Order Number 9136850

Optimal use of ethnobotanical resources by the Mountain Pima of Chihuahua, Mexico

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The University of Arizona, 1991

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OPTIMAL USE OF ETHNOBOTANICAL RESOURCES BY THE MOUNTAIN PIMA OF CHIHUAHUA, MEXICO

by

Joseph Edward Laferrière

A Dissertation Submitted to the Faculty of the

DEPARTMENT OF ECOLOGY AND EVOLUTIONARY BIOLOGY

In Partial Fulfillment of the Requirements

For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

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THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

As members of the Final Examination Committee, we certify that we have read the dissertation prepared by JOSEPH EDWARD LAFERRIERE

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ACKNOWLEDGMENTS

This work was funded by a grant from the University of Arizona Graduate Student Development Fund, and a Doctoral Dissertation Improvement Grant from the National Science Foundation to the author and Dr. Willard Van Asdall. Gary Nabhan and Amadeo Rea provided valuable advice on fieldwork. Bill Mitchell, Mark Kot, and Edward J. Whalen made indispensible suggestions on optimization methodology. Brian Bunday, Geoff Levin, Paul Martin, Steve McLaughlin, Bruce Winterhalder, Eric Smith, Allen Johnson, Robert Bye, Harriet Kuhnlein, Margarita Kay, Nancy Turner, Timothy Johns, Paul Minnis, Kik Moore, Adriana Rodriguez, David Shaul, Dean Saxton, and Lucille Saxton critiqued various portions of either the manuscript or the grant proposal and/or provided other useful suggestions. Adelle Unbauen and Joan Zokvic did a splendid job of keeping track of my grant money. Several people assisted in identification of specimens, including Becky VanDevender, Charles Mason, Richard Felger, John Reeder, Charlotte Reeder, Miriam Fritts, Steve McLaughlin, Paul Martin, Phil Jenkins, Tony Burgess, Tom VanDevender, Karen Adams, Don Pinkava, Billie Turner, Alan Zimmerman, Geoff Levin, Matt Lavin, Jan Bowers, Matt Thompson, Wendy Hodgson, Roger Sanders, Alfonso Delgado, Rupert Barneby, Richard Hauke, Ralph Brooks, Reid Moran, Andrew Sanders, Richard Spellenberg, Jon Ricketson, Thomas Daniel, Mary Butterwick, Guy Nesom, George Yatskievych, Elizabeth McClintock, William D'Arcy, Douglas Henderson, Paul Fantz, Kevin Dahl, Leticia Cabrera, William Weber, Robert Gilbertson, Paul Fryxell, John MacDougal, Warren L. Wagner, Walter Kelley, Lauramay Dempster, Thomas Wendt, Daniel Austin, Landon McKinney, Ihsan Al-Shehbaz, Lincoln Constance, Rafael Corral-Diaz, James Bauml, David Keil, Jorge Marroquin, Dale McNeal, Thomas Wendt, W. Douglas Stevens, Ronald Hartman, and Dawn Frame. I also express my appreciation to the good people of Nabogame, Las Varitas, and Yepachi, especially Cruz Castellano, Hermalinda Tello, Antonio Alvarez, Donasieno Cruz, Marta Cruz, Miguel Angel Cruz, Teresa Alvarez, Lupe Alvarez, and Isidro Cruz, without whose patience and generosity this work would have been impossible. Special thanks to Alfonso Alvarez, who collected many specimens on my behalf, and to Deborah Ellstrom, who provided financial and emotional support through some very trying times. The dissertation is dedicated to the memory of Dionysia Sierra Cruz, 1985-87, of Nabogame.

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ABSTRACT

The Mountain Pima of the Sierra Madre Occidental of Chihuahua, Mexico, utilize a variety of domesticated and nondomesticated resources. Part of their agricultural system consists of shifting, or swidden, cultivation on steep hillsides. Wild edible plants contribute significant amounts of vitamins and minerals to the diet on a seasonal basis. The drought of 1988 caused a decrease in the availability of many resources, but an increase in availability of roots of saraviqui (*Prionosciadium townsendii*). A dynamic, nonlinear optimization study of Mountain Pima diet included requirements for adequate amounts of energy, protein, calcium, and vitamins A and C. Oxalate content of several plant foods and seasonal variation in resource availability were incorporated into the study. Two methods were compared: time minimization and a nutrient indexing method minimizing the product of the absolute value of the natural logarithm of the ratio of recommended intake to actual intake rates. This method allowed simultaneous optimization of several different parameters. The nutrient indexing model matched the actual diet of the Mountain Pima somewhat better than the traditional energy minimization model. It predicted higher

use of noncultivated plant species and of animal resources than the time minimization model. Analyses were conducted for years of adequate rainfall and for the drought year. A list of 612 plant species collected in the community of Nabogame is also included.

CHAPTER I

THE MOUNTAIN PIMA

The Mountain Pima live in the Sierra Madre Occidental of Chihuahua and Sonora, Mexico. They represent the southeasternmost extension of the Pima people. At the time of Spanish contact the Pima homeland encompassed the region from the present city of Phoenix, Arizona, south to Hermosillo, Sonora, with a branch extending east into the Sierra Madre Occidental (Hinton 1959; Sturtevant & Ortiz 1979). Since much of the region has been taken over by Anglo and mestizo peoples, the present disjunct range of the Pima is a small remnant of the aboriginal distribution. The Pima still occupy areas in southern Arizona, northwestern Sonora, east central Sonora, and the Sierra Madre. This last group has been called the "Yécora" (Hinton 1959) after one of the Pima towns in Sonora. More recently, Dunnigan (1970, 1981a,b, 1983) proposed the name "Mountain Pima"; this is the designation followed here.

Dunnigan (1970, 1981a,b, 1983), Nolasco Armas (1969), and Faubert (1975) discussed acculturation, reciprocity patterns and other aspects of Mountain Pima culture. The Mountain Pima use of wild plants for medicine is described by Pennington (1973).

The Pima belong to the Tepiman group of the Uto-

Aztecan language family, whereas the neighboring Tarahumara and Warihio peoples belong to the Taracahitan group (Miller 1983). Much of Mountain Pima culture resembles that of the neighboring Tarahumara and Warihio more than that of lowland Pima Bajo (Hinton 1959). The Mountain Pima do differ from the Tarahumara, however, in their level of acculturation and their dependence on noncultivated resources. The Tarahumara retain a very distinctive style of dress and a greater sense of identity than the Pima, and use a wider variety of wild resources. The Tarahumara consume acorns and a wide variety of vertebrate and invertebrate animals shunned by the Mountain Pima (Bennett & Zingg 1935).

There are, however, some similarities between the Tarahumara and Mountain Pima cultures. Some of these stem from the common montane habitat, but other reflect direct past and present Tarahumara influence. Some influence may date to the Tarahumara migration into the area during the late 17th and early 18th centuries (Pennington 1963). At that time, some Tarahumara fleeing an unsuccessful revolt against the Spanish settled in Yepachi and Maicoba and apparently were absorbed rapidly into the Pima culture. Contact between the groups continues at present; there are currently at least two Tarahumara women living in Yepachi married to Pima husbands. Tarahumara, Mountain Pima, and

Warihio all practice the Yúmari dance, although details vary considerably (Bennett & Zingg 1976; Thord-Gray 1955; Faubert 1975; Laferrière & Van Asdall 1992). Mountain Pima basketry techniques are similar to those reported for the Tarahumara, as are the sotol wreaths used in Holy Week decorations (Bennett & Zingg 1976; Fontana 1979; Laferrière & Van Asdall 1992).

Several plant and animal names considered as Spanish by the Pima are in fact of Tarahumara or Warihio etymology. Saraviqui (Prionosciadium townsendii [throughout the body of this dissertation authorities for names are given only for those taxa not listed in Appendix I]) and matariqui (Psacalium decompositum) are examples of names of Tarahumara origin (Thord-Gray 1955; Brambila 1976). The names wasiki (Prunus gentryi) and pipichewa (Acourtia thurberi (A. Gray) Reveal & King) are considered indigenous names among both the Tarahumara and Warihio but Spanish by the Pima, the former in the form "ahuasiqui" (Gentry 1963; Bye 1986; Laferrière 1989a). The name savaliki (Yucca grandiflora Gentry) is of Warihio origin (Gentry 1963). Another commonly used word of Tarahumara origin is "chavochi", which is a derogatory term meaning "bearded ones" and applied to mestizos (Kennedy 1978; Thord-Gray 1955; Deimel 1980).

I selected the Mountain Pima village of Nabogame as a study site, located approximately 18 km by foot northwest of the commercial center of Yepachi (also known as "Yepáchic") in the Municipio of Temósachi, Chihuahua, Mexico (Figure 1). Yepachi is served daily by a public bus to Cuauhtémoc. Nabogame is accessible only by foot, horseback, or four-wheel-drive vehicle. The population of Yepachi was estimated by Faubert (1975) at 1200, 60% of which was Pima. The total population of Nabogame during the fieldwork period varied from 70 to 75. All the residents of Nabogame consider themselves Pima, although there is some admixture of non-Pima genes. Estimates for the total Mountain Pima population range from 1500 to 3000 (Dunnigan 1983).

Information was gathered by means of participant observation and by interviews with residents of Nabogame and Yepachi during the period from October 1986 through November 1988. Interviews were conducted in Spanish. I spent a total of 13 months in Nabogame and one month in Yepachi during this time period. I also visted Maycoba, Sonora, and Las Varitas, Chihuahua.

There is a great deal of commerce between Nabogame and Yepachi, since the people of Nabogame frequently travel to Yepachi by foot or horseback to buy various goods, and people from Yepachi occasionally travel to Nabogame (often by pickup) to obtain lumber or firewood, or to buy animals or produce. A few residents of Yepachi own small ranches in the vicinity of Nabogame, which they occupy during a few months of the year. All the people of Nabogame have close relatives in Yepachi, and some possess homes there themselves. They frequently spend several months of the year and some of the major holidays in Yepachi.

Evidence exists of a long history of human habitation in the Nabogame valley. I collected a few small pieces of obsidian in the town, and observed three small burial caves in the vicinity, complete with basketry and old maize cobs. The burials are similar to those of the Tarahumara (Bennett & Zingg 1976). The Pima claim that these burials are pre-Christian and date from the time before God created the sun. Approximately one kilometer north of town there is a terraced hillside reputed to have been cultivated by the ancestors of the present inhabitants. The terracing effect appears to be at least partially natural, there being horizontal rock formations on the hillside, but the effect is augmented by stone walls and dams similar to those present in the currently farmed area. Similar terraces occur in the region of the lowland Pima Bajo (Pennington 1980). There is also a large wall running perpendicular to the terracing and continuing along the ridgetop above the hillside. The hillside is at present very badly eroded and sparsely vegetated, incapable of supporting agriculture in its current condition. In some places, the soil is only a few centimeters thick, while in others the underlying rock is completely exposed.

Acculturative pressures have been strong in the region, largely because of the construction of a road through the area in the early 1970s. This rapid cultural change can be expected to intensify greatly once the current work to pave the road through Yepachi from Chihuahua to Hermosillo has been completed. Cattle, lumber, and other commercial vehicles regularly use the unpaved highway. Little aboriginal Pima culture remains visible in Yepachi or Nabogame, and that which remains may likely disappear in a few decades (Dunnigan 1970). Few people in either town use the ancestral Pima language regularly, although the use of the language in outlying ranches and communities may be somewhat stronger. The language is also used more frequently on the Sonora side of the frontier (Dunnigan 1970; Saxton & Saxton, pers. comm.). In Nabogame, most of the younger people currently know some words of the Pima language, but only the older residents of the town know enough of the grammar and vocabulary to converse in the ancestral tongue.

Some traditional crafts such as basketry, pottery, and leather tanning are still practiced, but on a reduced scale from in times past. Many of the men work occasionally for the lumber companies or in neighboring communities, and some have travelled to other parts of Chihuahua State in search of wage employment. Clothing, tools, and most other material goods are purchased from stores in Yepachi, as are several food items such as flour, coffee, salt, sugar, pasta, cookies, onions, garlic, and chiles.

A few of the older Mountain Pima describe dwellings of hay or of woven walls of sotol (Dasylirion wheeleri), which they remember from years past. Caves were still used as temporary shelters until a few decades ago (Nolasco Armas 1969). More recently houses were made of rocks or of pine shingles nailed to a frame of wooden poles. One of the latter is still in use in Nabogame, and two of the former remain as unused ruins. Most new houses in Nabogame are made of either adobe or logs, or some combination of the two. This is a very recent development; prior to the construction of the road through the area, adobe construction methods were unknown. Adobe bricks are made locally from mud strengthened with hay or dried pine needles.

Most families possess more than one dwelling, a primary one in the center of town in which they live most of the year, and one or more smaller house located some distance from the community, where they spend only a few months a year. These outlying dwellings or "ranchos" are generally less well insulated than even the in-town dwellings, since they are ususally vacant during the winter months. Some are only 3-sided; others lack walls entirely. They may be located in forested areas and serve solely as cattle stations, or may have small planted fields nearby as well. Arable land in such mountainous terrain is distributed in an extremely patchy manner, and the ranchos are necessary to facilitate exploitation of these resources. The crops grown in such fields supplement those produced in the larger agricultural areas in the center of town. Workers planting and weeding the fields during the spring and summer frequently commute by foot daily from town, using the ranch houses only in the event of thundershowers. During the fall milking and harvesting season, however, entire families relocate to the ranches. The town is thus often nearly deserted at this time of year. Other ranches in the general vicinity house isolated ranchers who work their fields and cattle herds as their primary source of subsistence.

All the buildings in Nabogame have dirt floors, which are kept dust-free by being periodically sprinkled with water. Roofs are made of wooden shingles nailed to a frame of poles. Formerly they were flat, but now virtually all buildings have slanted roofs. Shingles are made by splitting sections of pine logs with an ax. They are then stacked to dry.

Outhouses are coming into general use in Nabogame although they were uncommon in the past. Locations and construction techniques vary. Some outhouses are located directly over small creeks, while most have pits underneath. Some are rectangular in design while others are conical, made of poles tied together at the top. Most lack doors.

Wood is frequently used in construction of household items. Pine is prefered for most purposes, but occasionally other species are used as well. Sabino (Cupressus arizonica) is valued in house-building because of its resistance to rotting. Household furniture is homemade, partly from rough-hewn wood from the forest, partly from machine-cut planks from Yepachi. Benches, beds, shelves, and tables are made in Nabogame. A few older sleeping mats of woven sotol (Dasylirion wheeleri) are still in use.

The people generally bathe in the creek, although during colder weather a bucket of heated water may be poured over someone's head. Some people still bathe nude, although some women have adopted the mestizo custom of bathing fully clothed.

Maize, beans, and potatoes are stored inside the house in metal barrels, burlap bags, or baskets made of sotol (Dasylirion wheeleri) or palmilla (Nolina sp.). The baskets are rectangular in design, similar to those used by the Tarahumara. These are located in the living quarters or in special storage rooms. Cheese is stored on platforms suspended from the roof. Maize stalks (used as hay for animals destined for work) are stored in old abandoned houses or on makeshift platforms in the limbs of large oak trees.

Traditional ovens were made of a semicircular array of stones cemented together with mud, with a flat ceramic plate laid across the top on which to cook. A few such ovens with metal instead of ceramic plates are still in use. Formerly, all cooking was done in the traditional outdoor ovens, with a small fire being constructed in the house during the winter, with the smoke being allowed to escape through cracks between the shingles. Much of the food was formerly prepared by boiling, since frying pans and lard were generally unavailable. Today, however, most of these traditional ovens have been replaced with ovens made from one half of an oil drum set in a platform of mud and large flat stones. A hole is cut in the side for adding firewood to the center of the oven, and a smaller hole cut in the top to affix a chimney. The women say these ovens are much more convenient than the older ones since the presence of a chimney permits the cooking to be done indoors.

The residential and agricultural portions of town are surrounded by a barbed wire fence strung between crude wooden posts 100-130 cm high and 8-10 cm in diameter. Smaller fences surround outlying ranches. Live trees are used as posts in some instances. Cliffs and boulders are utilized as parts of the perimeter, to lessen the amount of wire needed. Older, more traditional fences of dead branches and tree trunks still exist in a few areas. Fences around gardens consist of slats of wood 10-20 cm broad and 2-4 cm thick, strung together with plain (non-barbed) wire. Four lengths of wire are used to secure the fence, two above and two below. First a wire is strung between the corner posts, then the slats are placed against this wire and held in place with the second wire, which is twisted around the first wire on either side of the wood.

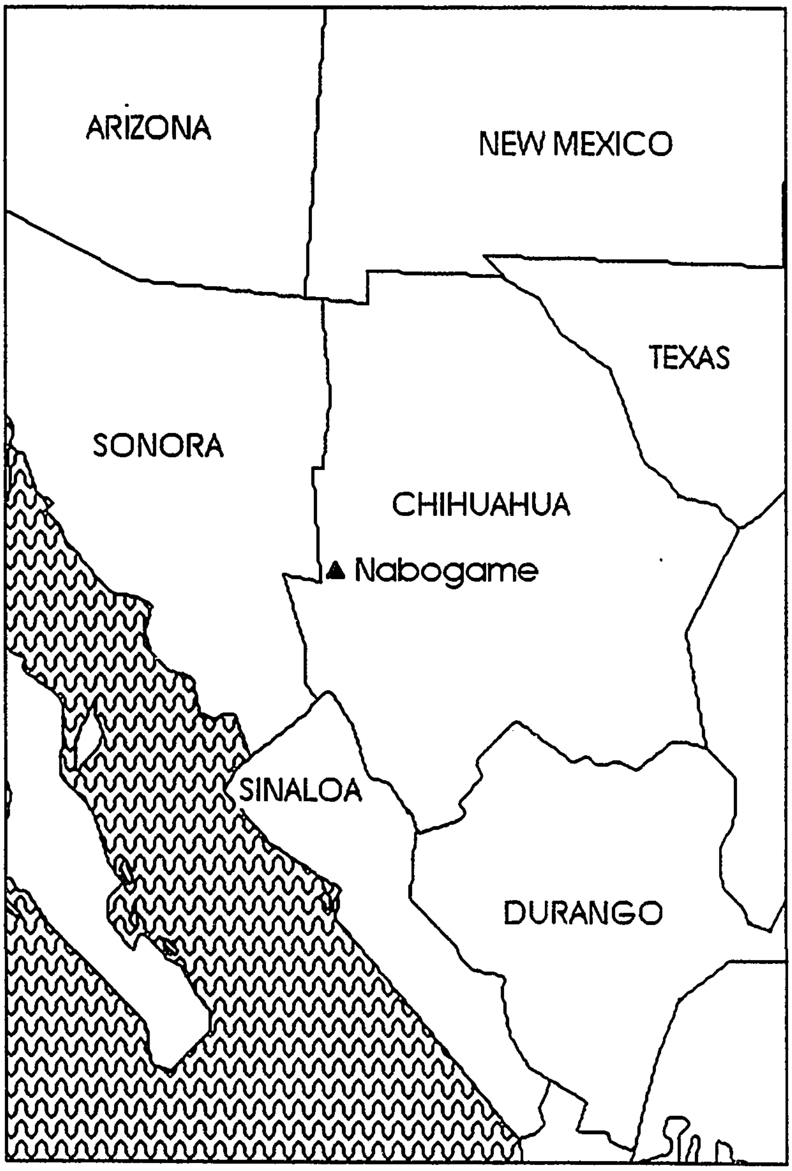
Gates are of two types. Those across roads are made of three or four poles strung together with barbed wire with no crossbeams. These are thus indistinguishable from a distance from other parts of the fence except that the poles are not inserted into the ground and that the final one is fastened loosely to a large stationary pole top and bottom with non-barbed wire. Gates across foot trails consist of three or four horizontal poles up to two meters long inserted into holes carved into vertically placed logs. The gate is opened by sliding the poles through the holes until the pathway is cleared.

