57398	-3.95537	-0.71849
27	127	6	-0.46768	-3.92508	1.71015	-6.22655
28	128	E	-2.38067	-3.64502	1.86252	1.72668
29	129	G	-0.42362	-0.45013	-0.48754	1.63681
30	130	E	-1.28698	-2.42444	1.51745	3.24067
31	201	3	-5.34767	2.18582	-0.31892	-0.32802
32	202	3	-6.99495	2.88813	0.81468	0.28302
33	203	3	-4.74323	2.47991	0.30285	-0.05088
34	204	BG	1.03515	0.41859	0.75014	0.46257
35	205	3	-4.32989	2.25627	0.69104	0.50967
36	206	E	-3.31652	-0.70824	1.66774	1.71722
37	207	3	-5.91083	5.69878	0.32887	-0.80707
38	208	3	-6.17048	2.39564	0.94858	0.29423
39	209	3	-7.20182	4.65115	-0.40603	-1.03191
40	210	3	-6.01713	4.55509	0.48141	-0.83349
41	211	3	-7.08679	4.61857	0.32127	-0.35461
42	212	3	-6.52718	3.54079	-0.04623	-0.41680
43	213	1	-0.35609	0.18966	-4.32917	-0.68635
44	215	C	-4.99525	0.27099	1.24073	1.00529
45	216	1	-1.82663	-2.44227	-7.04760	-0.56316
46	217	3	-7.74491	5.91671	-0.47609	-1.19410
47	218	1	1.77709	-1.92032	-4.64912	0.36302
48	219	C	-4.17700	0.32974	1.35047	0.01570
49	220	7	2.16602	-0.49815	-2.07811	0.36783
50	221	E	-4.33296	-1.30522	1.65637	2.04266
51	222	F	-2.58841	-1.35525	-0.15868	0.31364
52	223	3	-6.75512	5.37239	-1.07213	-1.34698
53	224	3	-4.38696	2.82134	-0.08072	0.56552
54	225	3	-6.85735	2.71600	0.29864	-0.40797
55	226	3	-5.08009	2.88464	-0.73034	-0.41751
56	227	1	-0.24919	-2.64802	-4.38735	0.82888
57	228	7	0.53657	-0.51218	-3.24530	-0.46208

OBS	ID	CLUSTOT	CAN1	CAN2	CAN3	CAN4
58	229	3	-5.66791	2.84652	-0.36814	0.16707
59	230	1	-2.01269	-2.88251	-6.62687	-1.76110
60	301	7	1.73967	-0.71140	-2.63071	0.23772
61	302	1	-0.93205	-3.48181	-6.38225	-0.36508
62	303	D	2.28692	1.01324	-0.17043	-0.26037
63	304	4	6.34062	2.79701	1.08207	-0.81970
64	305	D	3.10318	2.49076	1.12445	0.29991
65	306	7	4.01734	0.85245	-1.08531	0.02149
66	307	6	-1.77056	-5.12195	2.84037	-4.06461
67	308	5	-0.78237	-5.26765	3.84720	-0.65672
68	309	5	-3.03096	-6.11398	3.65388	4.69777
69	310	G	-0.38847	-2.36535	-0.76513	1.30904
70	311	E	-3.40189	-4.22355	1.68125	3.47213
71	312	D	4.20084	1.53321	0.81108	-0.98944
72	313	B	2.74271	-0.32854	1.35834	0.42259
73	314	7	2.69924	0.88543	0.57502	-0.08097
74	315	7	3.04526	-0.27360	-1.16515	-0.21614
75	316	G	0.73391	-0.62672	0.97923	2.41918
76	317	G	1.39474	-1.03959	-0.22188	1.50222
77	318	BG	1.17573	0.10200	1.02133	-3.07157
78	319	G	-0.19601	-1.31069	0.05297	0.77289
79	320	5	-1.40103	-3.71092	2.39677	3.17052
80	321	1	1.86479	-2.78153	-7.61311	-0.75017
81	322	BG	0.71917	-0.17703	-0.52010	-1.15523
82	323	7	1.91236	-0.49834	-0.49387	0.72650
83	324	BG	0.24400	0.24982	2.11174	-1.33980
84	325	4	6.08971	3.07829	1.14285	0.35372
85	326	7	1.57429	-0.53092	-2.28472	0.43757
86	327	4	5.93506	2.71102	1.23245	0.15759
87	328	7	3.18232	-0.38025	-0.78601	-1.67013
88	329	4	5.05479	2.20185	1.09839	0.33375
89	330	F	-1.18931	-2.21626	1.11839	1.41315
90	401	4	6.32335	3.03764	1.20211	0.24026
91	402	4	5.18303	2.47026	1.11722	0.49740
92	403	D	4.35334	2.47161	0.59806	0.01252
93	404	4	6.07233	2.94589	1.12725	0.54197
94	405	D	3.05691	1.09378	1.02715	0.16854
95	406	3	-7.84778	5.38582	-0.57879	-1.18736
96	407	4	7.62698	3.73492	1.27626	0.01917
97	408	B	2.42264	-0.76630	1.63042	0.89020
98	409	7	0.82093	0.95329	-2.83010	-0.41042
99	410	5	-0.76396	-1.19984	1.52591	2.08950
100	411	BG	1.96953	0.10888	0.51545	0.07434
101	413	D	3.33627	1.29703	0.47256	1.51856
102	414	G	-1.28153	-1.25596	-1.61550	1.76412
103	415	B	2.72326	-0.34012	0.84637	0.89694
104	416	D	3.58424	1.45365	1.08748	-0.30033
105	417	7	2.15953	-0.26427	-3.28987	-0.93318
106	418	4	5.67011	1.92978	1.85096	-1.93324
107	419	7	2.68967	0.28859	-1.43281	0.42058
108	420	D	4.29086	1.70153	0.95966	0.00922
109	421	1	0.03292	-3.98101	-8.22272	-0.41226
110	422	7	1.18361	-0.51386	-2.18900	0.45753
111	423	6	-2.45065	-4.69865	2.96257	-5.64069
112	424	1	-1.82096	-2.11231	-1.93615	-0.58850
113	425	G	0.23272	-0.53837	-1.63990	0.67953
114	426	6	-1.74205	-5.74264	3.76639	-9.37585
115	427	5	-2.21302	-4.82208	3.36879	2.96617
116	428	G	-0.87175	-0.49511	-0.24397	2.50165
117	429	1	-1.35722	-2.13397	-5.98664	-0.16643
118	430	5	0.17793	-2.80537	1.55579	0.46641

(II) The results of the CDA procedure using 16 spp and 67 sites representing seven groups

Canonical Discriminant Analysis

67 Observations	66 DF Total
16 Variables	61 DF Within Classes
6 Classes	5 DF Between Classes

Class Level Information

CLUSTOT	Frequency	Weight	Proportion
1	11	11.0000	0.164179
3	18	18.0000	0.268657
4	11	11.0000	0.164179
5	8	8.0000	0.119403
6	5	5.0000	0.074627
7	14	14.0000	0.208955

Multivariate Statistics and F Approximations

S=5 M=5 N=22

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.00001042	27.7614	80	225.7661	0.0001
Pillai's Trace	4.33793292	20.4753	80	250	0.0001
Hotelling-Lawley Trace	59.05591596	32.7760	80	222	0.0001
Roy's Greatest Root	25.11599918	78.4875	16	50	0.0001

NOTE: F Statistic for Roy's Greatest Root is an upper bound.

	Canonical Correlation	Adjusted Canonical Correlation	Approx Standard Error	Squared Canonical Correlation
1	0.980668	.	0.004713	0.961709
2	0.973077	.	0.006539	0.946878
3	0.947237	0.935223	0.012647	0.897258
4	0.914208	0.901003	0.020214	0.835777
5	0.834452	0.813896	0.037382	0.696311

Eigenvalues of INV(E)*H
= CanRsq/(1-CanRsq)

	Eigenvalue	Difference	Proportion	Cumulative
1	25.1160	7.2913	0.4253	0.4253
2	17.8247	9.0916	0.3018	0.7271
3	8.7331	3.6438	0.1479	0.8750
4	5.0893	2.7964	0.0862	0.9612
5	2.2928	.	0.0388	1.0000

Test of H0: The canonical correlations in the current row and all that follow are zero

	Likelihood Ratio	Approx F	Num DF	Den DF	Pr > F
1	0.00001042	27.7614	80	225.7661	0.0001
2	0.00027220	22.2538	60	185.6923	0.0001
3	0.00512404	16.7590	42	143.1564	0.0001
4	0.04987286	13.1088	26	98	0.0001
5	0.30368924	9.5535	12	50	0.0001

OBS	ID	CLUSTOT	CAN1	CAN2	CAN3	CAN4
1	102	7	-1.17203	2.2250	0.50094	1.26661
2	109	4	-3.34347	2.1317	4.18218	-2.08881
3	110	5	0.52398	0.6764	1.09153	5.54160
4	112	4	-5.00517	1.7278	3.85399	-0.54584
5	118	1	0.51770	4.3808	-2.75875	-0.29125
6	119	5	-0.01069	-1.4377	0.03869	4.89540
7	120	3	5.94850	-1.8770	1.27568	-1.12500
8	124	6	-9.57178	-13.0035	-2.38212	-2.24274
9	126	1	-1.14504	3.7319	-2.69474	-1.22719
10	127	6	-7.44414	-8.8277	-2.24474	-1.53257
11	201	3	5.27532	-2.3822	0.76452	-0.80110
12	202	3	7.95953	-2.0962	0.65712	0.77773
13	203	3	5.31099	-0.8846	0.80208	0.61069
14	205	3	5.39283	-1.4904	0.91116	0.49486
15	207	3	7.55485	-1.5374	2.03919	-1.84228
16	208	3	6.74073	-2.2689	0.61491	0.76269
17	209	3	7.72221	-2.6488	1.04653	-1.62233
18	210	3	7.64190	-2.1416	1.23118	-2.07169
19	211	3	8.34681	-2.4767	1.16338	-1.28829
20	212	3	7.35939	-2.1040	0.69888	-0.90801
21	213	1	0.67655	3.8536	-2.66618	-1.05228
22	216	1	1.29114	4.6455	-6.11676	-1.30355
23	217	3	8.73486	-3.0667	0.98073	-2.53115
24	218	1	-1.74589	5.0614	-3.26238	-0.09179
25	220	7	-1.76446	2.3088	0.38248	-0.38855
26	223	3	7.19318	-2.3800	0.70683	-3.01281
27	224	3	6.69116	-2.1809	0.87361	-1.25612
28	225	3	7.48753	-2.3990	0.43285	0.11163
29	226	3	6.21736	-1.6372	0.02160	-1.35466
30	227	1	-0.35842	3.6105	-3.82662	0.45127
31	228	7	-1.75029	1.0918	-0.70965	-1.61638
32	229	3	6.07258	-1.9404	0.63664	0.09908
33	230	1	0.75848	3.7810	-7.01004	-1.18030
34	301	7	-1.71406	2.3783	-0.86193	-0.42676
35	302	1	-0.90581	4.1189	-6.16879	-0.53322
36	304	4	-4.96415	2.8229	4.30874	-1.00229
37	306	7	-2.71140	2.9088	1.55071	-0.58895
38	307	6	-7.68531	-10.4235	-2.47594	-0.61160
39	308	5	-1.25648	-3.0106	-1.09979	6.29043
40	309	5	1.17582	-1.5934	-1.24518	8.72995
41	314	7	-2.01928	1.2193	1.92852	0.51303
42	315	7	-4.04730	1.1768	1.02527	-1.20908
43	320	5	-0.96882	-1.3280	-0.86882	5.48886
44	321	1	-1.85276	7.2203	-6.35056	-1.48869
45	323	7	-1.91127	0.5070	1.59791	0.55381
46	325	4	-4.57553	2.6428	4.75211	-0.60353
47	326	7	-1.64903	2.5565	-0.61343	0.36731
48	327	4	-4.10606	3.1529	4.53639	-0.32021
49	328	7	-3.81708	0.8887	0.73056	-0.35205
50	329	4	-3.93897	2.5738	4.05193	0.22346
51	401	4	-4.66167	3.1209	4.85118	-0.80443
52	402	4	-4.78664	1.9945	4.24491	-0.42791
53	404	4	-4.98022	2.6744	4.84307	-0.41460
54	406	3	8.33950	-3.0335	0.88207	-1.79477
55	407	4	-4.34059	4.8482	5.41031	-0.11160
56	409	7	-0.49261	2.3617	-0.15995	-1.50765
57	410	5	0.36795	0.0999	0.95136	3.98759
58	417	7	-3.02540	2.7118	-1.14559	-1.87873
59	418	4	-6.04367	0.2871	3.71778	-1.03589
60	419	7	-2.29181	2.1031	0.84476	-0.58091
61	421	1	-0.99624	6.2633	-7.62735	-0.73639
62	422	7	-2.31891	1.3618	-0.10187	-0.49032
63	423	6	-8.42306	-11.2888	-2.47179	-1.81563
64	426	6	-8.56640	-13.1578	-3.39375	-1.40374
65	427	5	1.99144	-1.7698	-1.09452	7.37978
66	429	1	0.16312	3.9224	-5.69300	-1.11789
67	430	5	-1.09345	-0.7558	-0.09004	4.08572

(III) Results of CDA procedure using 16 spp and 62 sites representing five groups.

Canonical Discriminant Analysis

62 Observations	61 DF Total
16 Variables	57 DF Within Classes
5 Classes	4 DF Between Classes

Class Level Information

CLUSTOT	Frequency	Weight	Proportion
1	11	11.0000	0.177419
3	18	18.0000	0.290323
4	11	11.0000	0.177419
5	8	8.0000	0.129032
7	14	14.0000	0.225806

Multivariate Statistics and F Approximations

S=4 M=5.5 N=20

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.00012148	23.4523	64	166.6986	0.0001
Pillai's Trace	3.47803910	18.7408	64	180	0.0001
Hotelling-Lawley Trace	44.61065140	28.2302	64	162	0.0001
Roy's Greatest Root	25.46787882	71.6284	16	45	0.0001

NOTE: F Statistic for Roy's Greatest Root is an upper bound.