Metates are used to grind chilies, maize kernels, and other items. There are two parts to a metate, a large piece 40-60 cm long, with a flat bottom, rounded sides, and concave top. This is either placed on a cylindrical platform or mounted on a three-pronged stand. A smaller piece in the shape of a rectangular prism with rounded edges is used to grind the items placed in the concave portion of the larger piece. Both pieces are made by chipping at the rock with another rock, or sometimes with a metal implement. The surfaces must be perfectly smooth lest small chips of stone break off into the food. It can take a week or more to make a metate, but once made it may last many years. These metates are still being made in Nabogame.

Firewood is by far the most important resource gathered from the wild, being used every day in heating and food preparation. Dead, fallen wood is generally gathered from the forest every other day during the winter, every third or fourth day during the summer. Generally, a burro is used to haul the load back to the village, since it usually must be obtained from a considerable distance. Men usually perform the gathering and the chopping, although women can occasionally be seen doing both. Oak is the most frequently used firewood, since it is most common in the forest, but all other tree species can be used as well.

In addition to its use in basketry, sotol is made into in artificial flower decorations. Tarèchari (Agave polianthiflora) was reportedly also used to make smaller flowers at some time in the past, although it no longer is. Palmilla (Nolina sp.) and savaliqui or jamole (Yucca madrensis) are used in rope-making, although nylon ropes are now sometimes made from woven potato bags, with the ends melted together after twining.

Figure 1: Map showing Mountain Pima village of Nabogame



CHAPTER II

THE NATURAL ENVIRONMENT

Although several workers have contributed to our botanical knowledge of the Sierra Madre Occidental of northwestern Mexico the region remains underexplored. No flora covers the area. Brand (1937), Gentry (1942), LeSueur (1945), White (1948), and Maysilles (1959) provided floristic information on portions of the region. Bennett & Zingg (1935), Pennington (1963, 1980), Gentry (1963), and Bye (1979, 1981), have supplied ethnobotanical information on the Tarahumara, Warihio, and lowland Pima Bajo peoples bordering on the Mountain Pima.

The Nabogame valley ranges in altitude from 1600 m in the south at the confluence of the Nabogame Arroyo with the Rio Yepachi to 2100 m at the summit of the mountain to the northeast of the town. The east side of the valley is formed of a highly siliceous rhyolite, while the west side is of a purplish-red shale. There are also numerous granitic outcroppings in the vicinity, often forming steep precipices. The entire area is cut by numerous small canyons and arroyos. There are no deep barrancas in the immediate vicinity of Nabogame, such as those found south of Yepachi in the drainage basin of the Rio Mayo.

Precipitation in the Sierra Madre Occidental is bimodal, with two rainy seasons and two dry seasons (Figure 2) (Wallen 1955). Average annual precipitation in Yécora, Sonora, 40 km west of Nabogame, is reported at 1071 mm per annum (Hastings 1964). Most of the rain occurs in the form of thunder showers which approach from the southeast in late summer (Hastings 1964). Nabogame is in a strong rain shadow even with respect to Yepachi 18 km to the southeast. The name "Nabogame", i.e. "place of the prickly-pears", reflects the abundance of xerophytic vegetation at this site. In Yepachi, moist pine forest covers a much larger portion of the surface area than in Nabogame. Nabogame is nevertheless moister than Maycoba and other communities farther west and is by no means a desert.

The seasonality of rainfall has a significant impact on vegetation and streamflow. Fallow fields depleted of vegetation by grazing during the spring dry season become covered with a thick stand of herbs two meters or more tall by the end of August. Creeks in the town dry out completely during the May-June dry season, then become raging torrents during July and August thunder showers. The desiccation of the annual dry season combined with the scouring effect of the summer floodwaters prevents the formation of swamps and marshes in the valley.

During the latter half of my fieldwork period, beginning in August 1987, the Mountain Pima area experienced the worst drought in the memory of the local people. The drought adversely affected many of the local plant populations, and uncommon mesophytes may be underrepresented in this survey. Indirect effects of the drought (i.e. increased grazing pressure) were as devastating as the direct effects.

Although the predominant natural vegetation of Nabogame is pine/oak forest (Rzedowski 1986), this has been greatly modified by human utilization. The valley can be subdivided into various vegetation zones according to use, soil, slope, aspect, and availability of water. The inhabitants of the town impact on the landscape in several ways: livestock grazing, plowing of fields for agricultural use, and direct utilization of wild plants for food, fiber, medicine, construction materials, and firewood. Grazing intensity varies seasonally due to the local habit of allowing the livestock into cultivated portions of town during the winter but keeping them in the forest during the summer planting season from May to November. This results in a great abundance of herbaceous vegetation inside the town during the summer rainy season. This luxuriant growth is nearly completely consumed by the livestock by spring. Direct human utilization of plant resources has severely depleted several useful species, according to many of the local people. Economic species they describe as having been more abundant in the past include Dasylirion wheeleri, Nolina sp., Yucca madrensis, and Prionosciadium townsendii.

The following habitats are present in Nabogame, characterized by their dominant species:

1. Cultivated fields: Amaranthus hybridus, A. rigidus, Cosmos parviflorus, Bidens aurea, Ipomoea spp.
2. Fallow fields, ungrazed in summer: Cosmos parviflorus, Bidens aurea, etc.
3. Cleared but unplowed fields: Hymenocallis pimana, Cosmos parviflorus, Bidens aurea, Opuntia spp. Within the perimeter fence protecting the agricultural sections of town from grazing livestock, there are areas too steep or rocky for planting. These are therefore left permanently as pasture, grazed in the winter but not the summer. Most of the annual species found in the fallowed fields may also be found here, in addition to perennial species such as H. pimana which cannot withstand the effects of the plow.
4. Permanently grazed pasture: various grasses and forbs. In the forest beyond the perimeter fence there are several permanent pastures devoid of trees and subject to year-round grazing pressure. Some of these represent fields formerly cultivated but now abandoned due to erosion, while others are covered with poor,

rocky soil.

5. Oak forest: Quercus chihuahuensis, Q. viminea, Q. hypoleuca, Arbutus xalapensis. This constitutes the most widespread vegetation zone, covering large sections of hillside.

6. Moist pine forest: Pinus engelmanii, P. chihuahuana, Quercus chihuahuensis, Q. viminea. Moist pine forest generally occurs in more protected, sheltered areas than oak woodland, although the two do intergrade considerably.

7. Dry pine forest: Pinus lumholtzii, Quercus chihuahuensis, Juniperus deppeana, Arbutus xalapensis. The soil in certain areas is poorer and more porous than in others, resulting in slightly more xerophytic vegetation. The trees in this area are shorter than in the moist pine forest, the herbaceous vegetation more scanty, and the general aspect more open.

8. Cypress forest: Cupressus arizonica, Pinus spp., Quercus spp., Prunus gentryi, Arbutus xalapensis, Fraxinus spp. Along the intermittent creeks where the water table is rather shallow, there occurs a very moist community dominated primarily by tall trees. Many of these areas were steep-walled canyons, with such shrubs as Berberis pimana, Holodiscus dumosus, Rhus trilobata, and Forestiera neomexicana. Some

utilizable plants such as Prionosciadium townsendii, Dahlia spp., and Hedeoma patens are also found in these regions.

9. Maple forest: Acer grandidentatum, Cupressus arizonica. Along the banks of the Rio Yepachi, there are two small stands dominated by these two tree species. Though of a small extent, these groves are important floristically since many mesic, sun-intolerant herbs are present only in these groves.

10. Manzanita thickets: Arctostaphylos pungens, Quercus chuhuichupensis, Juniperus erythrocarpa. This community dominated by shrubs and small trees is found in areas of extremely poor, porous soil. This type grades into the dry pine forest.

11. Aquatic: Ranunculus subrigida, Potamogeton spp. The only truly aquatic habitat in the area is the Rio Yepachi. In its waters are found a few submerged and emergent species.

12. Sunlit springs: Eryngium longifolium, Lobelia cardinalis. Most of the sunlit springs are very heavily grazed, but approximately 1 km north of the town there is a permanent spring on a slope too steep for even the goats. This spring was flowing even during the drought of 1988.

13. Shaded springs: Quercus spp., Prunus gentryi, Cupressus

arizonica.

14. Steep cliffs and near-cliffs: *Dasylirion wheeleri, Agave shrevei* ssp. *matapensis, Opuntia* spp., *Eysenhardtia orthocarpa.* These open rock-faces are largely immune to grazing pressure.

15. Sun-lit creekbanks: *Baccharis salicifolia, Polygonum* spp.

I collected specimens of 612 plant species in Nabogame between October 1986 and November 1988 (Appendix I). This included 23 seedless vascular plants (3.8% of total), 8 conifers (1.3%), 447 dicotyledons (73.0%) and 134 monocotyledons (21.9%). There were 98 botanical families represented, the largest being the Asteraceae (120 species, 19.6% of total), Poaceae (64, 10.5%), Fabaceae (50, 8.2%), Cyperaceae (20, 3.3%), Lamiaceae (19, 3.1%), Scrophulariaceae (18, 2.9%), Euphorbiaceae (14, 2.3%), Orchidaceae (14, 2.3%), Convolvulaceae (12, 2.0%), Adiantaceae (11, 1.8%), and Solanaceae (10, 1.6%).

The region included in the floristic survey covers the drainage basin of the creek running through the center of Nabogame, plus the neighboring drainage basin locally referred to as "La Mesa." This basin to the east of the main drainage basin was included since one house socially and politically considered part of Nabogame lies to the east of the divide, and because the vegetation there more closely reflects the natural vegetation of the area. The eastern drainage has been subjected to less intensive agricultural exploitation and no commercial logging. The creeks of both drainage basins are tributaries of the Rio Yepachi, which in turn drains into the Rio Papigochic and the Rio Yaqui. The portion of the river between the mouths of the two creeks was also included in the survey. Estimated total area of the survey was 20-25 square kilometers.

The number of species collected compares favorably with those of other local floras from northwestern Mexico and the southwestern United States (Bowers 1981, 1982). White (1948) listed 1200 species from the Rio Bavispe, an area close to Nabogame but approximately 200 times as large. Welsh & Moore (1968) reported 224 taxa from an area in Utah slightly larger than Nabogame. Hazen (1978) listed 220 taxa from 51.8 square kilometers in northern Arizona. Reeves (1976) listed 687 species from Chiricahua National Monument, Arizona, an area of approximately 43 square kilometers. Fletcher (1972), Little & Campbell (1943), Langenheim (1955), Rondeau (1991), Halse (1973) all recorded fewer than 600 species from areas 15-40 times as large as my study area. Toolin et al. (1979), however, listed 624 spp. from 9 square kilometers in Sycamore

Canyon, Arizona. Montane environments often tend to have higher species richness than desert habitats (Felger 1980). Given these comparisons to other studies, I feel confident that the list represents the vast majority of the plant species present in Nabogame during the study period. I cannot, however, estimate the number of species missed because of the drought.

Nabogame is the type locale for seven recently described plant and fungal taxa. These are Prunus gentryi forma flavipulpa (Laferrière 1989a), Hymenocallis pimana (Laferrière 1990b), Berberis pimana (Laferrière & Marroquin 1990), Laennecia pimana (Nesom & Laferrière 1990), Pectis pimana (Laferrière & Keil 1991), Albatrellus mexicanus Lafer. & Gilbn. (Laferrière & Gilbertson 1990a), and Polyporus tenuiparies Lafer. & Gilbn. (Laferrière & Gilbertson 1990b). Five other taxa on this list (cited as Quercus mcvaughii, Gnaphalium sp., Browallia angustifolia, Asclepias madrensis, and Arabis microcarpa) represent new species soon to be described elsewhere (Spellenberg pers. comm.; Nesom, pers. comm.; Van Devender & Jenkins, pers. comm.; Stevens, pers. comm.; Al-Shehbaz, pers. comm.).

Ethnotaxonomy

Collection of ethnotaxonomic information was hampered by the limited number of Pima speakers in Nabogame and the high level of disagreement among them. Logistical limitations and the obligations imposed by my optimization study in Nabogame prevented me from travelling extensively in the region to gather data from more informants. I did, however, collect some information from an elderly couple in Las Varitas, 6 km south of Nabogame and 14 km west of Yepachi.

The differences between informants were at times difficult to deal with. Repeating names given by one native consultant sometimes elicited hearty laughter from another. Several reasons for the discrepancies were apparent. The Mountain Pima are rapidly losing their traditional ethnobiological knowledge through disuse. Even many of the older people who speak Pima say they have not used the language in years. Traditional medicine is being replaced with health care provided by the Mexican government and with herbal medicine imported from lower elevations. Mountain Pima names for many plants are being replaced with mestizo and Tarahumara borrowings. My inquiries as to the Pima names for various plants often elicited only Pimatizations of Spanish names, e.g. "yerbaviiv" for "hierba de la vibora".

Many of the names I received represented spontaneous descriptions rather than fixed names. Many plants were called "lali sha'i" ("small herb") or "kokmok sha'i" ("gray herb"). The tendency toward spontaneous descriptions was true even of economically useful plants, which occasionally shared names. For example, Hymenocallis pimana and several wild species of Allium, especially A. rhizomatum, were both referred to in Spanish as "cebollin" ("little onion"). I overheard a Pima woman differentiate H. pimana from the Allium by refering to it as "lo que florece blanco, muy grande asi" ("the one with white flowers this big"). Similarly, Arctostaphylos pungens and the garden herb Chamomilla recutita are both called "manzanilla" ("little apple"), the former because of its fruit shape, the latter because of its odor. The same woman and I were discussing A. pungens when her son asked which manzanilla we were talking about. "Ese arbusto que le mostraste el año pasado" ("that shrub you showed him last year") was her reply. This contrasts with the usual ethnotaxonomic situation in which related species are distinguished by standardized adjectives (e.g. "white oak" or "sugar maple").

Several names applied to unrelated groups of species with similar appearances or uses. All banded snakes, regardless of color, even the brown and tan lyre snake (Trimorphodon biscutatus), are lumped together as "coralio" ("coral snake"). The Pima term for this folk taxon, "h+m+ktash ko'o", translates as "one-day snake", in reference to the fact that a bite from a true coral snake can kill a person in one day. The Spanish name "contrayerba" (Pima "kontrayerv") refers to a variety of plants with similar medicinal properties, i.e. Euphorbia cyathophora, Gomphrena nitida, Guilleminea densa, and Zinnia peruviana. "Malamujer" (Pima "haramkulyi") referred to plants with adhesive propagules, such as Triumfetta discolor, Priva mexicana, and Heterotheca subaxillaris. All twining plants were called "redadera" (Pima "shitulyi"), except Clematis drummondii was "redadera del nopal" (Pima "kaava boporo"). Mammillaria spp. and Echinocereus spp. were included in the taxon "cholla" (Pima "tu'i shogi"), although M. sonorensis was also called "pitaya".

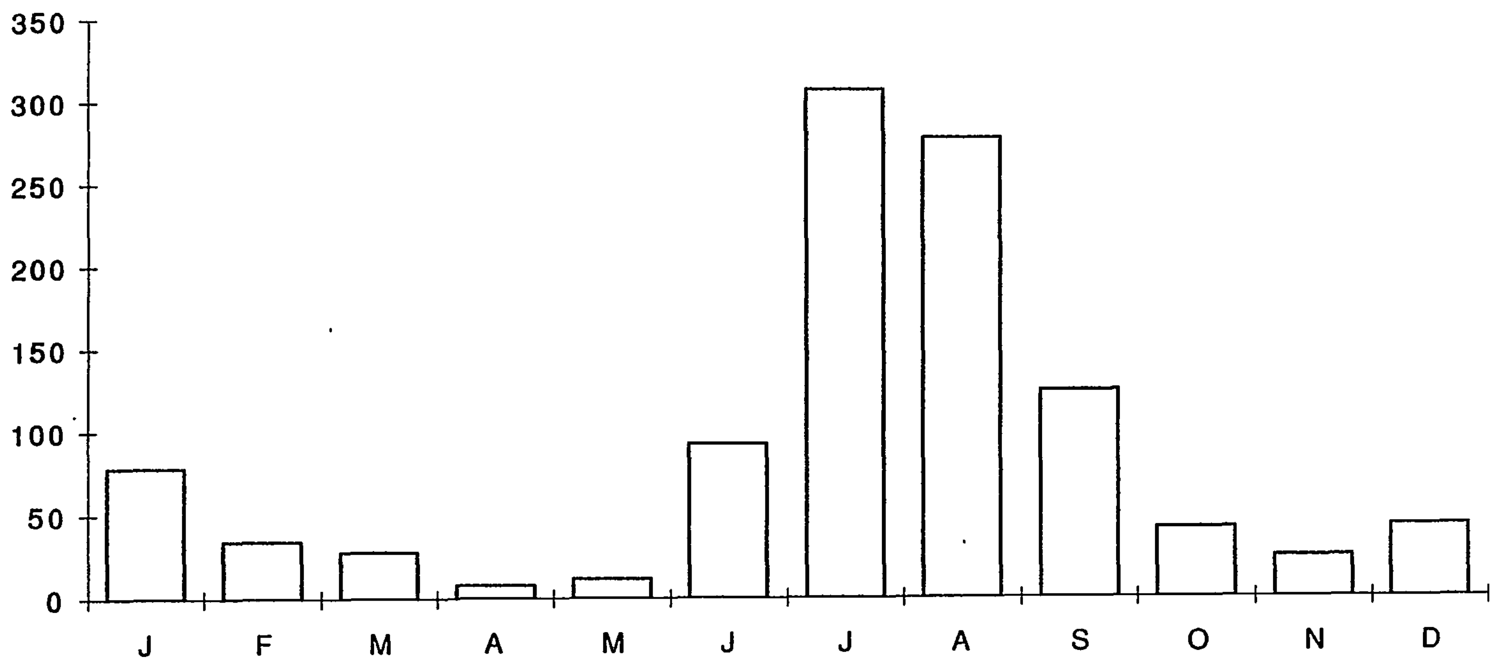
Sometimes informants disagreed concerning inclusion of taxa. Lumpers classed all orchids as "kiki" and all ferns as "carnahual" while splitters considered only Bletia gracilis and Cheilanthes cuneata, respectively, as true representatives of these groups.

Fungi are extremely underclassified among the Pima, with only a few folk species recognized. This contrasts sharply with other indigenous peoples such as the Purepecha, who have a very elaborate folk taxonomy of fungi (Mapes et al. 1981). Fungi are named primarily according to habitat or substrate, being grouped into "hongo de la tierra" ("earth fungus"), "hongo de encino" ("oak fungus"), "hongo de pino" ("pine fungus"), "hongo de fresno" ("ash fungus"), "hongo de sabino" ("cypress fungus"), etc. A fungus growing on the pine shingles of a house is called "hongo de la casa" ("house fungus"). Cuscuta campestris, a common angiosperm parasitic on herbaceous vegetation, is called "hongo de zacate" ("hay fungus") or "hongo de juve" ("Cosmos parviflorus fungus"). All mosses, lichens, and liverworts are lumped together as either "barba de encino" ("oak beard") or "barba de piedra" ("rock beard"). Selaginella is also included in this taxon except for S. lepidophylla, which is "flor de piedra" ("rock flower"). The epiphytic bromeliad Tillandsia erubescens, however, is called "flor de encino" ("oak flower") regardless of substrate.

The Mountain Pima do acknowledge the existance of unnamed taxa subordinate to the named folk species, and that specimens collected from different substrates represent identical species despite the different names. Occasionally, the native categories cut across the boundaries of scientific classification; for example, specimens of Lentinus levis were named as "hongo de encino" when collected from oak (Quercus spp.), "hongo de madroño" when found on Arbutus xalapensis. This conflict between named taxa and unnamed covert categories contrasts with the more usual hierarchial folk classification described by others (Berlin et al. 1966, 1968). More often, however, fungi recognized as different species by mycologists are lumped together in heterogenous folk species by the Mountain Pima.