	Canonical Correlation	Adjusted Canonical Correlation	Approx Standard Error	Squared Canonical Correlation
1	0.980927	0.974852	0.004837	0.962218
2	0.953905	0.940259	0.011532	0.909935
3	0.926771	0.912590	0.018065	0.858905
4	0.864280	0.844408	0.032396	0.746981

Eigenvalues of INV(E)*H
= CanRsq/(1-CanRsq)

	Eigenvalue	Difference	Proportion	Cumulative
1	25.4679	15.3648	0.5709	0.5709
2	10.1031	4.0156	0.2265	0.7974
3	6.0874	3.1352	0.1365	0.9338
4	2.9523	.	0.0662	1.0000

Test of H0: The canonical correlations in the current row and all that follow are zero

	Likelihood Ratio	Approx F	Num DF	Den DF	Pr > F
1	0.00012148	23.4523	64	166.6986	0.0001
2	0.00321530	16.8625	45	128.5226	0.0001
3	0.03569969	13.4910	28	88	0.0001
4	0.25301937	10.2194	13	45	0.0001

OBS	ID	CLUSTOT	CAN1	CAN2	CAN3	CAN4
1	102	7	1.74456	-0.01409	1.52315	-2.60925
2	109	4	4.94853	3.66201	-2.89968	0.58737
3	110	5	-0.41120	1.50288	4.83269	1.00703
4	112	4	5.89994	3.85338	-1.15891	1.66025
5	118	1	1.66292	-4.17186	-0.71727	1.65455
6	119	5	-1.00367	1.39656	5.18511	0.18513
7	120	3	-5.67635	1.15112	-1.71587	0.71687
8	126	1	2.43948	-3.50271	-0.77623	0.85465
9	201	3	-5.59763	0.92409	-0.76935	-0.93101
10	202	3	-7.61256	0.51675	-0.28272	1.73566
11	203	3	-4.72748	0.44354	-0.23201	0.67548
12	205	3	-5.22746	0.82958	-0.09903	0.60810
13	207	3	-6.65106	1.26637	-3.23801	2.08280

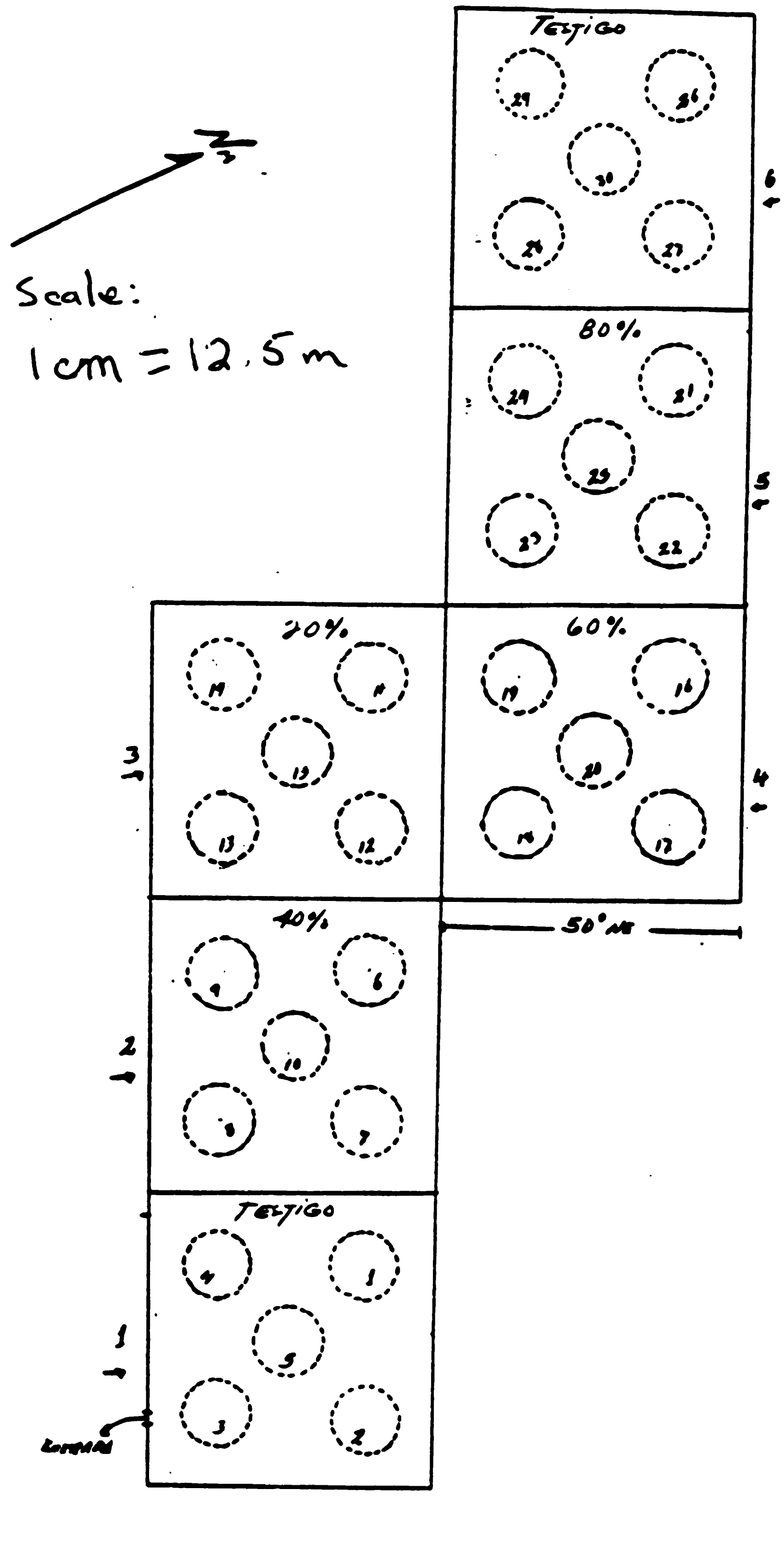
OBS	ID	CLUSTOT	CAN1	CAN2	CAN3	CAN4
14	208	3	-7.02580	0.77438	0.44239	0.08393
15	209	3	-7.98760	0.90274	-1.74006	-0.52280
16	210	3	-7.38625	0.68456	-2.72778	0.91829
17	211	3	-8.09590	0.88922	-2.10254	1.11497
18	212	3	-7.26610	0.51282	-1.33291	0.19321
19	213	1	1.52497	-3.88099	-1.40373	1.37348
20	216	1	1.15485	-7.25967	-0.96375	0.98225
21	217	3	-8.68818	0.74221	-2.96923	0.34150
22	218	1	4.18360	-4.43584	-0.26308	0.45620
23	220	7	2.55337	-0.16005	0.08098	-3.03673
24	223	3	-7.15353	0.36739	-3.01175	-1.14210
25	224	3	-6.67719	0.87341	-1.40492	-0.70835
26	225	3	-7.76818	0.40272	-0.07749	-0.27257
27	226	3	-6.57520	-0.09408	-0.88087	-1.50698
28	227	1	2.08401	-4.55458	0.74951	-1.08598
29	228	7	2.04749	-0.80810	-0.24513	-5.64158
30	229	3	-6.31891	0.72409	0.01359	-0.56971
31	230	1	1.36188	-7.57033	-0.63981	2.58049
32	301	7	2.63897	-1.28033	0.09197	-2.32099
33	302	1	2.85354	-6.80010	-0.04412	1.76614
34	304	4	5.31069	3.62912	-1.11384	-0.22763
35	306	7	3.50527	0.49923	-0.20542	-3.90387
36	308	5	-0.63580	1.44984	7.19903	1.44451
37	309	5	-1.81642	1.18420	8.39549	2.76310
38	314	7	2.07843	1.60713	0.75649	-1.62457
39	315	7	3.65233	1.52128	0.08891	-2.37424
40	320	5	0.19466	1.25560	5.83434	1.32412
41	321	1	5.15902	-8.12431	-1.38336	2.07460
42	323	7	1.95613	1.68794	1.01797	-3.61083
43	325	4	6.27832	4.19578	-1.84979	1.00057
44	326	7	2.00967	-1.08003	1.27256	-2.86758
45	327	4	6.04681	3.29270	-2.04520	1.72685
46	328	7	3.90251	1.05693	0.46538	-1.90382
47	329	4	5.36048	3.14059	-1.11335	1.26828
48	401	4	6.91407	3.92184	-2.65206	2.43245
49	402	4	6.19371	4.05008	-1.56059	1.77266
50	404	4	6.76400	4.54351	-1.75584	2.04624
51	406	3	-8.52637	0.76247	-2.07187	0.09909
52	407	4	7.05341	3.47314	-2.41045	2.28059
53	409	7	1.76824	-0.99407	-1.36268	-2.03717
54	410	5	-0.27464	1.61766	3.51045	1.11366
55	417	7	3.02398	-1.43378	-0.33033	-2.61601
56	418	4	6.64567	4.61229	-1.33543	2.16011
57	419	7	3.05463	0.36460	-0.31221	-2.17060
58	421	1	3.43336	-8.88974	0.15469	0.49452
59	422	7	2.64471	-0.27065	0.37101	-4.07083
60	427	5	-2.88632	0.49062	7.11939	1.93214
61	429	1	1.83833	-6.43236	-0.68967	1.42061
62	430	5	0.10327	0.98129	4.78323	-1.17725

APPENDIX L

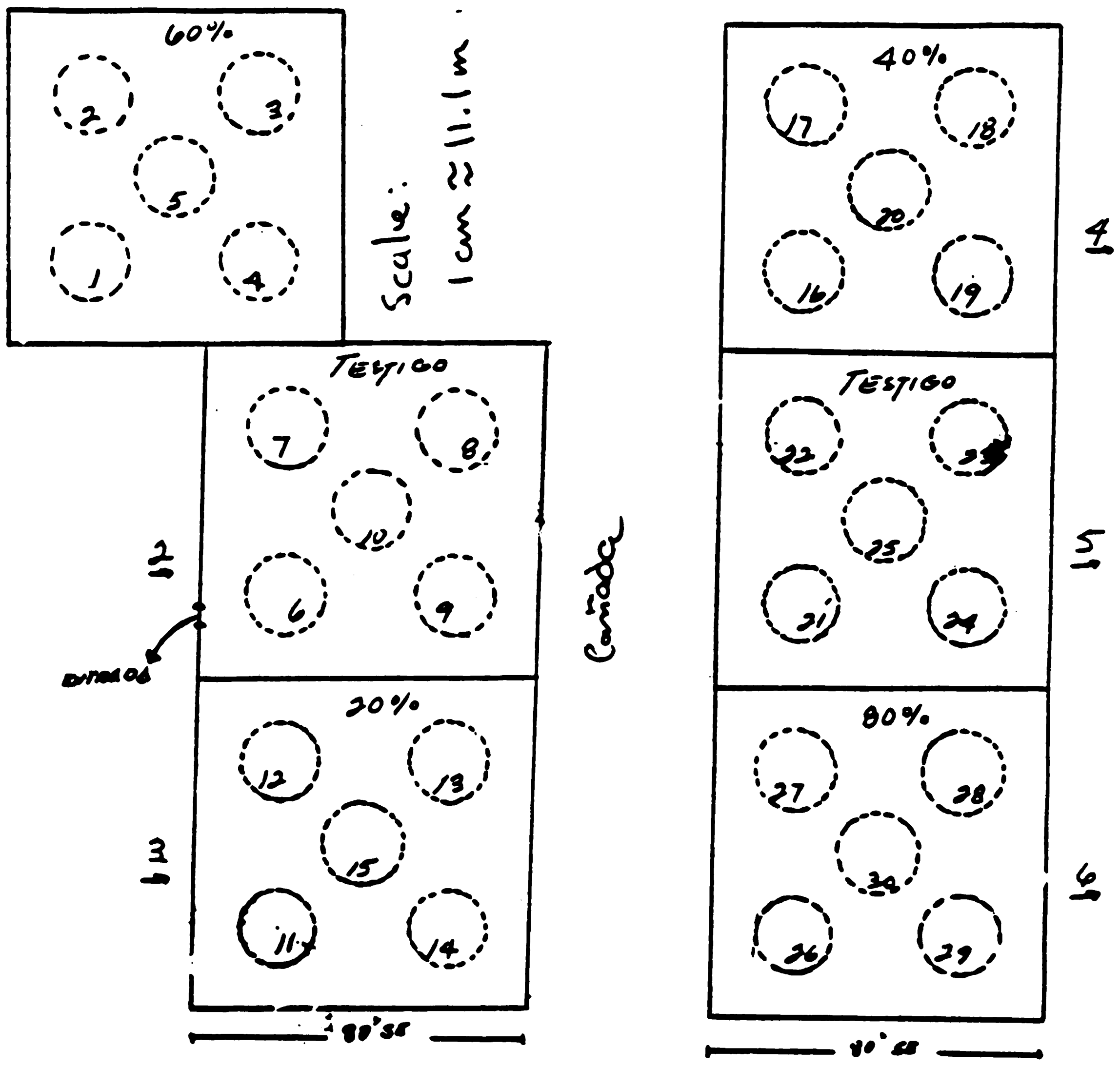
Scaled diagrams for the four experimental blocks of the ISA-Mao silvicultural study