Appendix II contains listings of the names of plants and fungi for which I have enough corroboration to consider trustworthy. Animal names are listed in Appendix III. These were obtained primarily by showing color pictures published by Udvardy (1977), Behler & King (1979), Whitaker (1980), and Boschung et al. (1983).

Figure 2. Yearly distribution of rainfall (mm) in the Mountain Pima community of Yécora, Sonora (after Hastings 1964).



CHAPTER III

AGRICULTURAL TECHNOLOGY

When asked about the local field fallowing system, the Pima in Nabogame initially reply that there is a two-year cycle, in which fields are planted one year and left fallow the next. However, the situation is more complex. There is a gradation between fields on the best land, planted every year; fallowed fields on hillsides, some planted a few years before being left fallow, others with just the opposite scheduling; and temporary fields on extremely steep hillsides, formed by clearing primary forest. This soil is extremely thin and rocky, and many of the fields are planted on the sides of hills of up to 35 degree (80%) slope. Erosion, both gully and sheet, is common on these fields, and the people clear them fully knowing that the fields will only be productive for 3-5 years. Stone walls are built along the upper edges of the arroyo. Stone dams are also occasionally placed across gulleys to control erosion. Shallow trenches may also be dug uphill from fields to divert water. Even these measures are inadequate to control the loss of topsoil from the steepest fields. A considerable amount of the nonplanted grassy area in the town is covered by badly eroded former cropland. The heavy grazing inhibits the regeneration of the forest.

There is one ridgetop 2 km northwest of town, however, which was felled but never burned nor planted. The forest is regenerating in this plot despite the grazing pressure. Some of the regeneration is due to stump sprouting, but some is due to new growth of táscate (Juniperus deppeana var. robusta). The persistent cover of herbaceous vegetation has prevented large-scale erosion, permitting the regeneration.

New fields are cleared by girdling the trees, letting them dry for a year or more, then felling them and burning the stumps and logs too large to be carried away as firewood. Plowing and planting take place often while the ashes are still smoldering. Some medium-sized rocks, too large for the plow to turn over easily but still small enough to be lifted by hand, are removed from the field and placed in a pile or used in constructing stone walls, but smaller stones and large boulders are left in the field. The plows are simply steered around the latter. Several such new fields have been cleared in the last two decades, doubling the amount of cleared land in the town. Some of the swiddens are along ridgetops a considerable distance from water.

Hence part of the Pima agricultural system satisfies Conklin's (1954) definition of swidden or slash-and-burn agriculture, i.e. that a field be left fallow for more years than it is planted. It does not, however, satisfy Pelzer's (1945) definition since the soil is plowed before planting. There are no unplowed fields in Nabogame, although Dunnigan (1970) reported some from Sonora. Swidden agriculture is common among traditional peoples in the tropics, but is rare among present-day groups in temperate regions. In the past, however, swidden techniques were common in many temperate areas, including the American frontier (Jordan & Kaups 1989). Swidden techniques in temperate areas have largely been replaced by more efficient systems, but persisted in Finland, Hokkaido, and Appalachia well into the 20th century (Otto & Anderson 1982).

The formation of these swiddens by removal of climax vegetation places the Pima in the minority of swidden agriculturalists who farm in this manner instead of relying strictly on areas revitalized through secondary succession (Conklin 1954). This swidden farming is a new phenomenon in Nabogame, a result of the rapidly increasing population of the last few decades. The abandoned fields north of town, however, while not directly analagous to these temporary fields, suggest that this may not be the first time the Pima have experienced difficulty with the sustainability of their agricultural system.

There are numerous wild legumes in the fallow fields, including Dalea, Crotalaria, Desmodium, Trifolium, and Cologania, which may be important in contributing nitrogen to the soil. All fields tend to be irregularly shaped, since the perimeters are defined by natural gulleys and rocky areas. Often there are one or two rows extending several meters from the main part of the field into the surrounding land. This is sometimes unintentional, the product of unruly animals or bored planters. There is also a considerable amount of land which is never planted, since it is too steep or too rocky to be planted, or because the soil is too poor to yield much. Much of this represents permanent pasture, while other land remains forested. The amount of cleared land is said to have doubled in the town in the last 20-30 years, as a result of the swidden techniques.

Fields are generally plowed twice before planting, using wooden plows equipped with metal plowshares. The second plowing is not done perpendicular to the first, as is the case among the Tarahumara (Pennington 1963; Bennett & Zingg 1935). Occasionally, fields may be planted after only a single plowing, especially if the field was planted the year before.

The plows must be made annually, or more often if one breaks. The block of the plow is made first, shaped using an ax. A hole is chiseled into the top, into which several pieces of wood are inserted to hold the tongue. The point consists of a flat metal plowshare without moldboard. A handle is inserted into a second hole in the rear and is used to guide the apparatus. Sometimes the handle is carved from a branch of the tree from which the block was made; hence the two parts are a single unit. The plow is often soaked in water overnight to make it heavier and less brittle.

Commercially-made metal plows with moldboards are also used, but only with equine draft animals. These plows tend to be curved so as to move soil primarily in one direction, unlike the symmetrical wooden plows. When metal plows are used, the fields are plowed in a spiral formation, with the soil being pushed toward the outside. This results in a very slight terracing effect, with each half being somewhat flattened. The trough in the center of the spiral is flattened by turning the plow on its side and having the animals drag it along the ground.

Pairs of horses, burros, or oxen are used as draft animals. The equine species are preferred since they walk faster, but oxen are considered stronger. If oxen are to be used, the tongue of the plow is made long enough to reach the wooden yoke strapped to the animals' horns. The yoke for the oxen consists of a single piece of wood carved to the appropriate shape. The tongue from the plow is inserted into the hole in the yoke and a wooden peg is inserted through the hole in the tongue to keep the tongue from sliding out. A shorter tongue less than a meter long is used for horses and burros. Leather collars are used for these animals, chained to wooden or iron bars behind the animals, which in turn are chained to the plow. The yoke is made of a single piece of wood with curved indentations for the animals. These are identical to Tarahumara yokes (Pennington 1963; Bennett & Zingg 1935).

The method by which the animals are controlled also differs between the different species. Oxen are directed by whipping the slower of the two animals or poking it with a stick. Whips for this purpose are made of two leather straps tied to a one-meter stick which is notched at one end so the straps will not fall off. Horses and burros are controlled by a long rein connected to the bits of both animals and looped back to the operator. The plow itself is also manipulated to control the animals. Pressing it to the ground while turning can be effective in preventing the animals from going too far afield, and twisting the plow can be used to control the location of the furrow being created. Since the handle is located above the point at which the plow is connected to the tongue while the plow point is located below it, twisting the handle to the left causes the furrow to be moved further to the right, and vice versa. On relatively shallow slopes the plowing is done perpendicular to the general slope of the land. Toward the edges of such fields the rows tend to descend into gullies. On extremely steep slopes contour plowing is frequently practiced.

Fields are planted by plowing a furrow while a second person carrying a bucket of propagules (tubers, seeds, and/or caryopses) follows behind. Propagules are thrown into the furrow at approximately one-meter intervals, half that for beans, since the plants are smaller. Two potatoes or 4-6 seeds and/or caryopses are planted per step. A second furrow is made next to the planting furrow, to cover the propagules. This is done either with the same plow which created the planting furrow or with a second plow or horse-drawn weeding device following the person with the bucket. The latter method is faster, taking slightly more than half the time of the former, but requires three people and three or four animals instead of two of each.

After the field has been planted, it is sometimes flattened using a large limb cut from a tree which is dragged across it by a horse or burro. Once the seedlings have begun to appear, the farmers walk through the fields with pitchforks, removing stones and excess soil from the tops of the plants to permit them to reach sunlight.

Preferred planting dates vary according to species and land use type, and should be regarded as approximate. The stated preference for planting maize in permanent fields, for example, is May 15, but in 1987 the planting began on May 18 and was not finished until mid-June. The dates given in response to questions reflect ideal situations rather than actual practice. The people avoid planting when the soil is already wet since many more weeds will germinate, requiring extra plowing. They also prefer to plant while the moon is in the new crescent phase, since they believe that more rain falls while the moon is waxing than while it is waning. Potatoes are generally planted in late April or early May, and maize in late May, but planting of beans is postponed until the onset of the rainy season in July.

Weeding is done 2-5 times per year in each field. Three weeding methods are employed, pulling a horse-drawn weeding device through the soil between rows of seedlings, hoeing the soil around larger crop plants, or cutting larger weeds near the base with a sickle. Horse-drawn weeding requires the labor of two individuals, one to operate the plow, the other to replant seedling uprooted by the machinery. In hoeing, the soil is generally moved toward the bases of the planted crops, forming a hill-like appearance which serves to prevent the wind from uprooting the plants. Weeding usually ceases by mid-August; by harvest time, the weeds have usually grown back to large sizes. Some of the weeds, particularly Amaranthus hybridus, Tithonia tubaeformis, and Xanthocephalum eradiatum may stand well over two meters tall, taller than the maize itself. Morning glory vines (Ipomoea spp.) are also frequently found in the fields, making them difficult to walk across.

Irrigation is practiced on a very limited scale in Nabogame. Water is carried in buckets from the creek to kitchen gardens, or by siphoning water with a rubber hose. Both techniques are feasible only in low-lying areas near the creek. Most of the agricultural fields lie too far uphill from water sources for efficient irrigation.

Scarecrows are made from poles and draped with old pieces of clothing. They are used primarily on outlying fields far from houses.

Two general soil types are recognized by the inhabitants. The center of Nabogame and the western side of the valley are formed of a purplish-red shale while the eastern hills are of a highly siliceous rhyolite. The former is the parent material of the reddish to brownish "suelo colorado", while the latter gives rise to "suelo blanco". Suelo colorado is preferred, since it is richer in minerals and in clay, thus needing less fertilizer and having a greater water-holding capacity. In some fields intermediates between the two soil types can be found.

In the winter, goat corrals are constructed in cultivable fields, so that the manure can enrich the soil. They are moved every week or two so to distribute the manure more evenly around the field. The resulting increase in soil fertility is quite dramatic. This placement of goat corrals represents the only conscious use of excretory material as fertilizer in the community; horse, burro, cattle, and hog dung is permitted to dry in the sun wherever it happens to fall. No attempt is made to move the dung to make other locations more productive, except that during plowing someone may kick dried dung from the perimeter of the field toward the center. Much of the nitrogen and organic matter contained therein is therefore lost to runoff or to evaporation to the atmosphere (Keeney 1982). Ashes from wood fires are also occasionally added to permanent fields.

Commercial fertilizer is now sometimes used, but with limited success. The people lack proper instructions in how to use these materials. The fertilizer, purchased from travelling salespeople, is often inappropriate to local conditions. Two types of fertilizer are used, urea and phosphate. I had some soil samples analyzed at the Facultad de Fruticultura, Universidad Autónoma de Chihuahua. These show that phosphorous and potassium are present in large quantities in the soil, and need not be added. Nitrogen, however, was adequate but marginal and probably represents a limiting factor. The observed beneficial effects of goat corrals suggest that in places other than those where the actual samples were collected may well be nitrogen-limited.

Land ownership is semi-communal. Nabogame is part of the same "ejido" as Yepachi, Las Varitas, and several neighboring communities. Individual families plant and maintain fields, and have exclusive rights to the produce thereof. There are no prohibitions against trespassing, and people hunt and gather wild edible plants and animals from other people's fields regularly. There are also certain structures, such as the wells and a leather-tanning pit, which are used by several families. Livestock is permitted to wander throughout the valley during the winter months, and since there are no fences separating properties all the fields become in effect communal grazing land. During the summer the animals are kept in the forest which borders the town, and are free to roam at will.

It is possible that the communal farming arrangement may predate the Mexican Revolution and be traditional among the Pima rather than entirely imposed from the outside. A similar situation was reported among the Gila River Pima of central Arizona (Hill 1936). The River Pima also had individual land holdings, but a similar commonality of useage of noncultivated resources and grazing land. When a new section of land was to be cleared for planting, the work of preparing the land was done communally by men of one or more villages, then the land would be divided among the persons who had performed the work. Rights to harvest foods on other person's property among the River Pima extended to products only; felling trees, shrubs, or cacti was impermissible. In Nabogame, however, there is no restriction on clearing of land except that surrounding currently occupied houses or fields used within the last few years.

Significant differences exist between the agricultural systems in Yepachi and Nabogame, despite the proximity of the two towns, the common elevation, and the close cultural, kinship, and economic ties. Some of the differences, such as the more widespread use of insecticide and commercial fertilizer in Yepachi, can be explained by the mestizo influx into the town and by the easier access to non-agricultural sources of income. However, other differences are due to variations in soil and climate. Because of the gentler slopes and better soil conditions in Yepachi, all the cultivated fields there are planted every year, with no fallow rotation. The Nabogame rainshadow results in differences in the timing of various activities. The optimal date for maize planting in Yepachi is considered to be May first, some two weeks earlier than in

Nabogame. The crop is harvested in September in Yepachi but in late November in Nabogame.

Kitchen gardens are also planted, usually near houses but occasionally elsewhere as well. They are surrounded by stone walls or by wooden or barbed-wire fences. These gardens contain peach and apple trees, as well as ornamental shade trees such as sauco (elder, Sambucus mexicana Presl.) and sauzo de la casa (weeping willow, Salix babylonica L.). Chayote (Sechium edule Sw.), cebolla (onion, Allium cepa L.), ajo (garlic, A. sativum L.), and herbs such as cilantro (coriander, Coriandrum sativum L.), cordoncillo (Elytraria imbricata), sampual (marigold, Tagetes erecta L.), tostón (Cosmos pringlei Rob. & Fern.), tobaco (Nicotiana tabacum L.), etc., are planted beneath the trees.

Nutritional composition of major Mountain Pima food crops is given in Table 1. Information on crop productivity is given in Table 2. The amount of land devoted to each crop was estimated by measuring the length and azimuth of each bounding line segment of each field and calculating the area by computer (Laferrière 1989b).

Maize

Maize (Zea mays L.) is present in a wide variety of races and colors. The people mix different colors and kernel shapes indiscriminately, so that most of the fields contain a great deal of genetic diversity.

The maize crop is not harvested until the entire plant is well dried. If a particular field is slow in dessicating, the tops of the stalks are cut off with a sickle several weeks prior to harvest, just above the ear, to kill the plant and hasten ripening. The ears are generally harvested and husked simultaneously. A small wooden knife called a "piscador" is held in the right hand with a leather strap around the wrist and used to slit the husks at the distal end of the ear. The lowland Pima Bajo of Sonora use similar knives (Pennington 1980). This facilitates the husking of the ear, which is then broken off and thrown on a pile. The impact of the incoming ear on the pile frequently results in the loss of a few kernels, which are generally left on the ground. In fields close to the houses, chickens generally consume the seeds, but in more distant fields they are wasted.

Some farmers knock down the maize stalks after harvest by stepping on the base of the stalks immediately after the ear is removed. This has several advantages. The downed canes serve as a marker, letting the farmer know which rows have already been harvested, and clears a space so that ears may by flung on the piles more easily. It also permits greater mobility in the harvested field. Ten rows are generally harvested as a set, two rows at a time. The fifth and sixth rows of the set are done first, in order to clear a space in the center so that the piles of harvested ears may be located in the center of the set, unencumbered by standing vegetation. Most of these stalks are left for the animals as winter feed, and are sometimes gathered into bundles to dry in the sun and to be more conspicuous to livestock grazing in the snow. Some of the stalks are stored to be fed to animals destined for work detail. Taller weeds such as juve (Cosmos parviflorus) are sometimes removed just before harvest by striking them with a strip of tire rubber, approximately one meter long and 3-5 cm wide.

A slight variant of this procedure was introduced from mestizo commercial farms near La Junta during the two-year fieldwork period and has been adopted by the majority of the people in the town. A bag is rigged with a strap so it can be worn over the shoulder while harvesting. Ears are placed directly into the bags and carried to a collection site. Using this method, the order of harvest of rows simplifies to a sequential arrangement from one side of the field to the other.

After harvest the ears are loaded into burlap bags to be transported back to the house. For short distances, the people carry the bags directly; for longer distances the bags are strapped to a burro. Many of the ears are small and diseased, especially in wet years, such as 1986 when a Pacific hurricane caused severe flooding in Nabogame.

Occasionally ears are picked unhusked, then removed from the husk by grabbing the stems below and shaking to remove the ear. The best of the bracts are then saved to make tamales.

Ears are shelled using an empty cob as a tool. Several rows of kernels are first removed from the ear by striking it with the end of the empty cob to release the kernels. The remaining rows are then removed by placing either the thumb or the side of the empty cob against the row and pushing in the the direction of the empty rows. Only ears lacking fungus or insect damage are used as human food, the others being fed to the livestock. Kernels from diseased ears are sometimes removed the same way as those for human consumption, but sometimes the ears are placed in a burlap bag which is then beat with a stick to release most of the kernels. This speeds up the process, but results in more chaff being included with the grain.

The kernels are collected in a basket, and winnowed by dropping the kernels repeatedly into a second container. Maize may be stored either as kernels stored in burlap bags or as entire ears placed in the rafters of the house. The best ears are saved as seed corn, and stored on the cob until just prior to planting time. Kernels near the distal end of the cob are not used since many of them are diseased.

Tortillas form the primary staple, consumed at virtually every meal. Maize tortillas are made by boiling the kernels with lime then grinding them. The lime (calcium oxide) is made locally by mixing crushed limestone with dried cow dung and igniting the mixture in special stone ovens. The rocks are then separated from the ashes, placed in a wooden trough, and covered with water. The water reacts with the rocks, forming a powder when dried.

In past times, the grinding of maize kernels was done entirely using a stone metate, but today the traditional methods are in decline. Some of the women use a hand-cranked metal meat grinder exclusively, while others use a combination of the two methods. They grind the kernels coarsely with the grinder, then knead the dough by hand before grinding it finer using the metate. The tortillas are formed by scooping a portion of dough from the bowl metate, and shaping it into a flattened patty by repeatedly rolling the ball in cupped hands. Once the disk-shaped patty has been made, it is flattened further by slapping it back and forth between the palms of the hands. The top of the stove is then greased using a rag containing a small piece of lard, then the patty is placed on the stove to cook. The edges of the tortilla are then flattened further by pressing down with the tips of the fingers while rotating the tortilla on top of the stove. The tortilla is flipped after several minutes, and placed in a basket when done. The resulting product is somewhat thicker than tortillas made with a press, weighing approximately 100 grams for a 15 cm tortilla. A few tortilla presses have been introduced into the community in recent years.

Flour tortillas are also consumed, made from store-bought white flour mixed with water, lard, and baking powder. The preparation technique is similar, except that the patties are rolled between a flat board and a cylindrical wooden roller instead of being pressed manually. These tortillas are generally pressed down upon with a cloth while cooking to prevent them from becoming filled with air.

Tortillas serve as the traditional eating utensil of the Pima. Enamel spoons and sharp knives are available and used for some purposes, but many items, especialy beans, are eaten by tearing off a piece of a tortilla and using it to scoop up a mouthful of food.

A maize soup called "cacale" is made occasionally, most notably on Holy Thursday. Ground kernels are boiled with onions and/or garlic.

Maize is also used in the preparation of two beverages, atole and tesguino. Atole is made by germinating the kernels by placing them in water for several days, then grinding them and pouring hot water over them. It is generally consumed hot. Tesguino is the alcoholic equivalent, made from ground germinated corn, mixed with hot water and allowed to ferment several days before consumption. The fermentation is done in the same ceramic pots and bottle gourds year after year. These containers are lined with yeast which cause the fermentation (Litzinger 1983). Between uses the pots, stored upside-down in the shade, smell like rising bread. Today, plastic containers are used to supplement the traditional ones, with the liquid being periodically poured from one container to another to assure dissemination of the fermenting microbes.