APPENDIX L

BLOCK ONE



BLOCK TWO


60%
1
2
3
4
5
Scale: 1 cm ≈ 11.1 m
Testigo
7
8
10
6
9
2
Cañada
20%
12
13
15
11
14
3
40%
17
18
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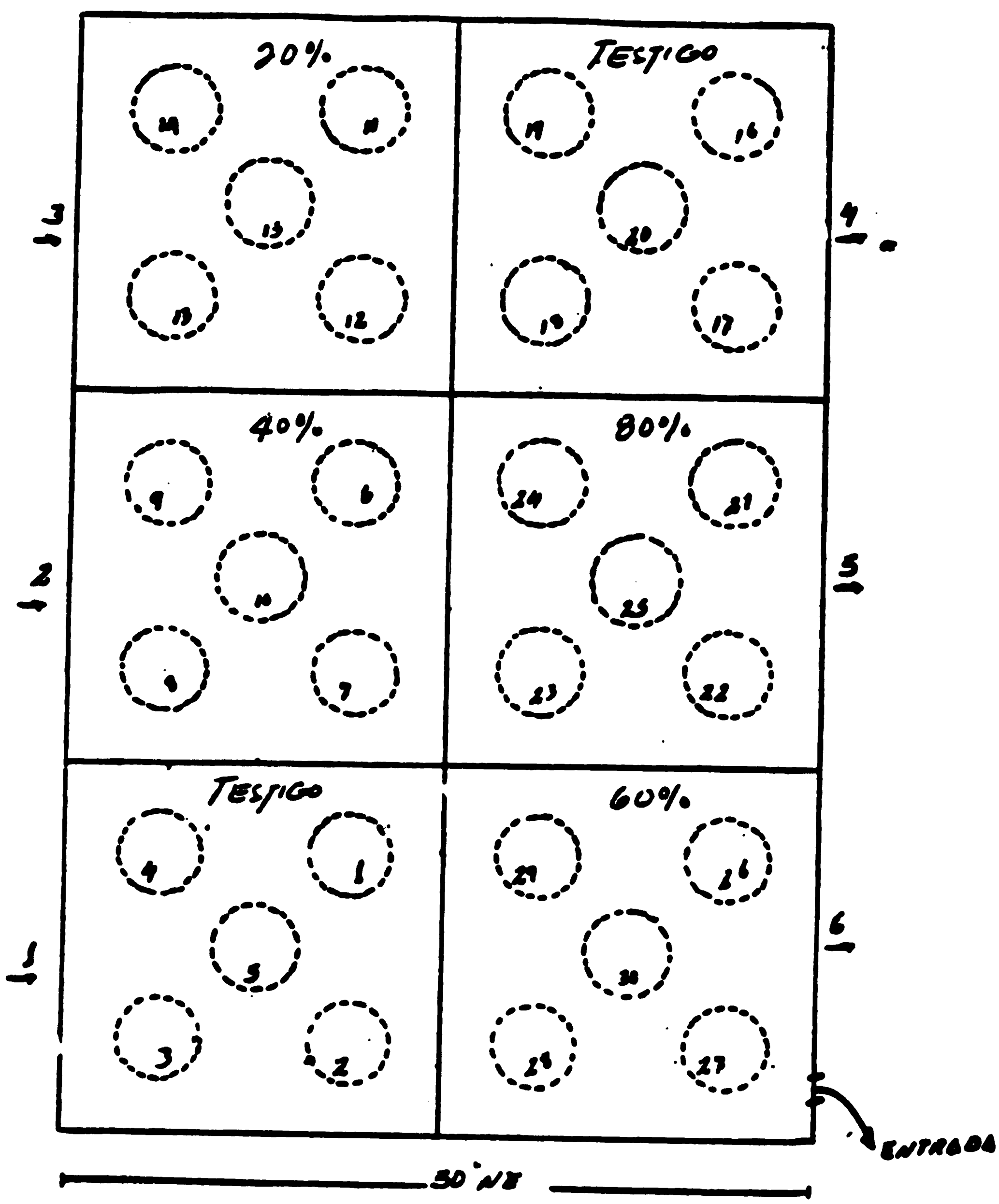
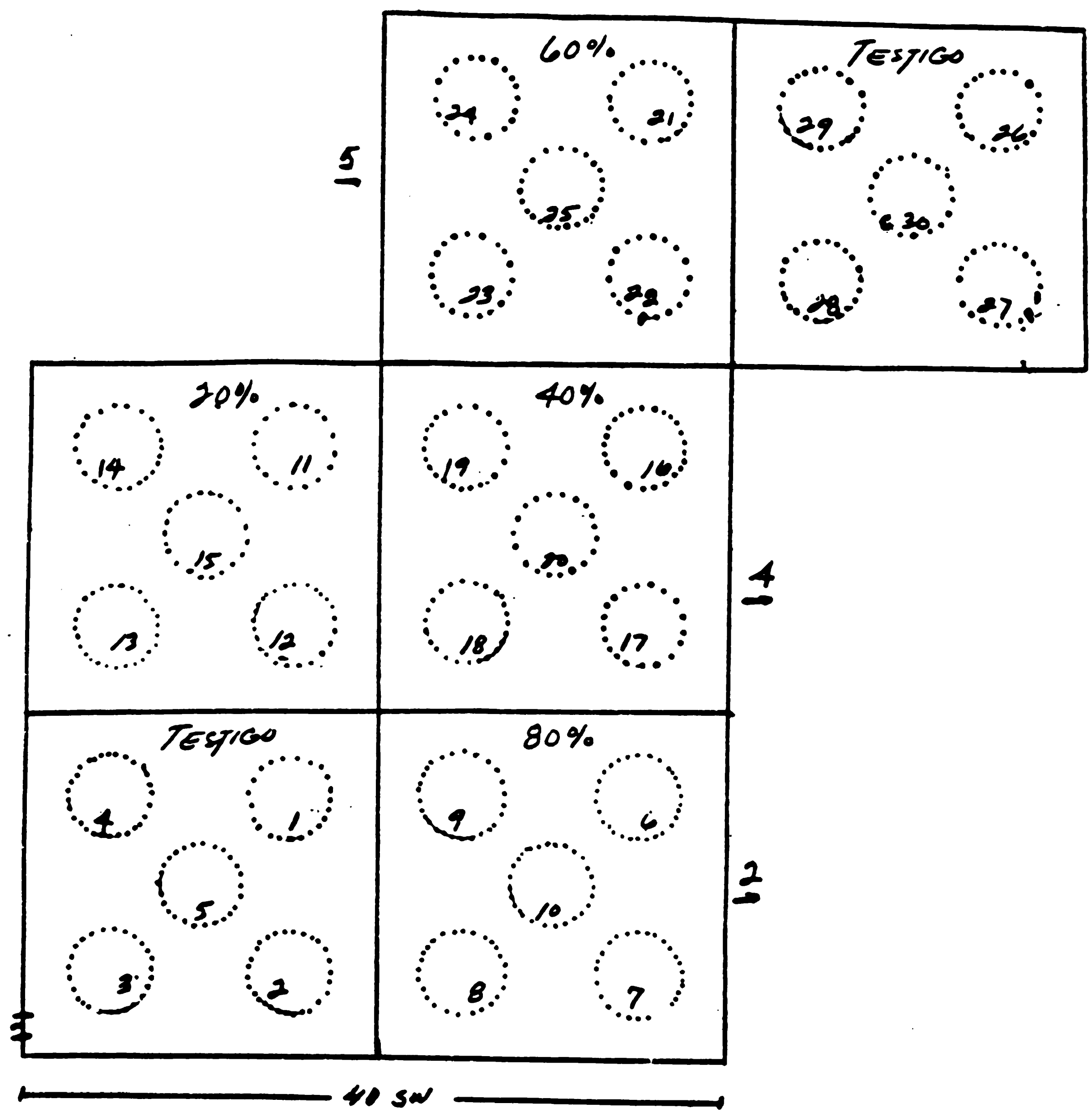
16
19
4
Testigo
22
25
21
24
5
80%
27
28
26
29
6

BLOCK THREE



Scale: 1cm = 10 m

BLOCK FOUR



Scale: 1cm = 10m

APPENDIX M

Representative maps with profile icons indicating cluster group membership and relative contribution of each of the sixteen species used in the cluster analyses and ordinal procedures

APPENDIX M

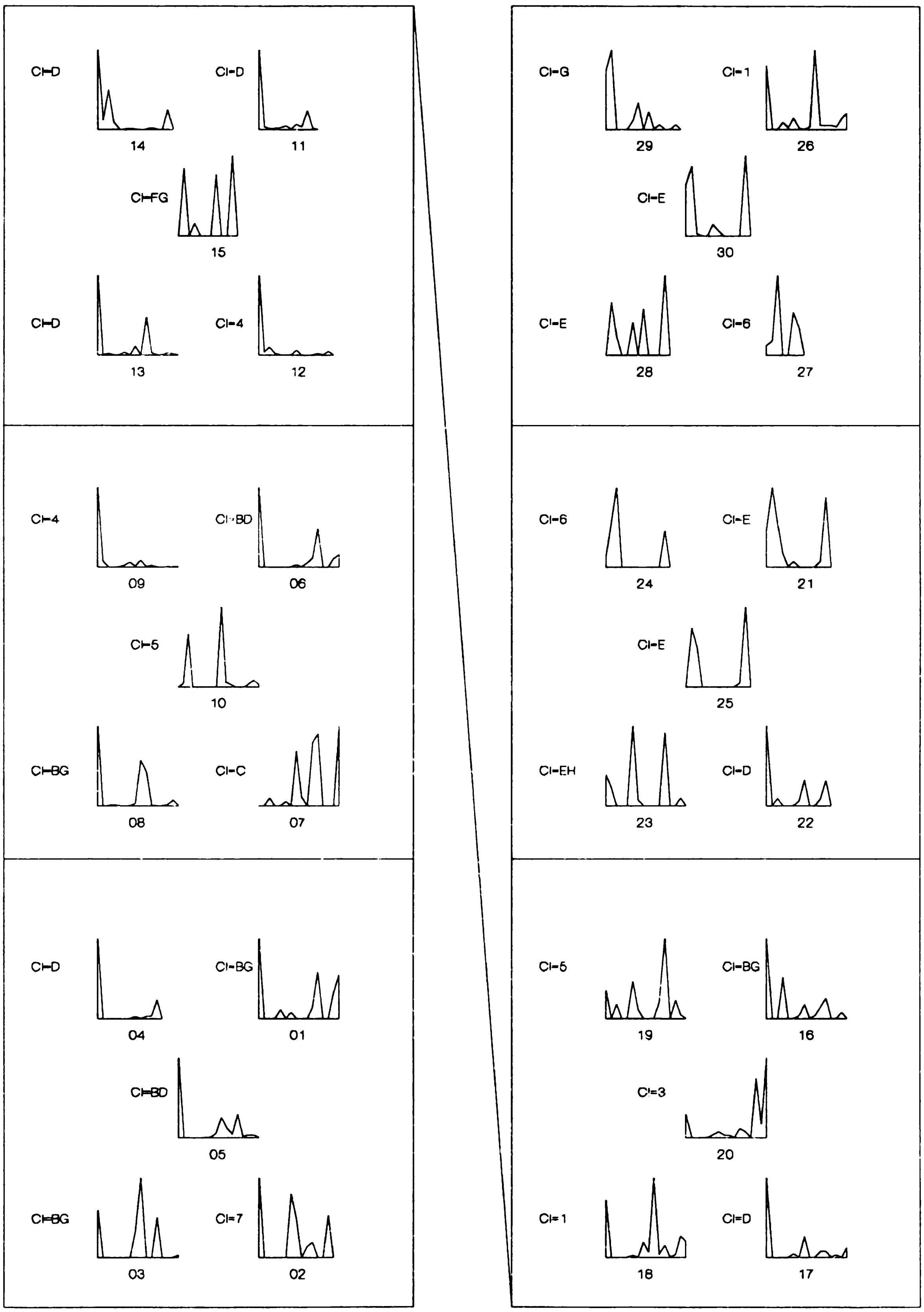
Key to the diagrams, the cluster groups and the profile icons

The number below each icon indicates the site designation (1-30 in each block). Squares represent original 50 X 50 m treatment plots (See Figure 2). Contiguous plots are reprented by contiguous squares. Lines connecting plots represent plots which are contiguous. See scaled diagram in Appendix N.

The peaks in each profile represent the relative basal area contributions of the sixteen species used in these analyses. In order from left to right, the peaks represent *P. brasiliensis*, *Prosopis juliflora*, *A. farnesiana*, *C. leoganensis*, *L. lanceolatus*, *Cassia emarginata*, *Pithecellobium circinale*, *Capparis flexuosa*, *C. cynophallophora*, *B. simaruba*, *G. officinale*, *Caesalpinia coriaria*, *T. pallida*, *M. buxifolia*, *E. caribaeum* and *A. scleroxyla*. This order is based on the scores of these species in the first dimension of a CA procedure using 16 species and 120 sites.

"Cl=" indicates cluster designation based on four cluster procedures. Numbers indicate core site cluster groups. Letters indicate the core site cluster group with which a noncore site was most closely associated. "A" indicates Group One, "C" indicates Group Three, etc. Group One (Cl=1) represents sites with the characteristic species *B. simaruba* and *E. caribaeum*. Group Three (Cl=3) sites are characterized by *A. scleroxyla*, *E. caribaeum*, *M. buxifolia* and *T. pallida*. Group Four (Cl=4) sites are characterized by *P. brasiliensis* and *Cassia emarginata*. Group Five (Cl=5) sites are characterized by *Caesalpinia coriaria*, *Cassia emarginata*, *A. farnesiana* and *G. officinale*. Group Six (Cl=6) sites are characterized by *A. farnesiana*, *Coccoloba leoganensis*, *Caesalpinia coriaria*, and *Prosopis juliflora*. Group Seven (Cl=7) sites are characterized by *Phyllostylon brasiliensis*, *Pithecellobium circinale*, *B. simaruba* amd *L. lanceolatus*.