Besides the mature caryopses, the maize plant serves or has served as sources of three other food items and one medicinal use. The soft pith of immature corn stalks is highly valued as a snack. People chew the pith to extract the sweet sap, then expectorate the fibers. This is done early in the season, just as ears begin to form on the plants. Plants without ears are removed and used for pith chewing; these are considered sweeter than plants with ears. This also serves to thin the field of plants which will not produce seed. Immature ears are also consumed, boiled or roasted over an open fire. Harvesting of these ears is also used as a mechanism for thinning out the crop, so that only 2-3 ear-bearing plants are left in each hill. In years past, maize pollen was harvested from flowering tassels. Two tassel spikes per plant would be picked early in the morning before the flowers opened, then partially dried in the sun before being boiled and eaten. Finally, maize "silks" are saved during harvest and used to make an infusion for treating heart problems. This is probably effective, since these silks contain cardiac glycosides (Hoppe 1975).

Beans

Beans are grown on steeper land and poorer soil than maize. As with the maize, several colors and sizes of beans (Phaseolus vulgaris L. and P. coccineus L.) are frequently intermingled. They are harvested by dislodging the entire plant including the roots. This is done early in the morning since the ground is still moist at this time and less dust is released into the atmosphere. The people then place the plants on a sheet of polyethylene and beat it with a 2 m pole to release the seeds. The plastic is rolled so that the seeds form a pile in the center. The larger stalks are removed by hand and fed to the livestock, while the smaller chaff is removed by winnowing. The beans are poured from one wicker basket held at shoulder height to another on the ground, allowing the wind to blow away the debris. The beans are stored in barrels or burlap bags and picked over by hand to remove rocks and small clods of dirt prior to use. The beans are generally soaked in water and boiled several hours before being either served as a soup or fried in lard. Cheese is sometimes added at the table before consumption, if available. One farmer has a small patch of peas (Pisum sativum L.) which he considers a variety of bean.

Tortillas and whole boiled beans are used as weaning foods, served to children approximately one year of age. Mother's milk is phased out gradually.

Potatoes

Potatoes (Solanum tuberosum L.) are only planted in the best farmland, since the rocky nature of the soil on steeper hillsides make harvest impractical and yields low. There are two types of potatoes present, white and yellow, the white being much preferred. They are frequently rotated with maize since the yields drop considerably if potatoes are planted in the same field two years in succession.

Potatoes are more labor-intensive than other crops, since they must be harvested from below ground level. They are planted in April or early May and harvested in September or October, well before the maize and bean crops.

The Pima remove sprouts from the tubers before planting since they believe tubers with sprouts will not germinate. This is just the opposite of present commercial practices. Sprouting, or "chitting" is considered essential for successful germination (Rastovski et al. 1987). Desprouted potatoes form the same number of sprouts as in the first sprouting, but growth will be delayed (Rastovski et al. 1987). The Pima technique, however, may be adaptive given Pima storage techniques. Commercial growers "green" potato sprouts by exposing them to sunlight prior to planting (Rastovski et al. 1987). This thickens and hardens the sprouts to lessen physical damage incurred during planting. Long, etiolated sprouts such as those found on stored Mountain Pima potatoes may suffer tip damage causing release of apical dominance and formation of several weak plants instead of a single strong one (Rastovski et al. 1987).

The Pima eat larger potatoes, while saving only the smaller ones for planting. This results in a very gradual diminution in the size of the potatoes as somatic mutations for small size accumulate. Tubers rarely grow more than 5-6 cm in diameter.

Potatoes are consumed in a variety of ways. One common method is by peeling, slicing, and boiling, the resulting mixture being consumed as a soup. Cheese, onions, garlic, and other flavorings are added if available. Occasionally the mixture is fried in lard before consumption. Potatoes are also sometimes baked, by leaving them unpeeled on top of the stove, or fried in lard with onions and/or garlic. Potato chili is also made. The people are aware of the potentially toxic nature of green tubers and do not use them.

Squash

Squash (Cucurbita pepo L.) is intercropped with maize on good permanent fields by mixing maize caryopses with squash seeds in a ratio of approximately 20:1. A variety of shapes, ranging from nearly spherical to more elongated, may be harvested from the same field. Most are green when ripe, although some may turn entirely orange or have green and yellow stripes.

The plant yields several distinct products, all currently utilized by the Pima. Immature fruits are picked in August and September, and eaten boiled or fried. Male flowers are harvested during the same period, and served fried. This flower collection is usually performed by small children in the early hours of the morning, before bees and other insects become numerous in the flowers. Slightly immature fruits are harvested in November, peeled in a spiral direction around the perimeter, then cut into strips and dried. When partially dried they are wound helically into a spool-like form which can be further dried and stored for the winter. Mature fruits are harvested in November and December, after the vines have completely dried. The squash is cut open and the seeds removed and dried for use in soup. The flesh is cooked by boiling, and eaten by using a spoon or the teeth to scrape the edible portion from the harder skin.

Wheat

A few families plant wheat (Triticum aestivum L.) in an fenced field resembling an extended kitchen garden. The seed is broadcast-planted in January and the crop harvested in June or July using a sickle. Maize is then frequently planted in the same fields during the summer. The entire dried wheat plant is cut from the ground and placed on the roof to dry. The grain is removed, winnowed, and ground into flour for bread or tortillas. Wheat today constitutes a small proportion of the total yield of the community, but was more important in times past.

Oats

Oats (*Avena sativa* L.) are a minor crop grown almost exclusively as livestock feed, although atole is occasionally made from the caryopses. Oats are broadcast-planted during the last few days of August. The second plowing of the field serves to bury the seeds in the soil. The plants are allowed to dry in the field, then are cut with a sickle near ground level and bound together in bundles to dry in the sun. Many stalks seem to be missed by the harvesting, especially where weeds are tall. The entire plant is dried for storage and later fed to the animals. It is valued over the natural vegetation largely because of the seed production which supplies a much-needed source of protein and energy to the livestock. Seeds of the non-cultivated weeds in the fallow fields, in contrast, generally fall to the ground before the animals can eat them, leaving only the fiber-rich stallks.

Sorghum

A small amount of "caña dulce" (*Sorghum bicolor* (L.) Moench.) is sometimes planted in the flat arroyo land in

July. It is valued for the sweet pith of the stems, which are used in a manner similar to those of maize.

Garden vegetables

Traditional garden vegetables include chiles, tomatoes, onions, garlic, and cilantro. Chiles (*Capsicum annuum* L. var. *annuum*) are germinated in soil in enamel pots, then transplanted to the field. When the fruits are mature, they are ground first with the metate, seeds and all, before being mixed with flour to form a red paste. This paste is then placed in a pot with water and cooked, then mixed with meat, beans, or potatoes before consumption. Tomatoes (*Lycopersicon esculentum* Mill.), are also planted in the same gardens, and eaten raw or stewed. Onions and garlic are planted as well, and used primarily as flavoring ingredients to enhance the appeal of other foods. Cilantro is broadcast-planted in kitchen gardens during the winter. The leaves are valued as flavoring ingredients in soups.

Chayote is planted in the kitchen gardens and is allowed to climb the fences and the trees. The fruits are harvested by picking them directly off the vine. They are cooked by placing them whole directly in a fire and allowing them to bake several hours. They are eaten by cutting them in half and scooping out the soft flesh with a spoon.

Bottlegourds (Lagenaria siceraria Standl.) are another minor crop which has been declining in importance in recent years. The gourds were formerly used as ladles, drinking implements, and as containers for liquids, roles now largely superseded by metal and plastic implements. A few gourd plants, however, are still occassionally planted.

In recent years several other vegetables have been imported into the town, such as "calabaza mayera" (zucchini, Cucurbita pepo). This is a bushy rather than viny variety, producing a large quantity of fruit in a small space. The fruits of this plant are eaten green. Seeds must be purchased each year since the variety mixes genetically with the local traditional varieties. Repollo (cabbage, Brassica oleracea L. var. capitata L.) and lechuga (lettuce, Lactuca sativa L.) are also planted, but these seeds must also be purchased each year since the people do not know how to induce flowering.

Fruits

Duraznos (peaches, Prunus persica Batsch.) are commonly planted in the gardens surrounding the houses. Several different varieties are present in the town, varying in color, ripening time, and degree of adherence of the flesh to the stone. The fruits are peeled and eaten raw and are sun-dried for the winter. Some peaches are picked green and eaten roasted or boiled with sugar. Green peaches are higher in fiber but lower in carbohydrate than ripe peaches (Laferrière et al. 1991a). Seedlings sprout naturally in the ground, and are transplanted to appropriate sites. Peach seeds are not used medicinally, as they are among the Navajo (Elmore 1978). Manzanas (apples, Malus sylvestris Mill.) are very common in Yepachi, but attempts to introduce them into Nabogame have been unsuccessful because of the drier climate. One schoolteacher tried to introduce plums (Prunus sp.) but the trees were eaten by goats.

Table 1: Estimated nutritional composition of Mountain Pima crops

	moisture (%)	protein (%)	carbohydrate (%)	lipid (%)	Ca mg/100g	A RE/100g	C mg/100g	lys %	met+ cys %	Energy kcal/100g	REFERENCE
maize											
(immature)	69.6	3.3	25.1	1.3	2	22	6.2			125	1
(tortillas)	47.5	4.6	45.3	1.8	196	20	0.0	0.16	0.22	216	2
beans	66.9	8.7	22.8	0.5	28	0	1.2	0.60	0.22	131	3
wheat	13.1	12.6	71.2	1.5	29	0	0.0	0.34	0.52	349	4
squash											
(immature)	93.7	0.9	4.3	0.3	27	29	5.5			24	1
(mature)	89.0	0.9	8.8	0.6	14	356	9.6			44	1
(seeds)	4.5	18.6	53.8	19.4	55	38				464	5
potatoes	77.5	1.7	20.0	0.1	8	0	7.4	0.10	0.05	88	1
chayote	93.4	0.6	5.1	0.5	13	5	8.0			27	1
peaches											
(immature)	78.1	0.6	14.1	1.7	28	20	3.7			74	6,7
(mature)	78.1	1.2	19.7	0.3	9	20	3.7			86	7

REFERENCES:

1 = Haytowitz & Matthews 1984a

2 = Leung & Flores 1961

3 = Haytowitz & Matthews 1984b

4 = Drake et al. 1989

5 = McCarthy & Matthews 1984

6 = Laferriere et al. 1991a;

7 = Gebhardt et al. 1982

Table 2: Productivity of Mountain Pima crops

	LAND PLANTED (ha)	YIELD (kg/ha)	OVERHEAD (h/ha)	OVERHEAD (h/kg)	EFFECIENCY (h/kg)	TOTAL WORK (h/kg)	SHORTFALL IN 1988
beans	6.0	544	163	0.30	0.23	0.53	70%
chayote	0.1	2500	30	0.00	0.15	0.15	30%
maize	28.6	256	146	0.57	0.40	0.97	80%
peaches	0.1	25000	0	0.00	0.15	0.15	30%
potatoes	1.5	3850	320	0.08	0.20	0.28	120%
squash	10.9	50	14.6	0.29	0.30	0.59	80%
wheat	5.0	550	120	0.22	0.20	0.42	100%

CHAPTER IV

HUNTING, FISHING, AND ANIMAL HUSBANDRY

Cattle, goats, pigs, horses, donkeys, chickens, turkeys, cats, and dogs are raised in Nabogame. Larger livestock are allowed to roam free much of the time. During the summer they are excluded from the agricultural areas by the perimeter fence. During this time the weeds in the fallow fields grow to 2-3 m in height, making the fields nearly impossible to walk through. The danger of snakes lurking in the vegetation adds to the difficulty of mobility through this area. After harvest season the gates in the perimeter fence are opened and the livestock is allowed to graze on weeds and agricultural stubble.

The land in the town is severely overgrazed. There are very little undergrowth and few tree seedlings in the forest. Older Pima maintain that as recently as 30-40 years ago there were many more herbs present in the forests, and blame the decline on the overabundance of livestock. During the winter, the animals consume the overwhelming majority of the crop stubble and the weeds and other vegetation present in the agricultural areas in the central part of the valley. By May, when the dry season overlaps the end of the winter grazing period, the vegetation is depleted to the point where there is a considerable amount of bare soil on the cultivated land.

Corrals effectively enclose hogs and goats and also exclude them from sites where trees have recently been planted. They are made from poles lain on top of one another, notched at the point of contact to prevent rolling. No nails or adhesives are employed. Square corrals are built with alternating series of parallel beams. Enclosures of more than four sides may also be constructed by laying a single pole at one side of the polygon, then laying two more poles at either side overlapping the first. More poles are lain across the free ends, two at a time, until a single pole can be added to finish the enclosure. Further layers are added parallel to the first, so that the resulting corral appears from the side to be slanted away from the initial beam. Some corrals near seasonal ranchos are built in the mouths of caves.

Average annual animal consumption in Nabogame at present is given in Table 3. Nutritional composition of domesticated animals is given in Table 4. A composite was calculated to reflect consumption patterns.

Cattle, horses and burros

Cattle are used primarily as sources of milk which is frequently made into cheese during September and October.

They are occasionally killed for meat and leather. Horses and burros are used for transportation, and as beasts of burden. They, along with oxen, are also used as draft animals. It can sometimes require a considerable length of time to find an animal in the forest when needed. Horses are sometimes tied to trees or posts in town, if the need to use them soon is anticipated. This allows the animals to feed during the night, and permits the people to get an early start in the morning with well-fed animals. Unruly cattle are tied with chains, and burros are sometimes shackled by tying their forelegs together with rope. Calves are weaned by placing a nail through its nose with a flattened steel juice can suspended from it.

Leather is tanned in a rectangular, concrete-lined pit in the center of town. Cattle hide is placed in the pit, in alternating layers with the crushed bark of carnero (alder, Alnus oblongifolia) or encino colorado (Quercus durifolia). Water is then poured over the mixture, which develops a reddish tint because of the tannins in the middle layers bark. The leather is allowed to remain 15 days, with fresh water being added periodically to prevent the contents of the pit from drying out. The leather is then hung to dry. It is used to make cords and shoes.

Goats

Goats are allowed to roam free during the day but are corralled at night to protect them against coyotes. They are fitted with bells and tended by dogs referred to as "chiveros" ("goaters"), who herd them and protect them from coyotes. Coyotes are not very common, but can do a significant amount of damage to the herd when present. The dogs are said to be difficult to train since they have a tendency to attack small kids.

Kids are born in March or early April. Mothers with kids too young to forage for themselves are allowed to remain outside the corral with their offspring at night, then separated in the day so the mother can feed. The young kids are placed in a corral. Older kids are separated from their mothers at night in separate pens in order to increase milk supply. Mothers are milked in the morning, then the kids are released from their corrals. Both the kids and the nannies are capable of climbing over the walls of the maternal corral, and the kids are permitted to enter and feed for a few minutes. They are then thrown out of the corral and herded in a different direction from their mothers. Theoretically, the two herds remain separate for the entire day, but in practice they can often be seen to have merged by afternoon. The dogs herd the goats back toward the corrals in the evening, whereupon children with lassos round up the goats and force them into the corrals. This is generally more difficult with kids than with nannies, who have learned the routine and acquiesce more easily.

Occasionally a kid is orphaned by the death of its mother. When this happens, the kid is allowed to enter the human living quarters. They are thus the only animals other than cats and chickens permitted indoors. They are fed by allowing them to enter the nannies' corral during milking time and permitting them to feed from a female whose horns are held to force it to allow the kid to feed.

Goat milk is available only from April until June. Milking is done by climbing into the nannies' corral and using a plastic container to collect the liquid. The goats are immobilized by squatting with the goat's right rear leg behind the milker's knee. Particularly unruly animals are further stabilized by having an assistant hold the goat by the horns. Most of the milk is used in the manufacture of cheese. The milk is first strained through a cloth into a plastic bucket. A tablespoon of rennet obtained from a goat's stomach is then mixed in. Approximately 90 minutes later, the curds are collected by sticking one's hands into the bucket and squeezing out the liquid. The curds are then placed in a cloth and squeezed to release more liquid, then placed under a rock on a metate overnight. Cow cheese is made in a similar manner except that a special cheese press is utilized. The cheese is similar to feta but considerably drier and can be stored several months. From the whey a second curdling operation is performed by adding more rennet and heating the mixture on the stove. The resulting product, called "requez'on," is similar to cream cheese in texture and must be consumed the same day it is made.

Male goats and post-reproductive females are butchered and eaten. The meat is hung from the rafters of the houses to dry, then cooked when needed. Meat is cooked in soup or skewered and roasted in the fire.

Hogs

Hogs are kept corralled in the summer but during the winter are allowed to roam the valley with the larger animals. While corralled they are fed kitchen waste and spoiled or insect-infected agricultural produce. While free they dig for roots and other items not consumed by the other livestock. In the process they can cause a significant amount of erosion, especially on steeper slopes overlooking the larger arroyos, since these slopes are composed of powdery, loosely packed soil and are nearly devoid of vegetation in the dry season. After planting but before the plants come up, the pigs are allowed outside the corral but are shackled to limit their mobility and prevent them from digging up and eating the propagules which have been planted.

Chickens and turkeys

Fowl are allowed to roam free in the village and in the homes. Chickens are much more common than turkeys. The chickens are provided elevated wooden roosts or rock enclosures in which to escape from the rain and from predators, but during the day can frequently be seen in the maize fields consuming unharvested grain. The people also feed grain directly to the birds by scattering it on the ground.

Chickens are occasionally killed for meat, but are primarily valued for egg production. Eggs are sometimes laid in the roosts, but often they are hidden in the field by the free-roaming hens and the people must search for them. Many of the eggs are probably fertile, since no attempt is made to separate hens from roosters. They are invariably white-shelled, brown eggs being unknown. They are cracked into a bowl, then cooked in molten lard in a cast iron frying pan, either scrambled or sunny-side up, with large quantities of salt being added. The pan is held inside the oven rather than being placed on top of it, as is the case with most cooking. Excess melted lard is generally scooped from below the eggs to their top during cooking. Eggs are generally available only from November through April.

Cats

Cats are kept primarily for rodent control. They are fed largely on table scraps but are encouraged to chase mice, gophers, and whatever other animals they can find. They regularly bring their prey into the house to consume it. The people, especially small boys, also kill birds with slingshots to feed to the cats. Two types of slinghots are used, small commercially-produced ones consisting of a forked piece of plastic connected by solid rubber straps to a leather sling, and larger locally-made ones entirely of leather with long straps. Both kinds are used for herding animals as well as killing birds. All types of wild birds except hummingbirds are killed in this manner, since birds are considered destructive of grain crops (or trees, in the case of woodpeckers).

Dogs

Dogs are fed a slurry of table scraps, tortilla dough, meat, and other kitchen waste, mixed with water in a metal bucket and heated on the stove. This is poured into a trough made of a hollowed log.

Fish

Four species of fish are found in the waters around Nabogame, but most are small. They are however occasionally eaten, primarily during the dry months of May and June. The largest is vagre (Ictalarus sp.), a catfish up to 60 cm in length. The other three unidentified species are called matalote, sardina, and pescado chino. A fifth, striped species, pescado de zorrillo, was common in the past but locally extinct at present.

Three methods of capturing fish are presently in use in the area. The first involves a stick, a metal hook, a worm, and a nylon line, thus resembling the technique used by American sports fishermen. Leaves of chugilla (Agave shevei ssp. matapensis) are crushed in water to stupify large quantities of fish. This is only effective in ponds lacking a powerful current which would dissipate the toxin. Traps are occasionally used, made from wood or from stalks of some of the larger weeds of the fields (e.g. jarilla grande, Xanthocephalum eradiatum). These traps are in the shape of rectangular prisms, open at the top. These are placed in running water and strain the fish from the water preventing them from moving up- or downstream.

Fish once caught are cleaned by slitting them, starting from the dorsal fin and proceding first forward then backward along the spine. The air bladders and other internal organs are discarded, and the remainder washed in the water and strung onto a despined sotol leaf to be brought home. The entire exterior portion of the fish, including head and bones, are eaten fried with onions and/or garlic.