Characteristic species for subgroups include *Phyllostylon brasiliensis* and *Caesalpinia coriaria* for Subgroup B (Cl=B) sites, *P. brasiliensis* and *Capparis cynophallophora* for Subgroup BG (Cl=BG) sites, *Caesalpinia coriaria*, *A. scleroxyla*, and *E. caribaeum* for Subgroup C (Cl=C) sites, *P. brasiliensis* for Subgroup D (Cl=D) sites, *C. coriaria* and *Prosopis juliflora* for Subgroup E (Cl=E) sites and *P. juliflora* for Subgroup G (Cl=G) sites. "Characteristic species" were not determined for subgroups represented by only one or two sites.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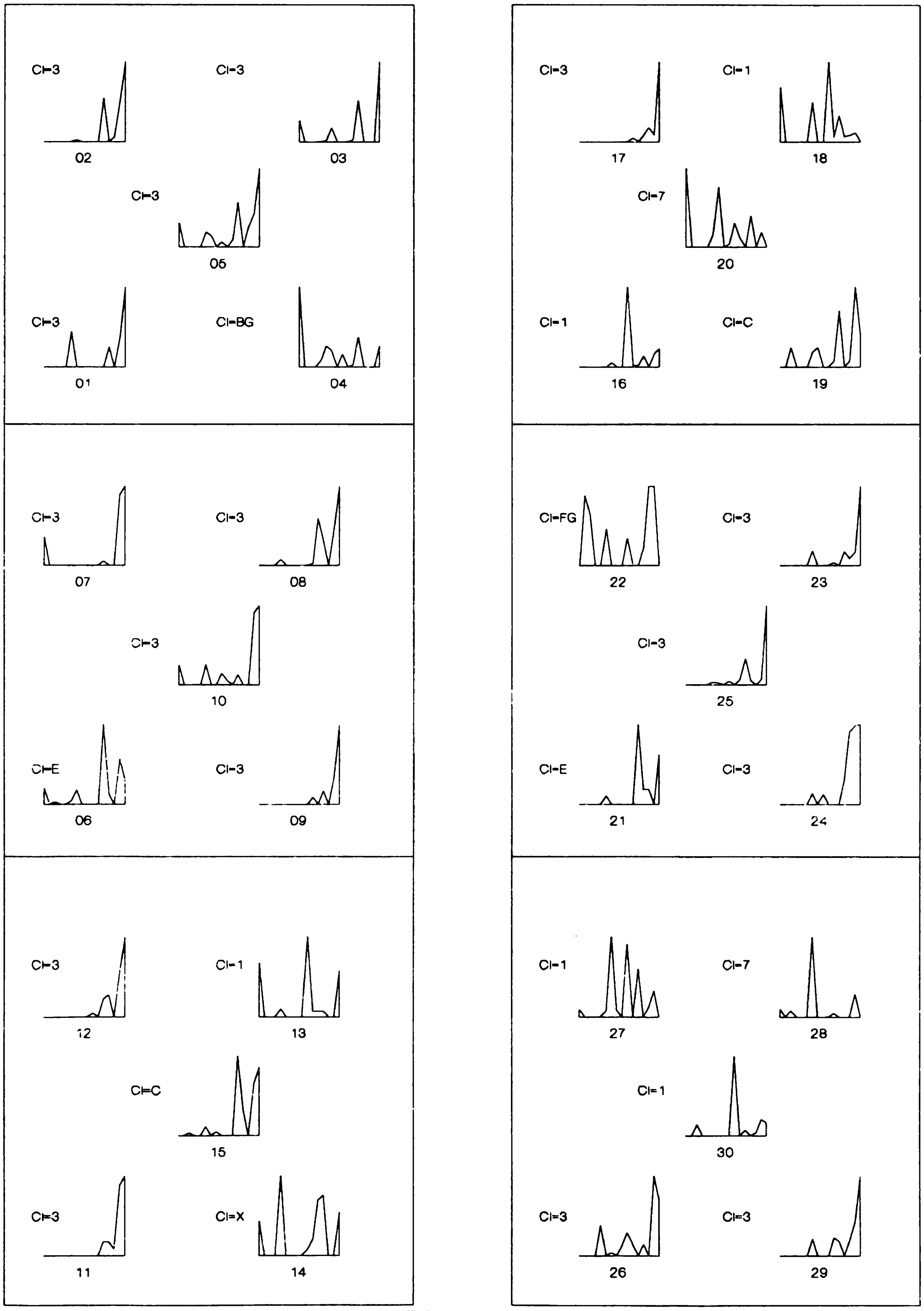
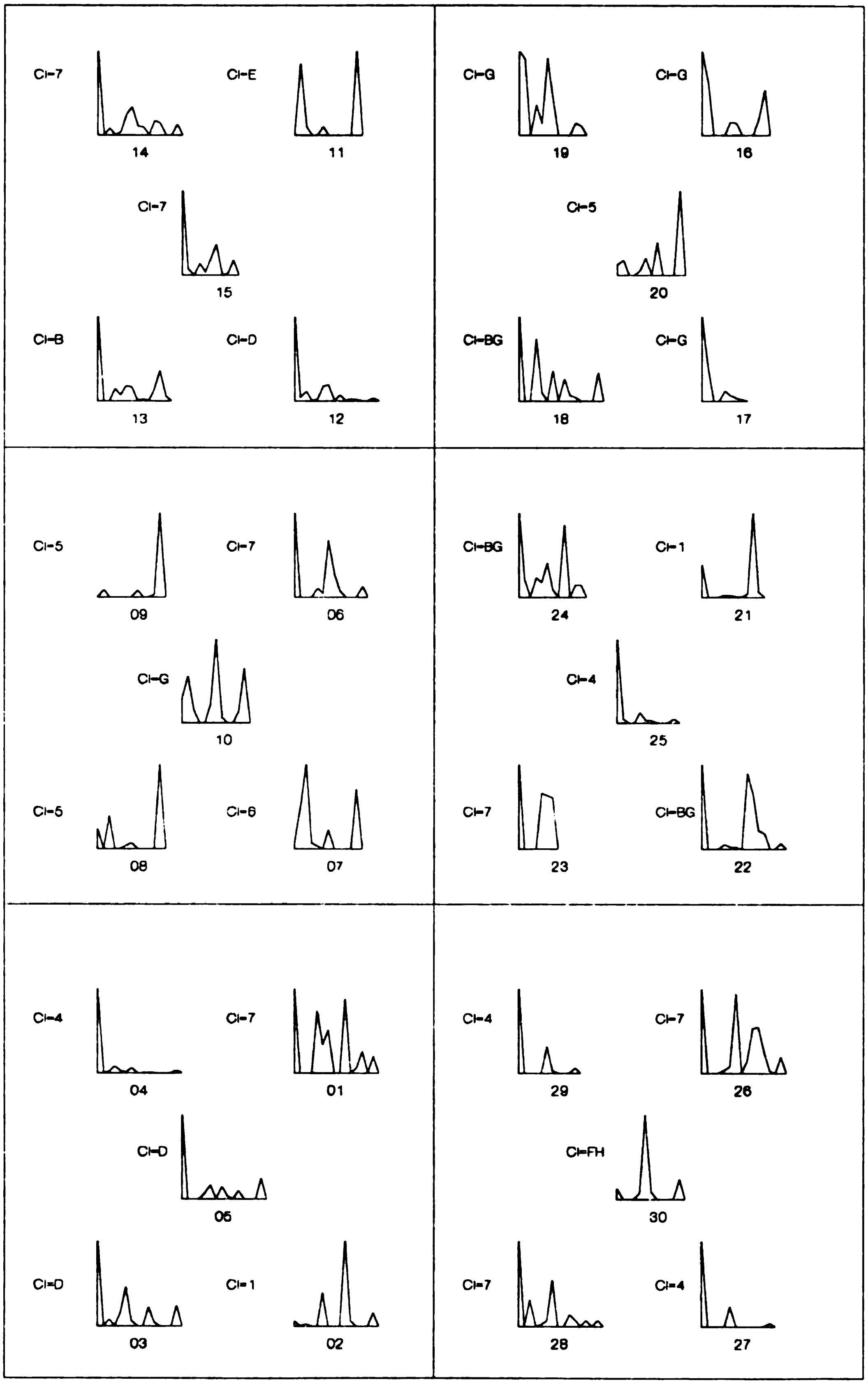
Cl=D
11
Cl=FG
15
Cl=D
13
Cl=4
12
Cl=G
29
Cl=1
26
Cl=E
30
Cl=E
28
Cl=6
27
Cl=4
09
Cl=BD
06
Cl=5
10
Cl=BG
08
Cl=C
07
Cl=6
24
Cl=E
21
Cl=E
25
Cl=EH
23
Cl=D
22
Cl=D
04
Cl=BG
01
Cl=BD
05
Cl=BG
03
Cl=7
02
Cl=5
19
Cl=BG
16
Cl=3
20
Cl=1
18
Cl=D
17