Hunting

Wild animals are commonly hunted with rifles or slingshots, or killed by throwing rocks at them. Species eaten include venado (white-tailed deer, Odocoideus virginianus), ardilla parda (Arizona gray squirrel, Sciurus arizonensis), ardilla roja o voladora (Nayarit squirrel, S. nayaritensis), javelin (collared peccary, Dicotyles tajacu), cholugo (coatimundi, Nasua nasua), conejo (eastern cottontail, Sylvilagus floridanus), liebre (probably the black-tailed jackrabbit, Lepus californicus), huijolo (turkey, Meleagris gallopavo), gogorniz (Montezuma quail, Cyrtonyx montezumae), tortolita (Inca dove, Scardafella *inca)*, and paloma (mourning dove, *Zenaida macroura)*. No reptiles, amphibians, or invertebrates are consumed as food, although rattlesnake blood is used medicinally. People kill squirrels by throwing rocks at them to knock them from the tree, then sending dogs to run them down. They are butchered by removing the feet and tail, scraping off the fur, then cutting the animal in half and boiling it. Deer are killed with rifles and butchered much the same as goats. Turkeys are either killed with rifles or caught in pit traps.

Immature wild animals are occasionally captured alive by lassooing them with a rope, then kept in a cage or tied to a stake. They thus can be kept alive and fed for several weeks. I have observed both cottontail rabbits and white-tailed deer treated in this manner.

Nutritional composition of Mountain Pima game animals is given in Table 5. A composite was calculated based on an average weighted to reflect contemporary consumption patterns in Nabogame.

Honey

Honey is harvested from wild bee hives found in the forested areas surrounding the community. The people throw rocks at the hive to dislodge it from the tree, then let it sit for three or four days, by which time the bees have vacated the hive. The papery combs are then consumed unprocessed for the honey contained therein. Care is taken not to consume the white, waxy cells, which are known to contain bee larvae.

Table 3: Annual animal consumption per family

	Number consumed	Amount (kg)
chickens	6	36
coatimundi	1	10
cow cheese	-	50
deer	1	100
doves	50	25
eggs	2400	136
goat cheese	-	21
goat meat	2	40
grouse	8	4
peccary	1	22
pigs	1.5	80
rabbit	1	2
squirrels	50	35
turkey	1	5

Table 4: Nutritional composition of Mountain Pima livestock

	moisture (%)	protein (%)	carbohydrate (%)	lipid (%)	Ca mg/100g	A RE/100g	C mg/100g	lys %	met+cys %	Energy kcal/100g	REF
goats											
(meat)	68.2	27.1	0.0	3.0	17	0	0.0	2.02	1.05	135	1
(cheese)	55.2	14.2	4.1	21.3	492	250	0.0	0.81	0.38	265	2
cattle											
(meat)	46.9	25.0	0.0	26.9	10	0	0.0	2.08	0.92	342	3
(cheese)	41.1	23.2	2.8	29.7	674	302	0.0	2.12	0.70	371	2
chickens											
(meat)	60.1	26.8	0.1	13.3	15	189	0.5	2.16	1.07	227	4
(eggs)	73.2	11.1	2.2	12.2	71	195	0.2	0.87	0.59	163	2
pigs	59.0	27.0	0.0	13.0	8	2	0.4	2.66	1.02	225	5
Composite		19.6	1.0	11.3	39.4	114.7	0.3	1.65	0.83	184	

REFERENCES:

1 = Anderson 1989

2 = Posati & Orr 1976

3 = Anderson et al. 1986

4 = Posati 1979

5 = Anderson 1983

Composite is an average weighted to reflect current Mountain Pima utilization patterns.

Table 5: Nutritional composition of game animals

	moisture (%)	protein (%)	carbohydrate (%)	lipid (%)	Ca mg/100g	A RE/100g	C mg/100g	lys %	met + cys %	Energy kcal/100g	REFERENCE
coatimundis	54.3	29.2	0.0	14.5	10	0	0	2.54	0.62	247	Anderson 1989
deer	65.2	30.2	0.0	3.2	7	0	0	2.64	1.08	150	Anderson 1989
doves	56.6	18.5	0.0	23.8	13	73	6.1	1.91	1.07	288	Posati 1979
quail	70.0	21.8	0.0	4.5	13	17	7.2	1.91	1.07	128	Posati 1979
peccaries	72.5	21.5	0.0	3.3	12	0	0	2.12	0.81	116	Anderson 1989
rabbits	61.4	33.0	0.0	3.5	18	0	0	2.89	1.24	164	Anderson 1989
squirrels	70.3	24.1	0.0	3.7	2	0	0	1.75	0.53	129	Anderson 1989
turkeys	62.0	28.0	0.1	9.5	26	68	0.1	2.56	1.10	198	Posati 1979
Composite		25.6	0.0	8.4	9.4	17.9	1.6	2.31	0.94	178	

Composite reflects average weighted to reflect Mountain Pima utilization patterns (see table 3).
Figures for peccaries and coatimundis are taken from those for wild boar and raccoon, respectively.

CHAPTER V

WILD EDIBLE PLANTS AND FUNGI

The Mountain Pima utilize several noncultivated plants and animals for food, fiber, building materials, medicine, and several other uses (Table 6). On a percent weight basis, noncultivated edible plants constitute only a small portion of the total diet, but their importance is far greater than this small percentage would suggest. Many of the wild plant foods represent important sources of vitamins and minerals, especially vitamins A and C. Such resources represent important sources of these nutrients for the neighboring Tarahumara (Connor et al. 1978, Cerqueira et al. 1979). Wild plants become extremely important during certain seasons of the year. Most of them are available in summer, when stores of the previous year's maize and bean harvests are running low.

Estimated nutritional composition of some Mountain Pima noncultivated plant foods is given in Table 6. For some species, lack of published information required use of estimates based on species related to the actual species used by the Mountain Pima. Calcium figures for *Amaranthus* and *Opuntia* were adjusted to reflect oxalate content (Haytowitz & Matthews 1984a; Trachtenberg & Mayer 1982b). This resulted in net negative calcium figures for the former. Vitamin values for all species except Amaranthus are estimates based on published figures for close relatives of the species indicated. All are congeners except as follows. Vitamin values for Arbutus xalapensis, Prionosciadium townsendii, and Dahlia coccinea are those of Arctostaphylos tomentosa Lindl., Pastinaca sativa L., and Helianthus tuberosus L., respectively (Leung & Flores 1961; Haytowitz & Matthews 1984a). Ascorbate value for Jaltomata procumbens is for Solanum tuberosum L. (Duke 1985), while the vitamin A value is for Physalis peruviana L. (Leung & Flores 1961).

Harvest effeciency of noncultivated plants is given in Table 8. Search time incorporates time spent travelling to and from collection site, whereas handling time represents time spent harvesting and processing food items. Quelites (wild eidble greens, especially Amaranthus hybridus) had a virtually infinite availability during June and July because any harvested were immediately replaced. The Mountain Pima kill far more quelites in the course of weeding their fields than they could ever possibly consume.

Cacti

Fruits and cladodes (pads) of Opuntia spp. have been widely utilized as food sources in much of the New World

(Meyer & McLaughlin 1981; Russell & Felker 1987). Six folk taxa of prickly pear (Opuntia spp.) are recognized by the Pima of Nabogame. These include the cultivated nopal de Castilla (O. ficus-indica (L.) Miller) and five wild taxa, i.e. nopal temporal (purple-fruited individuals of O. cf. robusta), tuna noviembreña (red-fruited O. cf. robusta), nopal de zorra (O. cf. macrorhiza), duraznillo blanco (yellow-fruited O. durangensis), and duraznillo colorado (red-fruited O. durangensis).

The cladodes are especially important during the spring dry season since they are one of the first noncultivated resources to become available in the year. Cladodes of all six taxa are used in much the same manner. Nopal temporal is the most important, producing the largest cladodes and growing abundantly in virtually any nonplowed site. Tuna noviembreña is very similar, but has red rather than purple fruits which mature in October or November rather than August. Nopal de zorra is a small recumbent species producing narrow obconical fruits. The immature cladodes of both these species have an orange tint, especially toward the distal edge. Duraznillo is strikingly different in general appearance, being a darker shade of green and having smaller cladodes bearing shorter but more numerous spines while lacking the reddish tint. Nopal de Castilla is planted in a few kitchen gardens, and is valued for its large size and absence of spines.

The Mountain Pima harvest the cladodes by holding a bucket underneath and cutting the base, allowing the cladode to fall in. They remove the spines and glochids on a rock at the bank of the brook, scraping away the areoles with a knife, spoon, or other metal object. The small glochids can cause inflammation of the mouth if ingested (Georgi et al. 1982). Scraping is done first toward the distal end of the cladode, removing the majority of the spines, then reversing the scraping direction to remove the remainder. Water is periodically flushed over the cladode to clean away the loosened spines. A few of the cladodes are eaten raw, but the majority are chopped and fried in lard with onions and/or garlic. The cladodes are cut by holding them vertically in the left hand and making parallel slits downward toward the base, followed by further slits perpendicular to the first.

The Mountain Pima consume fruits or "tunas" of all local taxa of <u>Opuntia</u>. The fruits ripen in August and September except for those of tuna noviembreña which mature in October or November. Those of nopal de Castilla and nopal temporal are preferred, since they are much larger that the fruits of the other two species. The spines of both species are removed using cuts parallel to and just below the skin. Fruits of nopal de zorra are too juicy for this method, since the interior of the fruit consists primarily of mucilaginous endocarp; hence the juicy area is generally scraped out with a knife. The fruits of duraznillo are the smallest and driest of the four species in the community. These are seldom utilized, but are treated like those of nopal temporal.

All cladodes present in Nabogame are higher in carbohydrate and lower in ash and protein than the values reported for cladodes of the cultivated O. ficus-indica (Feitosa-Teles 1977; Feitosa-Teles et al. 1984; Laferrière et al. 1991a). Cladode composition can vary depending on degree of maturity; protein and fiber contents tend to decrease on a percent weight basis as the cladode matures, while starch, lipid, carotene and free sugar increase (Retamal et al. 1987; Rodriguez-Felix & Cantwell 1988).

The cladodes have a very high calcium content, although this may vary somewhat according to soil content (Nobel et al. 1987; Gonzalez 1989). The high calcium values of Opuntia cladodes are largely due to the plants' accumulation of insoluble calcium oxalate. Up to 85% of the calcium in some cacti may be in the form of calcium oxalate (Trachtenberg & Mayer 1982b). This may constitute as much as 21% of the dry weight of the cladodes (Rodriguez-Mejia et al. 1985). Opuntia plumbea Rose contains 1.5% oxalate content by fresh weight (Justice 1985). This makes much of the calcium unavailable for human consumption. The calcium present in the cladodes shifts on a diurnal basis from being bound as calcium oxalate to being bound to the mucilage (Trachtenberg & Mayer 1982a,b). This is as a result of the pH cycles characteristic of Crassulacean Acid Metabolism common to most cacti (Trachtenberg & Mayer 1982a,b). Hence the amount of calcium available for digestion may vary according to the time of day.

The quantity of carbohydrate available for utilization may be also somewhat lower than our figures indicate. Some of the mucilage which constitutes a significant proportion of the carbohydrate fraction is digestible, but a sizeable fraction is not. The proportion of digestible matter varies from one species of Opuntia to another (McGarvie & Parolis 1979b, 1981). The hypoglycemic effect reported for Opuntia cladodes (Ibañez-Camacho et al. 1983; Frati-Munari et al. 1987) may be due to an inhibition of the absorption of simple carbohydrates rather than any direct effect on insulin production (Frati-Munari et al. 1988).

Fruits of cholla (Mammillaria barbata, M. cf. sonorensis, Echinocereus stoloniferus ssp. tayopensis, E. sheeri var. sheeri, and E. polyacanthus var. polyacanthus), are also eaten raw when mature in late summer, but are small and comparatively rare. Echinocereus fruits possess sharp spines which adversely affect their utilization.

Fruits of other species of Mammillaria and Echinocereus have been reported consumed by the Navajo, Seri, and Tarahumara (Elmore 1943; Vestal 1952; Felger & Moser 1985), and by the Pima of Arizona (Curtin 1949). Stems of several species of Mammillaria have also been consumed as food (Robbins et al. 1916; Vestal 1952). Some of the latex-containing species, however, have been used as hallucinogens (Bye 1979). Fruits of E. coccineus Engelm. are reportedly poisonous and used by the Navajo as a heart stimulant (Elmore 1943). Stems of certain species of Echinocereus have been used as hallucinogens (Bye 1979; Ferrigni et al. 1982), although stems of other species have been used to make candy (Nobel 1988).

Agave

Chugilla (Agave shrevei) supplies the Mountain Pima with two food items plus a potent piscicide. Immature flowering stalks or "guiotes" are harvested in May and June. The people roast the stalks in the fire, then peel them and chew upon them to extract the juicy interior. The fibrous material which constitutes a large fraction of the stalk material is then spit out.

Leaves of Agave shrevei contain several compounds which inhibit their utilization as food sources. These leaves are used raw as fish stupification plants by the Mountain Pima and the Tarahumara (Bye et al 1975; Dunnigan 1970; Bennett & Zingg 1935; Gentry 1982). The plants contain several different saponins, primarily hecogenin and manogenin, but no flavones or tannins (Hegnauer 1963, 1986; List & Horhammer 1972; Dominguez et al. 1960). The saponins present in the leaves and rootstocks make these tissues useful for washing clothes (Sheldon 1980). Extracts from Agave sap affect the nervous system and produce diarrhea when injected into laboratory animals (Jones et al. 1932). Sap from Agave leaves also kills snails and inhibits the growth of fungi (Shoeb et al. 1986; de Cassia-Salomão & Purchio 1982) and has been used as an antiseptic (Davidson & Ortiz de Montellano 1983). An unidentified compound in many species, including A. shrevei, causes painful skin irritation (Gentry 1982, and personal observation).

Leaves of various species of Agave have, however, commonly been roasted and consumed as food throughout the range of the genus (Gentry 1982; Castetter et al. 1938; Ebeling 1986; Mitich 1976). The Mountain Pima use the white leaf bases of A. shrevei by roasting them in large pits, peeling them, and eating them. The roasting is sufficient to destroy most of the saponins, leaving a rather sweet, juicy but fibrous mass. The roasting pits are rather large and can often still be seen years after their utilization.

Roasting may alter the digestibility of some nutrients as well as lower the saponin content.

Other fruits

The Mountain Pima also utilize several other wild fruits, although none is common enough to make a significant contribution to the diet. The most important of these is ahuasiqui (Prunus gentryi), which grows along the banks of some of the larger creeks. The fruits mature in June and July. Two folk species are recognized, the purple-fruited ahuasiqui negro (P. gentryi f. gentryi) and the yellow-to-scarlet-colored ahuasiqui blanco (P. gentryi f. flavipulpa) (Laferrière 1989a). The latter is considered less astringent than the former. Capulin (Prunus serotina var. virens) is also present in similar habitats, but is underutilized because of its astringent taste. Parra (Vitis arizonica) is also present in shaded canyons, but rarely yields enough fruit to make a foraging trip worthwhile. This plant is more esteemed for the use of its leaves to treat pimples. The fruits are, however, consumed in the southwestern United States (Castetter 1935; Palmer 1878).

Berberis pimana, variously called palo dulce, palo aigre, or palo amarillo, is common in shaded canyons, and is eaten raw by some persons but disliked by others because of its strong acidity (Laferrière & Marroquin 1990). Norton et al. (1984) reported values of 1.91 mg calcium, 3 mg iron, 85 mg magnesium, 5 mg zinc, and 145 mg ascorbate per 100 g for B. nervosa Pursh. Petcu (1965, 1966, 1968) reported ascorbate contents ranging from 329 to 525 mg per 100 g fresh weight of fruits of various Romanian species of Berberis. Wierzchowski & Bubicz (1959) reported 92 mg beta-carotene per 100 g fresh fruit pulp of B. vulgaris L. Thirteen species of Berberis from the Soviet Union ranged from 22.0-73.3 mg/100g vitamin C and 0.41-1.17% sugar (Kharitonova 1986). Sugars of B. vulgaris are predominantly galactose and arabinose but significant amounts of fucose, xylose, and rhamnose are also present (Martynov et al. 1984).

Berberis fruits contain compounds limiting their utilization in large quantities. Fruits of B. siamensis (Takeda) Lafer. are eaten in Thailand and considered diuretic and a demulcent in dysentery (Ruangrungsi et al. 1984). Many alkaloids are known from the root bark of Berberis spp. (List & Horhammer 1972) and a few have been isolated from fruits (Brázdovičová et al. 1980).

Manzanilla (Arctostaphylos pungens) is very common in certain drier areas, forming open thickets with Quercus chuhuichupensis. Its dry, amber-colored fruits are eaten raw in June and July by the Mountain Pima, Tarahumara, Zapotecs and Warihio (Pennington 1963; Gentry 1963; Uphof 1959). Fruits of various species of Arctostaphylos have been consumed in large quantities by the natives of California, either fresh or dried (Wickson 1889; Balls 1962; Ebeling 1986). A cider can also be made from the fruits of several species (Ebeling 1986; Wickson 1889; Palmer 1878). The fruits, though edible, tend to be dry and mealy, and difficult to digest in large quantities (Harrington 1967; Kirk 1975). Arctostaphylos uva-ursi (L.) Spreng. is called "mealy-plum" is Massachusetts because of its dry, puckering contents (Sanford 1937). Kuhnlein (1989) reported similarly high fiber figures for A. uva-ursi. Leung & Flores (1961), however, reported a fiber value of only 4.62% dry weight for fruits of A. tomentosa Pursh. Seeded, dried fruits of A. pungens may contain over 40% sugar and 16% citric acid (Martinez 1939).

Fruits of A. pungens contain arbutin, and have diuretic properties (Sociedad Farmaceútica Mexicana 1952). Dried fruits are used in Baja California to treat gall bladder and urinary tract infections (Winkelman 1986). These compounds as well as the high fiber content prevent consumption of large quantities of fruit.

Orange fruits of madroño (Arbutus xalapensis and A. arizonica) mature in October. Madroño trees are fairly common in forested regions and along shaded arroyos.

Fruits of both species are eaten by both the Tarahumara and Tepehuan (Pennington 1963, 1969). Other species have been utilized in the United States (Balls 1962).

Tonolochi (Passiflora bryonioides and P. quercetorum) is occasionally found on drier canyon walls and in protected locations in manzanilla thickets. The whitish fruits are occasionally eaten by children. Fruits of several species of Passiflora are widely utilized as food sources in many tropical countries (Martin & Nakasone 1970). Orange fruits of palo del venado (Lonicera cerviculata) are considered edible but are not frequently eaten because of their relative rarity.

Fruits of the weedy tomatillo (Physalis caudella), common in agricultural fields, are consumed green or ripe, primarily by children. Two other related species, collectively called tomatillo chiquito (P. minima and P. microcarpa) are present in forested areas and beneath taller vegetation in agricultural fields, and are also eaten occasionally, but are too small and rare to be of much use. Fruits of Physalis spp. are widely utilized in several countries (Gibbons 1962; Harrington 1967).

Fruits of tulusin (Jaltomata procumbens) are also consumed. Jaltomata prucumbens is a common weed in much of Mexico and Central America. It is often encouraged by farmers because of its edible berries, and some populations demonstrate some evidence of domestication (Davis & Bye 1982).

Solanum diphyllum is a red-fruited species native to the Sierra Madre and occasionally cultivated there as an ornamental. The Mountain Pima sometimes eat the fruits, but also use them to make wreaths in holiday decorations (Laferrière & Van Asdall 1991).

The Mountain Pima recognize fruits of lima (Rhus trilobata) as edible but do not use them extensively due to their relative scarcity. These fruits are used in Arizona and California because of their pleasant acidic taste, due to malic acid in the hairs on the fruit (Hodgson 1982; Balls 1962). Piñones (seeds of Pinus discolor Bailey & Hawksworth) are available at lower elevations but not in Nabogame.

Immature fruits of savaliqui (Yucca grandiflora) and jamole (Y. madrensis) are also occasionally consumed (Gentry 1972; Laferrière 1990a). Fruits of several other species of Yucca were commonly consumed in the southwestern United States (Castetter 1935; Ebeling 1986). Green fruits of Y. madrensis are eaten by the Warihio as well as the Mountain Pima (Gentry 1972; Laferrière 1990a). Yucca grandiflora is also utilized at lower elevations in the canyons south of Yepachi (Gentry 1972). Fruits of several other species have been consumed in the southwestern United

States (Yanovsky 1936). Fruits of both the Mountain Pima species are dry and inedible when mature.

Greens

Quelites constitute a significant portion of the diet during the early part of the summer rainy season, when the plants are young and tender. The most commonly utilized species include quelite de mayo (red-leaved individuals of Amaranthus hybridus), quelite de agua (white-leaved A. hybridus), chuale (Chenopodium leptophyllum), and verdolaga (Portulaca oleracea).

Caña aigre (Begonia gracilis ssp. nervipilosa) is common in moist, shaded locations, and is occasionally consumed by children. The stalks are juicy, mucilaginous, and pleasantly acidic. Hierba aigre (Oxalis decaphylla and O. albicans ssp. albicans) is treated the same way. Shoots of Begonia and Oxalis are acidic due to the high concentration of oxalic acid, which is potentially toxic in large quantities. Fortunately, the children do not consume enough of these plants to cause noticeable harm. Shoots of O. divergens Benth. are used by the Mountain Pima as tea to relieve fatigue (Pennington 1973). Cravioto (1951) gave a figure of 3.7 mg carotene per 100 g O. divergens. Shoots of B. gracilis are used in treating toothache or gum disease

(Pennington 1973).

Begonias have been used as potherbs in Japan, India, Indonesia, and Myanmar (Burma) (Maheshwari & Singh 1965; Sonohara et al. 1952; Tanaka 1976; Watt 1972). In Sikkim and in the Moluccas of Indonesia begonias have also been used to make a sauce and with meat and fish (Burkill 1985; Uphof 1959; Watt 1972). In China, Indonesia, and Brazil begonias are used in salads (Tanaka 1976). _Begonia auriculata_ Hook. and _B. mannii_ Hook. are used in Gabon as a substitute for sorrel (Raponda-Walker & Sillans 1961). Other species are used in South America and the Caribbean (Buxton 1939).

In the West Indies begonias are used as tea for colds, and in Java, the Philippines, and Brazil they are used as flavoring ingredients (Burkill 1985; Tanaka 1976). Children in China use _B. grandis_ Dryander ssp. _evansiana_ (Andr.) Irmsch. in a similar manner, although it is recognized as potentially toxic (Duke & Ayensu 1985; Perry & Metzger 1980). Begonias are high in fructose, so they may taste somewhat sweet as well as sour (Tavant 1963). The Tarahumara of northern Mexico used the sap of _B. gracilis_ as well as that from _Oxalis_ spp. to curdle milk in cheese-making (Ebeling 1986). In Paraguay, the leaves of _B. cucullata_ Willd. are eaten fried or in soups or salads, while the sap is used to treat sore throat (González-Torres

1980).

The sour taste of begonia sap is largely due to the presence of oxalic acid (Hodgkinson 1977). Begonia cucullata contains 4.8 meq oxalate per g d.w., representing 96% of the total acidity present in the sap (Tavant & Mange 1965). 55% of total acidity in B. ulmifolia Willd. is due to oxalate (Kinzel 1964). Nordal & Resser (1966) reported CAM metabolism in B. x tuberhybrida Voss. with oxalic acid the predominant acid, followed by malic and citric.

In small quantities oxalic acid is harmless, but in larger quantities it can be toxic. Oxalic acid acts by binding to calcium and other minerals to form insoluble salts which cannot be absorbed by the body (Kelsay 1985). This is not usually much of a problem if the amount of calcium in the diet greatly exceeds the amount of oxalate, but if the ratio of oxalate to calcium in the diet as a whole exceeds 2.25 by weight the acid itself may be absorbed into the blood stream where it can do serious damage (Gontzea & Sutzescu 1968; Laker 1983). Excess oxalate reacts with calcium in the blood and is deposited in soft tissues (Hodgkinson 1977). Oxalate can also inhibit several enzymes, including lactose dehydrogenase and glycollate oxidase (Hodgkinson 1977).

Roots and tubers of begonias have also been extensively used in folk medicine. Roots of B. gracilis have been used as emetics, purgatives and cathartics (Hernàndez & Gally-Jordà 1981). Martinez 1939; Sociedad Farmaceutica Mexicana 1952). Cucurbitacins isolated from the tubers have been shown to have antitumor properties, but their toxicity precludes wider therapeutic usefulness (Doskotch & Hufford 1970; Doskotch et al. 1969). Overuse of the roots can create anemia (Hernàndez & Gally-Jordà 1981).

Other components of begonias are less well known. Several species of Begonia tested negative for the presence of alkaloids (Hartley et al. 1973). Anthocyanins are present in the leaves of several species (Bopp 1957; Langhammer & Grandet 1974). Sap of B. fusicarpa Irmsch is applied to wounds in Sierra Leone (Burkill 1985). Begonia humilis Dryander in Ait. is used in Trinidad for colds, cough, comsumption, and fever, and has been shown to contain oxalate, rutin, quercetin, and cyanidin (Wong 1976). Shoots of several species are used in Southeast Asia to treat sick stomachs and enlarged spleens (Burkil 1966; Perry & Metzger 1980). Leaves of B. oxyloba Welwitsch ex Hook. in Oliver are used in East Africa as an anthelmintic (Kowaro 1976). The Mountain Pima use begonia sap to treat toothaches and gum ailments (Pennington 1973). Leaves of B. oblongata Merrill are eaten in the Philippines as an antidote for poisoning by Dioscorea hispida Dennst. (Perry & Metzger 1980). Dimeric proanthocyanidins are present in

B. glabra Aublet which have significant antitumor properties (Ensemeyer et al. 1980). Begonias have been used in the West Indies to treat cancer (Hartwell 1967). Antibacterial properties have also been reported from *B. glabra* (Ensemeyer et al. 1980).

Subterranean organs

Roots of saraviqui (*Prionosciadium townsendii*, listed as *P. madrense* by Dunnigan [1970]), are eaten in August or September after the leaves turn brown. The species grows primarily along the steep sides of shaded arroyos, and is not very common in the area. The entire plant, including both above- and below-ground portions, is pleasantly aromatic. The roots of prereproductive specimens of this semelparous species are roasted in the fire, and considered as good as potatoes. The plant was much more common in the past but has declined in abundance due to extensive grazing pressure. The smaller purple-flowered relative, *P. madrense* is considered edible by some people but bitter by others. The Tarahumara consume *P. serratum* Coult. & Rose (Pennington 1963).

The Mountain Pima have eaten boiled tubers of kachana (*Dahlia coccinea* and *D. sherffii*), although their use is declining. Tubers of *Dahlia* spp. were widely used in pre-

Spanish Mexico and are very high in inulin and fructose (Whitley 1985). Tubers of D. coccinea have antibiotic and antiatherogenic properties and act as central nervous system depressants (Whitley 1985; Jiu 1966).

Tubers of grulla (Cyperus esculentus) are occasionally eaten during planting season, mostly by children. This plant grows abundantly in the fields, and since the tubers are produced above the level from which the plows throw up the soil, the plants and the intact tubers are pushed upward and can be gathered very easily. The tubers are gathered and eaten raw in the field with only a minimum of cleaning. They are reported to be very sweet, but do not constitute a major source of food because of their extremely small size, only a few millimeters in diameter. This widely distributed species is utilized in many countries (Mokady & Dolev 1970). Raw tubers contain 43.9% carbohydrate, 17.2% lipid, and 4.4% protein by fresh weight (Mokady & Dolev 1970).

The name "cebollin," from the Spanish "cebolla", meaning "onion", is shared by at least two wild species of Allium as well as the much larger Hymenocallis pimana. Allium bulbs are often used as a flavoring ingredient in soups and fried dishes. Hymenocallis is very common in permanently fallow fields, forming showy displays of white flowers early in the summer rainy season (Laferrière

1990b). The bulbs of this species resemble those of onions but lack the characteristic odor. They are extremely bitter due to the presence of varying amounts of several alkaloids. These alkaloids function in nature by protecting the plant from insects and pathogenic fungi, and are concentrated in the peripheral bulb scales, stem, and roots (Greathouse & Rigler 1941; Singh & Kataria 1985; Singh & Pant 1980).

Several species of the genus have been used in folk medicine in various parts of the world. The lowland Pima Bajo at Onavas, Sonora, approximately 50 km west of the Mountain Pima area, used <u>H. sonorensis</u> to make a lotion applied to wounds (Pennington 1980). <u>Hymenocallis caribaea</u> (L.) Herb. has been used in the West Indies as an emetic, as a remedy for asthma, and as a maturative cataplasm for tumors (Ayensu 1981; Wong 1976; Fitzgerald et al. 1958). <u>Hymenocallis tubiflora</u> Salisb. was used in Brazil as an astringent, expectorant, and diuretic (Uphof 1968). <u>Hymenocallis lacera</u> Salisb. has been used in Meixco as a diuretic (Sociedad Farmaceútica Mexicana 1952). Alkaloids extracted from the bulbs of <u>H. caribaea</u> have been shown to have antiviral, antineoplastic and antimalarial activities (Fitzgerald et al. 1958; Ieven et al. 1977; Van Den Berghe et al. 1978). The plants are, however, potentially lethal to humans and livestock (Schmutz & Hamilton 1979; Morton

1982). Hymenocallis declinata, native to the Bahamas, was even reported by Altschul (1973) as irritating to the skin. Lycorine has been shown to serve as a respiratory stimulant and cause scorbutic symptoms in experimental animals (Southon & Buckingham 1989).

Nevertheless, the Mountain Pima used the bulbs of H. pimana as a source of famine food until the early part of this century. I have been unable to find any reference to other native peoples anywhere in the world using Hymenocallis bulbs as a food source. Pennington (cited by Bauml [1979]) reported use of H. pimana as food in Yepachi. Several members of the related genus Lycoris have been used as famine food in China and Japan after the toxic substances had been washed out (Johns & Kubo 1988; Tanaka 1976; Wildman 1968).

The Mountain Pima detoxified Hymenocallis bulbs by boiling them in lye, then washing the material with large amounts of water to remove both the lye and the alkaloids. The technique is known only to a few of the older members of the community. Lye was described as taking up to two weeks to make. Ashes were placed in an apparatus made of sticks and dried herbage and fashioned in the shape of an inverted pyramid. The Tepehuan lye-making still described by Pennington (1969) is very similar. Oak ashes were preferred over pine ashes, since they are stronger; this is just the opposite of the stated preference for the use of ashes as a salt substitute. Water was then slowly dripped through the ashes and collected into a bowl below. The lye was described as so strong it would burn the skin. The bulbs were then sliced and boiled in the lye until clear, then placed on a cloth suspended between two poles. A second, finer cloth was placed below the first to strain the wash water. The pasty white substance accumulating in the lower cloth, presumably primarily starch, was the primary product sought after, although the bulb pieces remaining in the upper cloth were consumed as well. Both were described as being very bland in taste and had to be mixed with milk, maize, or some other more flavorful food before consumption. This processing method appears to be a post-Conquest innovation on the part of the Mountain Pima since the lye-making technique is part of the soap-making process introduced by the Spanish.

Epiphytes

Inflorescences of the epiphytic bromeliad "flor de encino" (Tillandsia erubescens) are occasionally eaten, and are reputed to be very sweet. The species flowers from March through May, and is thus one of the few wild plant species available in the early spring. The smaller *T. recurvata* is also present in the valley, but is less common. The two are ethnotaxonomically conspecific and are utilized in the same manner. *Tillandsia* has been widely used medicinally and as a source of packing material (Robinson 1947; Bennett & Zingg 1935) but I have been unable to locate any references to food uses for members of this genus. French & Abbott (1948) reported 1500 μg carotene and 46 mg ascorbate per 100g fresh weight of shoot material of *T. usneoides* L.

Tillandsia usneoides L. has received wide use in the southeastern United States as packing material, stuffings for cushions, and bedding material (Robinson 1947). The plants are high in cellulose and have been used as surgical dressings (List & Horhammer 1972; Mayo & Wakefield 1944). Shoots of this species are extremely hygroscopic and extracts have been shown to have estrogenic and antibacterial properties (Webber et al. 1952; Feurt & Fox 1952; Weld 1945). The shoots have, however, been shown to support aflatoxin production (Llewellyn et al. 1988). Ash from *T. usneoides* L. is unusually high in silica, ferric oxide, sulfur, and other minerals because of its reliance on dust and rainwater as mineral sources (Benzing & Renfrow 1974; Wherry & Buchannan 1926; Halligan 1909; Schrimpf 1984).

Medicinal uses of _Tillandsia_ spp. are widely reported. The Tarahumara of Chihuahua, Mexico, use a tea made from the shoots of _T. erubescens_ as a purgative (Bennett & Zingg 1935). The plant (reported as _T. benthamiana_ H.B.K.) is cooked to a soup, then mixed with 50% ethanol as a preservative and taken as a cure for anaemia and kidney trouble (Altschul 1973). Other species have been used for constipation, rheumatism, fevers, hemorrhoids, diabetes, infantile epilepsy and abscesses (Pennington 1963; Speck 1941; Roig y Mesa 1974; Gonzalez-Torres 1980; Martinez 1939).

Flavones and flavonols are widely distributed in bromeliads, including _Tillandsia_ spp. (Ulubelen & Mabry 1982; Williams 1978; Lewis & Mabry 1977). Some of these may have anti-viral activities (Arslanian et al. 1986). _Tillandsia_ spp. contain up to 4-5% wax (Feurt & Fox 1953, 1955). Triterpenoids have also been reported, but usually at low concentrations (McCrindle & Djerassi 1961; Atallah & Nicholas 1971). The strongly scented flowers of _T. xiphoides_ Ker. are used in South America for chest ailments (Uphof 1959). Salgues (1954) analyzed the primary alcohols present in the flowers of _T. fragrans_ E. Andre.

Condiments

Three local plant species are used in Nabogame as condiments to flavor beans. Oregano grande (Monarda austromontana) is very common in permanently fallow fields, while the smaller, rarer oregano chiquito (Hedeoma patens) is found in small clumps on the walls of shaded canyons. These, as well as H. floribunda Standl., are used in a similar manner by the Warihio (Gentry 1963). Pazote or epazote (Teloxys ambrosioides) is used in a similar manner.

Some of the organic constituents of both species, however, may be potentially toxic in large amounts. Foliage of Hedeoma pulegioides (L.) Pers. contains pulgenone, a terpene capable of causing dermatitis and, in large doses, death (Duke 1985; Sleckman et al. 1983). The plant has been widely used to treat headache, flatulance, colds, bowel disorders, and rheumatism (Duke 1985). Monarda didyma L. (Oswego tea) and M. fistulosa L. (wild bergamot) have been used in the eastern United States as tea and as condiments in cooking (Medsger 1939). The most common essential oil of M. fistulosa is thymol in the shoots, borneol in the roots (Heinrich et al. 1983; Pfab et al. 1980). Shoots of T. ambrosioides have been widely employed as anthelmintics but have been replaced by less toxic drugs (Claus et al. 1970; Osol & Rarrar 1960). The herbage contains 0.35% volatile oil, of which 45-70% is ascaridol (Ayensu 1981). The Mountain Pima use the plant in treating colic (Pennington

1973).

Wild chiltepines (Capsicum annuum L. var. aviculare (Dierb.) D'Arcy & Eshbaugh) are used to make chili and salsa, and are used to flavor beans, potatoes, and other foods. These are highly prized by the Mountain Pima but are relatively rare. Some people from Nabogame travel as much as three days to the north to collect the fruits.

Tea

The Mountain Pima prepare tea from several different species of herbs, some wild and some cultivated. The use of these traditional teas is declining due to the avilability of instant coffee, but many are still in use. The most frequently used is yerbanis (Tagetes lucida), which grows abundantly in the fallow fields in Nabogame. This plant is boiled whole in either the flowering or fruiting stage, and is frequently dried for winter use by hanging shoots from the rafters inside the house. As much as a liter of this tea may be consumed daily. Anis (T. filifolia) is also used, as is cordoncillo (Elytraria imbricata). The latter is planted in the gardens and also grows wild in the area. Hierba buena de olor (Mentha sp.) is also used. Several species of Mentha, including M. piperita, have been widely cultivated as culinary and medicinal herbs and for tea

(Ellis 1960).

Debarked roots of junco (Ceanothus depressus) and cocolmeca (Phaseolus ritensis) are used to make flavorful reddish tea (Nabhan et al. 1980; Pennington 1973). Leaves of Holodiscus dumosus are also used as tea.

In addition to use as everyday beverages, teas from these species and their relatives have been widely used for medicinal purposes. Tea made from Tagetes lucida is a popular beverage and medicinal preparation for colic and gastrointestinal disorders in much of Mexico (Linares & Bye 1987). It is also used for treating the common cold, pneumonia, headaches, and other diseases, and used as a condiment (Linares & Bye 1987). The plant contains active hypotensive properties and acts as a depressant of the central nervous system (Jiu 1966).

Tea of Elytraria imbricata has been used in Baja California to treat fever, and a variety of urinary tract problems (Encarnacion-Dimayuga et al. 1987). Elytraria tridentata has been used in El Salvador to treat dysentery (Uphof 1959). Leaves of Spiraea tomentosa L. and S. alba DuRoi, both closely related to Holodiscus dumosus, were used as beverage and medicinal teas in Canada and the United States (Erichsen-Brown 1979).

Roots of Ceanothus americanus L. have been extensively used in the folk medicine of the eastern United States as a hypotensive to hasten blood coagulation and treat tuberculosis (Taylor 1927; Densmore 1932). Roots of Ceanothus sp. were used in Louisiana to treat lung hemorrage (Bushnell 1909). Several alkaloids have been isolated from these roots (Lagarias et al. 1979). It was however the bark of these roots employed for this purpose (Taylor 1927). The Mountain Pima use the root xylem rather than the bark to make tea. A red dye has also been extracted from the roots (Sanford 1937). Leaves of New Jersey tea (C. americanus) have been used as a stimulating tea and shown to contain flavonoids (Sanford 1937; Pichon-Prum et al. 1985). The fruits of certain other species were eaten in the southwestern United States (Ebeling 1986).

Seeds and immature fruits of many Phaseolus species are widely consumed, but the use of the roots is restricted to a few species. The reddish roots of P. ritensis and P. metcalfei Woot. & Standl. are very large and woody (Davis & Kaplan 1983). These are sold in markets in northwestern Mexico and used to alleviate stomach upset and as a catalyst for the production of alcoholic beverages (Nabhan et al. 1980; Pennington 1963; Lumholtz 1902). The roots contain extensive reserves of water, carbohydrate, and protein, and have some diuretic properties (Nabhan et al. 1980). The roots of P. lunatus L. and several other species are reported to contain toxic cyanogenic glycosides (Duke

1985; Watt & Breyer-Brandwijk 1962). Roots of P. diversifolius Pittier were, however, boiled, mashed, and consumed by the Choctaw of Louisiana (Bushnell 1909).