Block One

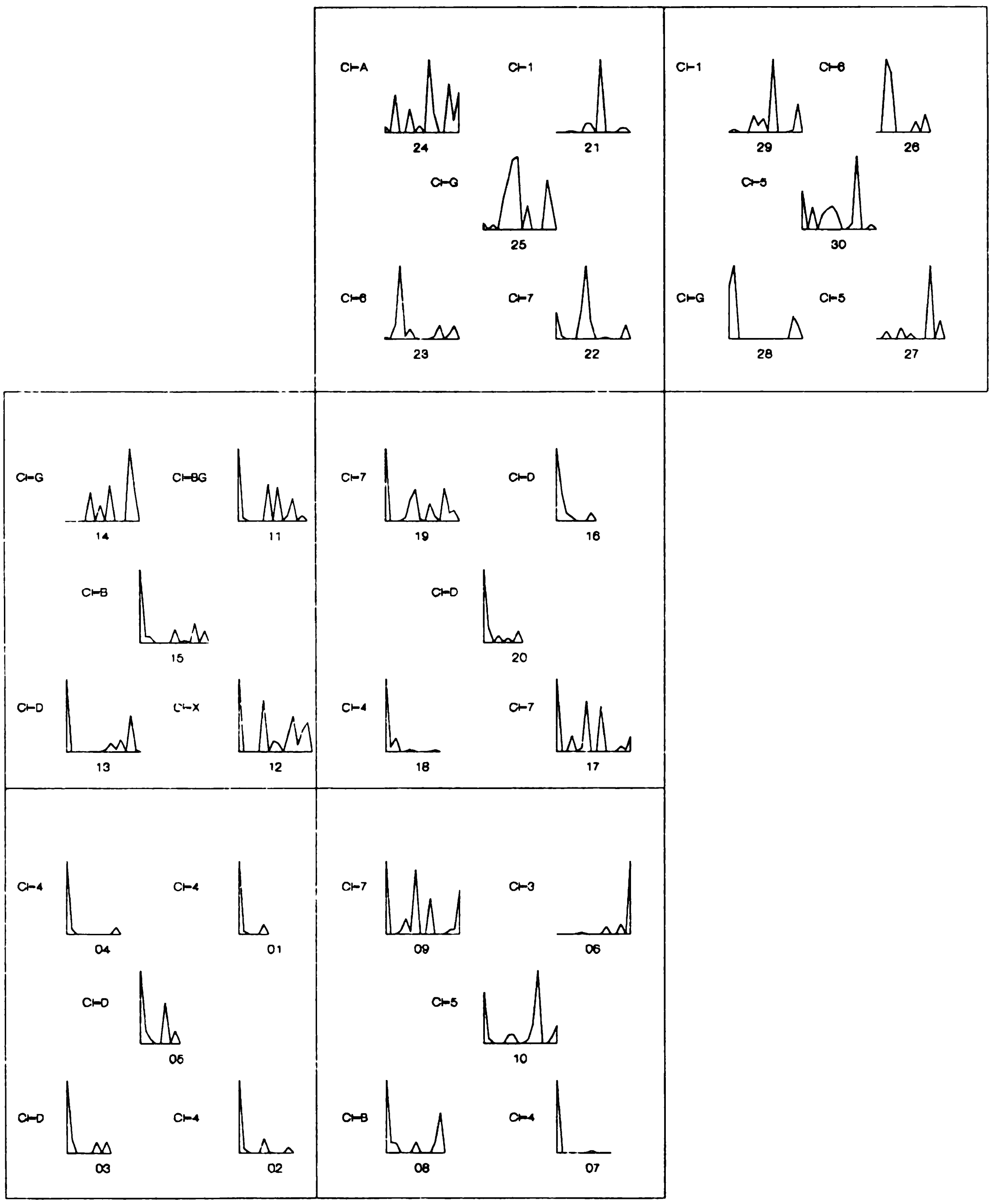

Cl=3
02
Cl=3
03
Cl=3
05
Cl=3
01
Cl=BG
04
Cl=3
07
Cl=3
08
Cl=3
10
Cl=E
06
Cl=3
09
Cl=3
12
Cl=1
13
Cl=C
15
Cl=3
11
Cl=X
14
Cl=3
17
Cl=1
18
Cl=7
20
Cl=1
16
Cl=C
19
Cl=FG
22
Cl=3
23
Cl=3
25
Cl=E
21
Cl=3
24
Cl=1
27
Cl=7
28
Cl=1
30
Cl=3
26
Cl=3
29

Block Two



CI-7
14
CI-E
11
CI-G
19
CI-G
16
CI-7
15
CI-5
20
CI-B
13
CI-D
12
CI-BG
18
CI-G
17
CI-5
09
CI-7
06
CI-BG
24
CI-1
21
CI-G
10
CI-4
25
CI-5
08
CI-6
07
CI-7
23
CI-BG
22
CI-4
04
CI-7
01
CI-4
29
CI-7
26
CI-D
05
CI-FH
30
CI-D
03
CI-1
02
CI-7
28
CI-4
27

Block Three


CI-A
24
CI-1
21
CI-G
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CI-6
23
CI-7
22
CI-1
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CI-6
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CI-5
30
CI-G
28
CI-5
27
CI-G
14
CI-BG
11
CI-B
15
CI-D
13
CI-X
12
CI-7
19
CI-D
16
CI-D
20
CI-4
18
CI-7
17
CI-4
04
CI-4
01
CI-D
05
CI-D
03
CI-4
02
CI-7
09
CI-3
06
CI-5
10
CI-B
08
CI-4
07

Block Four

APPENDIX N

A proposal for a study of soil-site interactions in the managed forest of the ISA-Mao Experimental Forestry Station

APPENDIX N

A soil-site study at the ISA-Mao station should first examine the effects of topography on soil development and available moisture. Within each of the four study blocks, two soil pits should be randomly situated in each of three topographic positions: toe slope, mid slope and ridge top. For each soil pit, standard taxonomic information should be collected (Soil Survey Staff 1992), including organic material in surface horizon, horizon depths and characteristics (including moisture content), textures, stoniness, and depth to root limiting layer if present. In addition, root biomass estimates should be taken, by depth, as outlined by Lugo and Murphy (1986b). Of particular interest would be the ability of roots to penetrate the layer of soil with a high bulk density which is present in much of the forest (Checo, personal communication). In total, six sets of data will be collected in four areas of the forest. Based on this data, it should be possible to determine the site characteristics which show the greatest correlation with available soil moisture and root distributions. These parameters are the ones most likely to be related to differences in site quality.

Based on this initial data, a set of specific site parameters will be selected which most clearly represent differences in site quality. Ideally, parameters should be selected which can be measured easily and relatively rapidly. This would make site selection unnecessary, as resources would be sufficient to collect data on each of the 120 original sites where species composition and growth and mortality data

is available. Using site data, multivariate techniques can then be applied to determine if site relationships correspond to species composition groupings. Initial analyses would focus on the subset of 67 sites which could be classified into distinct species association groups. Clusters of sites which correspond both in terms of species composition and site characteristics would be classified as species-site groups. Based on relationships observed among these groups, sites with intermediate species composition could be evaluated based on site characteristics and correlated with the species-site group they most clearly seem to represent. This aspect is essential, as only about half of the study sites were classified into a definitive species based group.

The final goal is to develop a comprehensive model of species-site interactions which, (1) describes the effects of site characteristics on species composition and (2) helps predict growth response to systematic silvicultural treatments. With such a model, hypotheses could be developed and tested in other areas of subtropical dry forest, both within the ISA-Mao station and in areas of forest managed communally by local residents. Understanding the limits of the forest as a whole and describing potential productivity as it changes across the landscape are important steps in transforming exploitation of a deteriorating resource into wise and sustainable use. Science meets campesino.