Fungi

Many fleshy fungi are consumed by the native peoples of Mexico (Guzmán 1978; Tablanda 1983), but the Mountain Pima use only a few. Knowledge of the edibility of various fungi is much less widespread among the Mountain Pima than knowledge of plants and was the subject of much more disagreement among native consultants. Most people seem aware that some types are edible, but are apprehensive about the use of fungi as food for fear of poisoning. Most other species are considered toxic, including morels (Morchella angusticeps Pk.) and puffballs (Calvatia booniana A.H. Smith). A few species are regarded as edible by some people but poisonous by others, e.g. Agaricus campestris Fr., Coprinus comatus (Mull.:Fr.) S.F. Gray, and Lentinus levis (Berk. & Curt.) Murr. (=Panus strigosus Berk. & Curt). Only two species are universally regarded as edible, "hongo de maiz" ("corn fungus", i.e. corn smut, Ustilago zeae (Beckm.) Unger, =U. maydis (DC.) Corda), and "hongo de comer" ("eating fungus", Amanita tuza Guzmán). The latter, distinguished from poisonous species by the pale yellow annulus, is collected by the bushel from moist pine forests in the area.

Table 6: Plants and fungi used as food and tea by the Mountain Pima (part 1)

	SPANISH	PART USED
FOOD PLANTS		
Agave shrevei ssp. matapensis	chuguilla	inflorescence, leaf base
Allium palmeri	cebollín	shoot
Amaranthus hybridus	quelite de mayo, quelite de agua	shoot
Arbutus arizonica	madroño	fruit
Arbutus xalapensis	madroño	fruit
Arctostaphylos pungens	manzanilla	fruit
Begonia gracilis ssp. nervipilosa	caña aigre	shoot
Berberis pimana	palo amarillo, palo aigre, palo espinoso	fruit
Capsicum annuum var. aviculare	chiltepine	fruit
Chenopodium leptophyllum	chuale	shoot
Cyperus esculentus	grulla	tuber
Dahlia coccinea	cachana	tuber
Dahlia sherffii	cachana	tuber
Echinocereus polyacanthus	cholla	fruit
Echinocereus shrevei	cholla	fruit
Echinocereus stoloniferus ssp. tayopensis	cholla	fruit
Hedeoma patens	orégano chiquito	shoot
Hymenocallis pimana	cebollin	bulb
Lonicera cerviculata	palo de venado	fruit
Mammillaria barbata	cholla	fruit
Mammillaria sonorensis	pitahaya	fruit
Monarda austromontana	orégano grande	shoot
Opuntia durangensis	duraznillo	fruit, cladode
Opuntia macrorhiza	nopal de zorra	fruit, cladode
Opuntia robusta	nopal temporal	fruit, cladode
Oxalis albicans	hierba aigre	shoot
Oxalis decaphylla	hierba aigre	shoot

Table 6: Plants and fungi used as food and tea by the Mountain Pima (part 2)

	SPANISH	PART USED
Passiflora bryonioides	tononolchi	fruit
Passiflora quercetorum	tononolchi	fruit
Physalis caudella	tomatillo grande	fruit
Physalis lagascae	tomatillo chiquito	fruit
Physalis microcarpa	tomatillo chiquito	fruit
Physalis pubescens	tomatillo grande	fruit
Pinus discolor	piñon	seed
Portulaca oleracea	verdolaga	shoot
Prionosciadium townsendii	saraviqui	root
Prunus gentryi	ahuasiqui	fruit
Prunus serotina var. virens	capulín	fruit
Rhus trilobata var. anisophylla	lima	fruit
Solanum diphyllum	naranjilla	fruit
Teloxys ambrosioides	pazote, epazote	shoot
Tillandsia erubescens	flor de encino	inflorescence
Yucca grandiflora	savaliqui	immature fruit
Yucca madrensis	jamole	immature fruit
TEA PLANTS		
Ceanothus depressus	junco	root
Elytraria imbricata	cordoncillo	shoot
Holodiscus dumosus	te	leaves
Phaseolus ritensis	cocormeca	root
Tagetes lucida	yerbaníz	shoot
Tagetes microphylla	aníz	shoot
FUNGI		
Amanita tuza	hongo de comer	basidiocarp
Ustilago zeae	hongo de mais	basidiocarp

Table 7: Estimated nutritional composition of nondomesticated Mountain Pima plant foods

	moisture (%)	protein (%)	carbohydrate (%)	lipid (%)	Ca mg/100g	A RE/100g	C mg/100g	Energy kcal/100g	REFERENCE
Agave									
(leaves)	25.7	0.4	42.3	2.0	0	0	0	189	1
(stalks)	66.6	0.2	22.5	1.6	0	0	0	105	1
Amaranthus	91.5	2.1	4.1	0.2	-286	277	41	27	2
Arbutus	73.5	1.1	15.4	0.8	98	170	78	73	1,3
Arctostaphylos	70	0.8	13.2	1.2	54	170	78	67	1,3
Berberis	80	1.9	11.6	1.3	47	15	100	66	1,4,5,6
Dahlia	41.7	9.6	27.9	0.1	219	2	4	151	1,2
Hymenocallis	73.6	0.6	20.5	3.8	98	0	0	119	1
Jaltomata	90	1.3	3.7	0.3	117	25	53	23	1,7
Opuntia									
(cladode)	95	0.7	2.4	0.1	28	22	9	13	1,3,8
	86	0.7	1.0	0.4	10	4	25	10	1,8
P. serotina	86.1	0.1	7.4	0.4	22	128	10	34	1,9
Physalis	88.3	1.6	8.8	0.5	10	25	6	46	3
Portulaca	93.5	1.5	3.6	0.2	-517	185	11	22	2
Prionosciadium	77.7	1.3	17.1	0.4	143	0	13	77	1,2
Prunus gentryi	86.1	0.6	10.7	0.0	29	128	10	45	1,9
Tillandsia	63.9	0.6	24.0	3.2	68	150	46	127	1,10

REFERENCES: 1 = Laferrière et al. 1991a, 2 = Haytowitz & Matthews 1984a; 3=Leung & Flores 1961; 4=Petcu 1965, 1966, 1968; 5=Kharitonova 1986; 6=Wierzchowski & Bubicz 1959; 7=Duke 1985; 8 = Trachtenberg & Mayer 1982; 9=Gebhardt et al. 1982; 10=French & Abbott 1948.

Calcium figures adjusted to reflect oxalate content.

Table 8: Costs and yields of nondomesticated Mountain Pima plant foods

	Search time (h/kg)	Handling time (h/kg)	Total time (h/kg)	Maximum yield (kg)	Month available	SHORTFALL IN 1988
Agave shrevei matapensis						
inflorescence	1.0	1.0	2.0	10	May	0
leaf bases	1.0	4.0	5.0	100	May	0
Amaranthus hybridus	0.0	0.5	0.5	infinite	June, July	20%
Arbutus spp.	2.0	1.5	3.5	10	October	50%
Arctostaphylos pungens	1.0	1.2	2.2	4	June	100%
Berberis pimana	0.5	1.8	2.3	6	August	70%
Dahlia spp.	1.5	3.0	4.5	500	September	0
Hymenocallis pimana	0.3	6.0	6.3	1000	September	0
Jaltomata procumbens	0.3	0.5	0.8	4	July	20%
Opuntia robusta						
cladodes	0.3	0.8	1.1	1070	May	90%
fruit	0.3	1.0	1.3	980	August	90%
Physalis spp.	0.3	0.5	0.8	7	July	40%
Portulaca oleracea	0.0	0.5	0.5	1000	June, July	20%
Prionosciadium townsendii	1.5	3.0	4.5	300	September	-50%
Prunus gentryi	1.0	1.5	2.5	30	July	0
Prunus serotina var. virens	1.0	1.2	2.2	3	July	0
Tillandsia erubescens	1.0	3.0	4.0	0.5	March	0

Search time incorporates time spent travelling to and from collection site.
Handling time represents time spent harvesting and processing food items.
Quelites had a virtually infinite availability because any harvested were immediately replaced.

CHAPTER VI

DROUGHT

Traditional agricultural peoples often tend to rely more heavily on noncultivated resources during times of crop failure than during years of adequate production (Campbell 1986; Grivetti 1979; Rahmato 1988; Scudder 1971). Indeed, many wild plants and animals serve as famine foods, utilized only during times of hardship (Bhandari 1974; Irvine 1952; Spittler 1989; Minnis 1991). Other common responses to drought stress include migration for wage labor and sale of livestock and other assets (Mortimore 1987; Swinton 1988).

During the latter half of my fieldwork (October 1986 - November 1988), the region underwent a period of extreme drought. This allowed me to observe cultural responses to the crop failures and the impact of the drought on the abundance of cultivated and noncultivated resources.

The 1988 drought covered most of the North American continent and was caused by warm ocean currents in the Pacific Ocean (Trenberth et al. 1988). The winter rains that year failed almost entirely in the Mountain Pima area, while the thunderstorm season began about two weeks late and ended a month early. The spring dry season from April to June was unusually hot and dry, with no rainfall at all.

Even the evergreen oaks, which constitute the dominant feature of the natural landscape, lost their leaves during this time. In contrast, 1986 and the first half of 1987 had been unusually wet.

Such severe droughts are very common in Mexican history (Castorena et al. 1980; Sancho y Cerbera & Pérez-Gavilán Arias 1978). Some of the cultural responses to such catastrophes have had major impacts on subsequent history (Hassig 1981). The Sierra Madre Occidental is a region of medium drought risk by Mexican standards (Sancho y Cerbera & Pérez-Gavilán Arias 1981).

Increases in pest problems during agricultural droughts are not uncommon and may be due to lowered plant defenses, higher nutrient content within plant tissues, a more suitable physical environment for pest growth, or other, more complex factors (Mattson & Haack 1987). As an indirect result of the 1988 drought, the potato crop in Nabogame was attacked by scabareid beetle larvae. This reduced the yields of the crop even further than the direct effects of the drought.

During years of adequate crop yields, noncultivated edible plants constitute only a small portion of the total diet, although many of them are important sources of vitamins and minerals (Connor et al. 1978, Cerqueira et al. 1979; Laferrière et al. 1991a,b). Wild plants become extremely important during certain seasons of the year. Most of them are available in summer, when stores of the previous year's harvest are running low.

Estimates for crop yields in good years are based on data supplied by Mountain Pima consultants. Yields in 1986 were reduced because of a Pacific hurricane which destroyed much of the vegetation that July. Values for yields of wild species reflect the author's own casual observations, supplemented with information obtained in interviews.

Crop yields in Nabogame during 1988 showed significant decline from good years as a result of the drought (Figure 3). Net yields of potato were negative, largely because of the damage done by the beetle larvae. This was particularly catastrophic since potatoes represent the only good source of vitamin C in the Mountain Pima winter diet. Wheat yields were close to zero. Maize, beans, and squash showed some positive returns, but greatly reduced from expected yields except for peaches. Production of goat- and cow-cheese was also greatly reduced.

The Mountain Pima responded to the crisis in three ways. First, the young men in the community went to work in the sawmill in the nearby town of Yepachi. A few travelled further seeking wage labor in cities at lower elevations. Second, people sold livestock for shipment by truck to Chihuahua City. Many animals died in Nabogame despite the selloff. The third option was to increase utilization of wild plants, especially quelites.

Productivity of noncultivated species varied markedly between species (Figure 4). Weedy species were abundant during the rainy season, albeit for an abbreviated period. The rains did provide adequate moisture for luxuriant growth of quelites. Supply of quelites is virtually infinite at that time, since there is quick replacement of any plants harvested. The people destroy far more quelites in weeding their fields than they could possibly consume. Tomatillos and tulusin were also present in the fields both years.

Wild plants showed a more mixed picture. Yield of manzanilla berries suffered a 100% decline, since the plants flowered in April during a heat spell in the dry season. The flowers dried without setting fruit. Supplies of kachana tubers and leaf bases of chuguilla were untouched by the drought because they are slow-growing storage organs. Ahuasiqui, capulin, and madroño were also largely unaffected, probably due to their preference for moister habitats along creeks. Palo amarillo, however, showed a marked decline in berry production despite its occurence in similar mesic habitats. This may be due either to a shallower root system or to the fact that palo amarillo, like manzanilla, flowered in April.

Yields of pads and fruits of prickly-pear were down by an estimated 80-90%. The decrease in productivity of the prickly-pear fruits was partly due to the direct results of the drought, and partly because the cattle were utilizing the pads of these plants as their reserve food supply. Of the three species present in Nabogame, nopal temporal (Opuntia cf. robusta) and nopal de zorra (O. cf. macrorhiza) were utilized the most heavily by the cattle. Nopal de duraznillo (O. durangensis) was left largely undisturbed. This species did, however, experience a large decline in fruit production.

One plant, saraviqui, showed an increase in availability for human because of the drought. Saraviqui is a semelparous member of the family Umbelliferae. It lives for 3-5 years producing only one or two large leaves, storing its photosynthate in its large taproot. When environmental conditions are favorable, it produces a flowering stalk 2-3 m tall, then sets seed and dies. Once the flower stalk has been initiated, the root becomes tough, woody, and inedible. Only prereproductive specimens are useful as human food. During 1987 20-30% of the Nabogame population was in flower, but during 1988 I observed only a single flowering individual. With the exception of that one plant, in the middle of a spring, the entire population was in a vegetative state and hence available for human consumption.

Neither emmigration for wage labor nor selling of livestock would have been as readily accessible prior to the construction of a road through the Mountain Pima country in the mid-1970's. The first is still not a viable option for women and old men. Use of noncultivated resources was undoubtedly even more important during past droughts than at present. Some species such as acorns and cebollin bulbs have been abandonned entirely. Techniques for processing these two plants are known only to a few older individuals.

Perennials tend to have more extensive root systems than annuals under the same environmental situations. This explains the resistance of peaches and many of the wild species to the drought. Manzanilla and prickly-pear, being upland species, have less access to ground water than riparian species. Annuals flourished in Nabogame during the short rainy season, even in 1988. Had the crop plants been able to mature as rapidly they might have showed yield declines comparable to those of the weedy species.

Other researchers have also noted increases in availability of wild plants during droughts. Some Australian plants increase fruit production during long dry spells, while other fruits are more readily available because they decompose more slowly (Gould 1980; Pate 1986).

Melon yields in the Kalahari increase during drought because of fires set to encourage new growth and attract game animals (Hitchcock 1979).

Reliance on a wide variety of resources often enables people to adjust to shortfalls in one or a few areas (Spittler 1985; Starr 1987; Swinton 1988; Turton 1977). Utilization of a number of resources can contribute a variety of nutrients during good years, as well as providing backup mechanisms during crises. The effects I observed in yield depletion in 1988 could well have been different had the timing of climatic events been altered. Gathering provides a succession of foods maturing throughout the year, some of which may be resistant to the effects of drought (Scudder 1971). Some resources, such as chuguilla leaves and kachana tubers, may be available year-round. Dependence on a few annual crop plants requiring a long rainy period increases risk even though it results in higher yields.

Use of several different wild plant species also prevents overdepletion of any single population. Human utilization can have a positive, negative, or neutral effect on plant populations. Any intense, prolonged negative impact is unsustainable. Many of the Mountain Pima resources, especially saraviqui, have become rare due to overutilization and overgrazing. Use of such depletable resources as reserve food supplies rather than for everyday subsistence would permit natural regeneration of the populations.

Some noncultivated species are affected by drought even more than some cultivated ones. Increased utilization extends both to species with reduced (but positive) yields and to plants such as quelites which are less affected. The diet breadth model of optimization theory offers a generalized explanation for the increased utilization. The model predicts that the choice of whether to utilize a less-favored resource is determined solely by the abundance of more favored resources (Smith 1983). Hence a shortfall in the preferred species will necessitate relying on less favored species regardless of the abundance of the less-favored species, provided the yields are greater than zero. Rankings of resource preference may change because of changes in search times and harvest effeciencies.

Pate (1986) found that in Australia, resources held in low preference by the Ngatatjara suffered more from drought than those of higher preference. Hence the drought resulted in a decline in diet breadth, exactly the opposite of the prediction of the model. The Mountain Pima results, however, do generally correspond to the predictions.

Noncultivated resources are generally less preferred by agricultural peoples because of lower returns per unit time invested, or because tannins, oxalates, or some other substances prohibit utilization in large quantities (Laferrière et al. 1991a). Wild foods can be difficult to digest, low in nutrition, and sometimes even with a negative net energy return (Hassig 1981). Some of the famine foods, such as cebollin, require extensive processing which add considerably to the cost. Crops also tend to require a lot of overhead in terms of labor invested in planting, weeding, etc., but yields per hour invested are much greater.

The diet breadth model, however, also predicts that the choice of whether to use the less-preferred resources should be all-or-nothing, i.e. no "partial preferences" (Pyke 1984). The micronutrient contributions from noncultivated resources may be essential in preventing the utilization from disappearing completely during good years. More complex linear and nonlinear optimization models are necessary to deal adequately with these situations.

Figure 3: Crop and cheese yields, Nabogame,1988

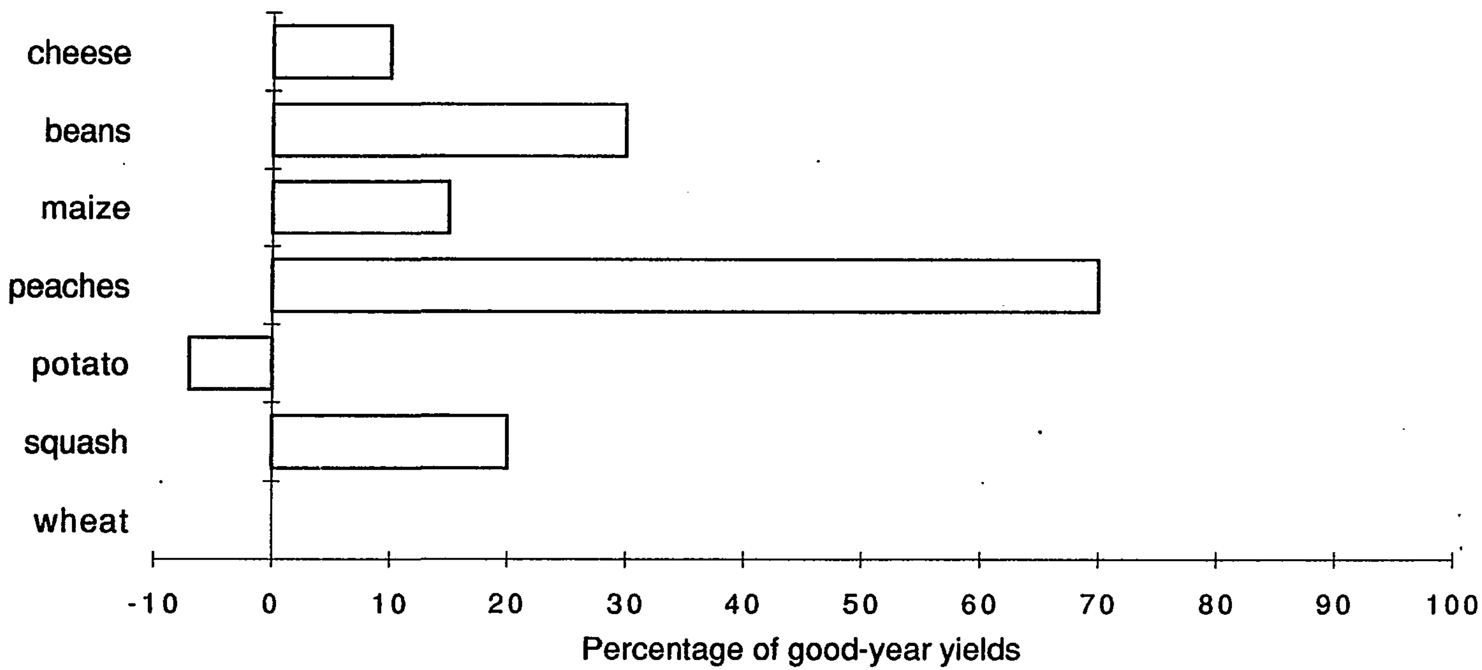
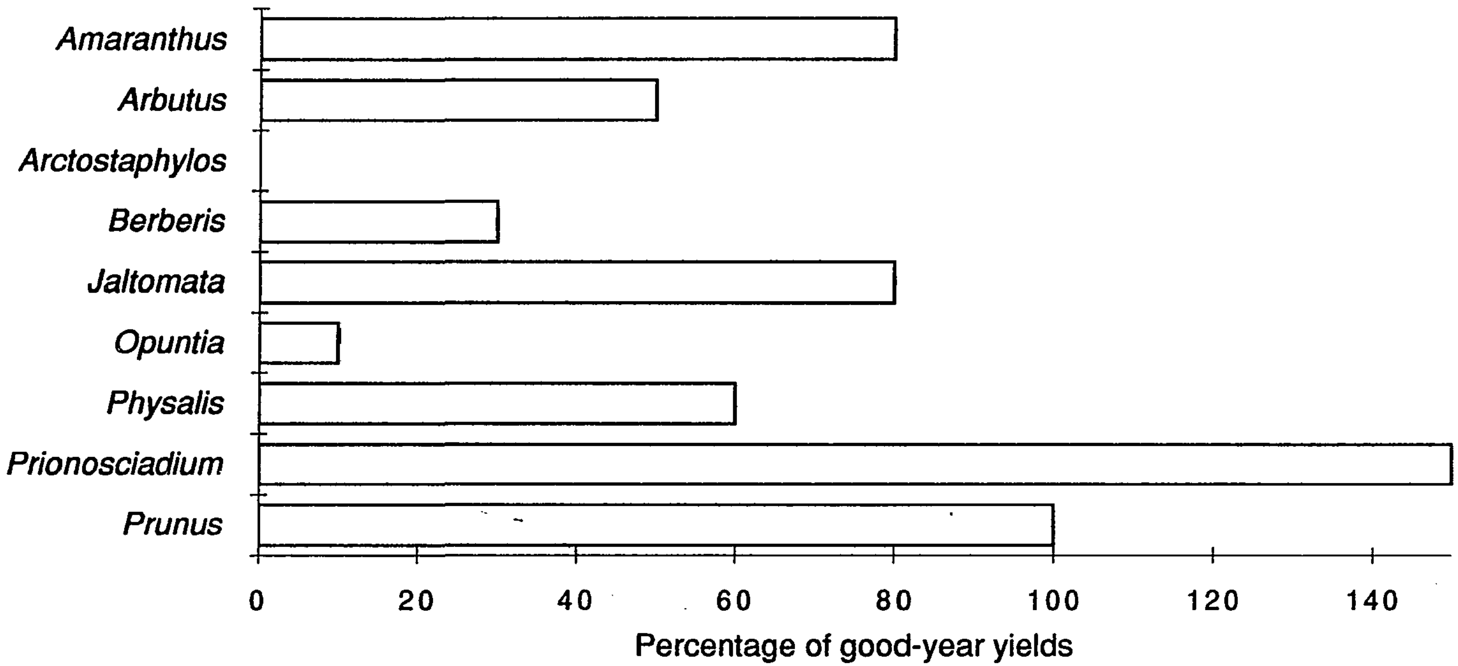


Figure 4: Yields of noncultivated plants, Nabogame,1988



CHAPTER VII

NONLINEAR OPTIMIZATION ANALYSIS

The Mountain Pima, like most traditional peoples, are aware of many edible resources in their environments which they in fact utilize seldom or not at all. Taste preferences offer inadequate explanations for underutilization of resources, because many of the items neglected are regarded as good-tasting. Conversely, many foods used in large quantities are not only bad-tasting but actually toxic, requiring extensive processing to render them edible (Johns & Kubo 1988). Optimization studies offer new testable hypotheses concerning human resource utilization patterns (Foley 1985; Smith 1983). Such models suggest alternative criteria for resource selection, especially efficiency in resource procurement.

Most previous anthropological applications of optimization theory have involved hunting-gathering populations, but a few have dealt with agricultural peoples (Keegan 1986). A few have considered seasonal variation in resource availability (Reidhead 1980). A few papers have incoroprated the need for balanced nutrition, but none of these has dealt with antinutritional factors which prevent utilization of certain resources. My study was designed to investigate these factors and to elucidate the importance of noncultivated plant and animal resources in the year-round diet of the Mountain Pima. I also wished to develop nutrient indexing optimization models permitting greater flexibility in predicted nutrient intake rates.

Optimization theory

The term "optimization theory" seems preferable to "optimal foraging theory" or "OFT" because many other types of problems besides foraging can be addressed using the same techniques. With respect to foraging, three primary types of models are available within the optimization framework. The simplest is the diet breadth model, which predicts that items will be added to the diet in order of utilization efficiency until addition of the subsequent item would decrease the overall efficiency (Pyke 1984). This model is useful in some contexts but is limited by its reliance on a single "currency", usually energy. Nutritional needs other than the chosen currency can be dealt with only with difficulty. Such considerations are important in dealing with problems such as the present one, because native peoples generally rely much more heavily on noncultivated resources as sources of micronutrients than for energy.

Linear programming has been used by several anthropologists to analyze the utilization patterns of various peoples, both contemporary and prehistoric (Johnson & Behrens 1982; Reidhead 1979; Belovsky 1987), and by biologists to predict the diets of herbivores (Belovsky 1978). It has the advantage of being a widely used and readily available technique for handling large quantities of data relatively rapidly and that it is designed specifically for the kinds of multivariate studies for which diet breadth studies have been criticized. Its disadvantages are that it requires linearity for all constraints and objective functions, and that small changes in the equations can often result in large changes in the optimal solution.

Nonlinear programming techniques which take such factors into account are more flexible than linear programs, and have received widespread use (McCormick 1983; Intrilligator 1971). The Complex method for non-linear optimization (Box 1965; Bunday 1984; Laferrière 1988) is an iterative algorithm in which a fitness equation (the "objective function") is minimized or maximized subject to any number of "constraint functions" which limit the possible solutions to the problem.

The classic "diet problem" of optimization theory consists of minimizing time or maximizing energy input while satisfying linear nutrient constraints. Neither of these objective functions may adequately reflect the full requirements of the situation (Hixon 1982). Some foragers, such as the Aché of Paraguay, concentrate more heavily on protein sources than on other foods with high energetic returns (Hill 1988). Some nonenergy nutritional needs may be met incidentally, in the course of persuing other goals (Belovsky 1990). The very fact that a choice must be made between these two hypotheses, time minimization and energy maximization, illustrates the problems inherent in both. In each case only one of these factors may be optimized at any given time, subject to constraints which prevent impossible solutions. Using these methods one cannot optimize more than one parameter at a time.

The nutrient constraints in the traditional method represent the minimum rate of nutrient intake required for life (Figure 5). These minima are by nature inflexible, sharp-line boundaries. If, for example, the program requires 60 mg of vitamin C, a rate of 59.999 mg is viewed as lethal, while 60.0001 mg represents a perfect state of health. Any amount in excess of this minimum contributes nothing to the fitness (physical or Darwinian) of the individual (Figure 6).

Such sharp distinctions are biological nonsense, although they are relatively easy to program into a computer. Individuals and indeed whole populations with suboptimal rates of nutrient intake may be in poor health and have reduced resistance to disease, but still persist for long periods of time. For certain nutrients, rates of intake well in excess of the minimum may result in greatly improved vigor. For others, especially water-soluble B and C vitamins, increased consumption has little or no detremental effect (National Resource Council 1980).

In this study I compared the traditional constraint method with a nutrient indexing model which eliminates sharp-line nutrient constraints. Rather than minimizing time or maximizing energy, the nutrient indexing model minimizes the product of the terms

$$(1-\text{abs}(\ln(\text{RDA}/\text{Intake})))$$

calculated for all months and all nutrients under consideration. The use of a multiplicative factor rather than an additive one is necessary to force the program to attempt to optimize all factors simultaneously. The "1" in the equation prevents the minimum value from reaching zero if any one factor should equal zero. Optimizing the ratio between intake rate and recommended daily allowance rather than the difference between these figures weights all nutrients equally, eliminating the necessity of choosing between essential nutrients. Using the absolute value of the logarithm creates a curve which rises asymptotically toward the y-axis and less steeply toward higher intake values (Figure 7). For some nutrients, particularly the water-soluble B and C vitamins, the fitness effects may not necessarily decline at high intake levels, but the above equation does serve the same purpose as the gut constraint, i.e. to prevent excessive consumption of a single highly productive resource.

The iterative non-linear optimization algorithm first proposed by Box (1965) has proved one of the most useful and most flexible methods available for calculating the optimal solution to a constrained set of non-linear equations. It has found a wide variety of applications in science, engineering, economics, and several other fields. The method involves a complex, or set of points, and uses a series of patterned steps to locate the minimal solution to a problem. The most valuable innovation of Box's method over older algorithms lies in the ability of the complex to move along specified constraint functions and turn direction when two or more constraint functions intersect.

Any optimization problem involves an objective function, or equation to be maximized or minimized. In practice, only minimization problems are generally used, since a maximization problem may be turned into a minimization problem simply by multiplying by -1. Many such problems also involve constraint functions which limit acceptable solutions of the problem. Box's method recognizes two types of contraints: explicit constraints, which set upper and lower limits on the ranges of each of the variables; and implicit constraints, which require that certain functions of the variables satisfy specified criteria, usually inequality considerations. Equality constraints are possible, but more difficult to satisfy and may slow down the program operation.

The complex in Box's algorithm consists of a set of points equal to twice the number of variables in the problem. A single point (any point which satisfies all the constraints) must be entered by the user at the start of the running of the program (Figure 8). It is recommended that the trials be run several times using different starting points in order to make sure that a global minimum rather than a local minimum has been located. The additional points of the complex are selected by means of a random number generator, which selects points within the bounds set by the explicit constraints. Any points which violate any of the implicit constraint functions are moved until they satisfy all the constraints.

The value of the objective function is then calculated for each of the points, and the points are ordered with respect to this value. A new point is selected by calculating the centroid, or arithmetic center, of all the points other than the one with the highest function value, and reflecting the point with the highest function value through the centroid, with a proportionality factor of 1.3 (Figure 9). In other words, a point is chosen 1.3 times as far away from the centroid as the worst point in the existing complex, and in the opposite direction. If the new point violates any of the constraint functions, either implicit or explicit, it is moved halfway toward the centroid. This is repeated until all the constraints are satisfied. The value of the objective function for this point is then calculated; if it represents an improvement over the old worst point that latter point is replaced with the new one and the process repeated with the new revised complex. If not, the new point is moved toward the centroid until it does represent an improvement.

Seasonality

Seasonality poses three problems with respect to an agricultural population (Belovsky et al. 1989). First, some foods, particularly noncultivated fruits and leaves, are available only for a limited time during the year and are largely nonstorable using traditional technology. Second, cultivated crops require extensive amounts of work which produce little or no benefits during those months when the work is performed. Third, some items are storable from one season to another. For the Mountain Pima, most of the cultivated crops produce durable items with high storage value. Exceptions include squash and peaches, only slightly storable, and chayote, which is nonstorable. Most of the noncultivated resources are unstorable with the exception of subterranean items.

Dietary importance of noncultivated resources

Noncultivated recources are often more important as sources of micronutrients than in filling energy needs. Previous studies in a variety of geographic locations have indicated that noncultivated foods are generally more important than their contribution to the diet on a strictly percent weight basis would suggest. In Mexico, quelites (noncultivated edible greens) are important dietary sources of protein, calcium, vitamin A, thiamine, riboflavin, and ascorbic acid (Bye 1981; Connor _et al._ 1978, Cerqueira _et al._ 1979).

Among the Gadio Enga of New Guinea, hunting and gathering account for only 10% of the diet by weight, but this fraction supplied 20% of the protein, 40% of the fat, and 54% of the vitamin A (Dornstreich 1977). Noncultivated green plants consumed by the black and Indian populations of South Africa have been shown to be particularly rich sources of lysine and tryptophan, complementing the amino acid composition of the maize gruel which is the predominant staple food in the region (Shanley & Lewis 1969; Santos & Fidalgo 1975). These same plants are also high in niacin, and thus may play an important role in preventing pellagra in these popluations (Hennessey & Lewis 1971). Wild vegetables in Malaysia have been shown to be important sources of vitamin C (Caldwell 1972). Noncultivated greens consumed by the Papago have been shown to be essential sources of minerals such as calcium and iron, precisely those minerals for which pregnant women of that tribe are at high risk (Greene 1972).

The contribution of noncultivated plant resources frequently takes on increased importance an a seasonal basis, often during planting season, when the previous year's reserves have become severely depleted. The Tonga of Zambia, for example, regularly experience an annual hungry season, during which time the women frequently take to the bush to gather wild foods to supplement their diet. They often make use of several plant species not utilized by the neighboring hunting/gathering !Kung (Scudder 1971). Body weight often falls dramatically during such hungry seasons (Hunter 1967; Nurse 1975; Flowers 1983). The availability of wild plant resources as an alternative food source has also been credited with alleviating the worst effects of droughts, enabling peoples to escape famine conditions (Grivetti 1979). Dunnigan (1983) reports that wild food gathering among the Mountain Pima also increases during times of scarcity.

Some plants, however, contain antinutritional compounds such as oxalates, phytates, or tannins, which prevent utilization of the nutrients contained in the plant tissues. Many common quelites, for example, contain high levels of soluble oxalates, which form an insoluble precipitate with calcium in the digestive system, preventing absorption of the calcium. This can result in net negative calcium balance due to consumption of these plants (Hodgkinson 1977).

Methods and Materials

Data were analyzed using a modified version of Box's (1965) complex method of nonlinear optimization (Appendix IV). The entire community was treated as a unit, assuming complete sharing of resources among the townspeople. Trials were run using compiled QuickBasic programs on a Compaq 386s microcomputer with math coprocessor. Two objective function were used. The first reflected the need to minimize the amount of work time necessary to satisfy the nutritional needs of the 70 members of the community. The second represented the nutrient balancing factor discussed above.

Several constraint functions limited the possible solutions to the problem. Minima and maxima were set on each variable to reflect the amount of each resource available to the people of the town. Upper limits were set on the amount of time spent at working in any one month and on the maximum mass of food consumed. The latter is necessary to prevent the program from recommending large amounts of a single efficient resource (Belovsky 1987; cf. Johnson & Behrens 1982). For both objective functions, the rate of intake of protein, calcium, and vitamins A and C were set according to USDA recommended daily allowances (National Research Council 1980). For the time minimization model these represented constraints, linear except for the protein balancing requirement. This requirement was effected by calculating the rates of intake for lysine and for methionine + cysteine, then dividing by a factor reflecting the ideal pattern for human consumption, and multiplying the total protein value by the lesser of these two values. These amino acids are the ones for which the Mountain Pima are most likely to be at risk; maize is deficient in lysine, beans in methionine and cysteine. These requirements for calcium, energy, vitamins, and balanced protein were incorporated into the objective function in the nutrient indexing model. Recommended daily allowances rather than minimum daily requirements were used for both models for ease of comparison.

To simplify the problem, food from livestock (other than cheese) was lumped together into a single factor. Time devoted to livestock raising was assumed to be equal in each month except for milk producing months (May for goats, October for cows). Time spent milking goats was limited to 16% of the time devoted to livestock management in other months, since without this extraseasonal labor the seasonal milk production would have been impossible. Caloric and nutritional returns from hunting and from animal husbandry were weighted to reflect contemporary utilization patterns in Nabogame. Food from various game animals was similarly lumped together, but allowed to vary with each month of the year. Separate variables were provided for maize, hunting, potatoes, wheat, and beans for each month of the year since consumption of these items in each month was largely independent of consumption in other months. January, February, April, and December were lumped together because no seasonal resources are available in any of these months. For simplicity, cheese, peaches, chayote, and sqaush were listed as seasonal, nonstorable items similar to noncultivated plant species, although the Pima do perform a limited amount of storage of all except chayote.

The total amount of land potentially planted to beans, maize, peaches, and potatoes was set at 36.14, i.e. the amount of land actually planted in the town in 1988. There is more arable land available, but one implicit assumption in the model is that the people are constrained to using current technology. Hastening of the fallowing rotation in the community would result in severe land degradation. Maximum amount of land planted to wheat was also set at 36.14. The people plant wheat in January in the same fields they later plant to maize, beans, or potatoes in May. Amount of land planted to squash was limited to the amount planted to maize, since the two are intercropped. Chayote yields were limited to one tenth peach yields, since chayote vines are planted only under peach trees.

During the drought year, optimal solution proved impossible using realistic parameters. The residents of Nabogame could not have met their nutritional requirements during the drought of 1988 without importing food from the outside. Assuming, however, infinite land availability and inexhaustible supply of game animals, a solution was possible. Though admittedly unrealistic, this proved valuable in providing insight on some aspects of the problem. Gut constraints were also relaxed to 10 times their good-year limits; this is reasonable given that humans are capable of increased consumption when presented with large amounts of food after a period of starvation (Belovsky 1987). The effects of the drought on yields of all resources were simulated by multiplying the nutritional contributions of each item per hour worked by the observed shortfall proportion.

Results

Results of the optimization analyses are shown in Table 9. In a year of adequate yields the optimal diet using the time minimization method consisted of six cultivated plants (maize, wheat, potatoes, peaches, and chayote), plus four noncultivated species (Amaranthus Berberis, Jaltomata, and Tillandsia). Cow cheese was also included in the optimal diet, but not goat cheese. Hunting was excluded during June, July, August, and October, but included in other months.

The inclusion of seasonal resources in the optimal diet altered the amounts of maize, wheat, potatoes, and hunting included in the predicted diet for that particular month. Inclusion of Tillandsia resulted in minimal change due to the small amount of this plant available, even though the model predicted that the maximum amount be consumed. Predicted intake of wheat was raised while hunting, maize, and potato amounts were lowered in each of the four months (March, June, July, August, and October) in which seasonal resources were included. Hunting was eliminated completely in June, July, and August.

Table 10 shows the calculated intake levels for each of the nutrients included in the survey. Table 11 gives predicted values for caloric intake and total weight of food, and predicted workloads. In each month, nutrient intake rates for good years using the time minimization hypothesis were predicted very close to the levels required by the nutrient constraints. Gut and energy constraints were inactive in each case.

During the drought year, wheat and potatoes were necessarily excluded from the solution because of zero net yields observed in 1988. The absence of potatoes left animals as the only viable (albeit poor) source of vitamin C. The predicted diets included huge amounts of hunting except in months when seasonal sources of vitamin C were available. Predicted levels of hunting were, however, higher in May and June despite the presence of seasonal resources.

Berberis was excluded from this optimal diet, but beans, *Arbutus, Prunus gentryi, Prionosciadium, Opuntia* cladodes, and *Agave* leaves were added. Cheese was excluded.

Amaranthus consumption played a far greater role in the optimal diet than in the diet for good years. Increased amounts of maize were required to overcome the negative calcium values for *Amaranthus*.

Predicted nutrient intake rates varied much more for the drought year than for the good year. During months when large amounts of hunting was predicted the predicted protein intake was as much as 82 times as high as the value required by the constraint function. Vitamin C requirements were considerably exceeded in July and August, calcium in July and September, vitamin A in every month except September. Work levels were generally higher than for a good year. Total work load for the enitre year was nearly eight times as high. Energy consumption was also higher, except in July, August, and September, when caloric intake barely met minimum requirements. Good-year gut constraints were exceeded in every month except July and September.

Using the nutrient indexing method, the results in a good year were somewhat different than using the time minimization hypothesis. Large quantities of livestock were included in the predicted optimal solution. These rates were higher than what the Mountain Pima actually consume but do not exceed the production levels possible in the community. Maize and potatoes were included at approximately the same levels as with the time minimization method, but wheat was reduced to approximately 40% its level under the time minimization hypothesis. More noncultivated plants were included in the predicted diet (Table 12). Amaranthus was excluded from the optimal solution, but Hymenocallis, Jaltomata, Physalis, and Tillandsia were included, as were Opuntia fruits and cladodes. Peaches, chayote, and cowmilking were excluded. Significant amounts of hunting were predicted for May, June, July, August, and October, just the opposite of the pattern predicted by the time minimization model.

Predicted nutrient and energy intake rates for a good year using the nutrient indexing method were very close to the recommended values, except for calcium rates which were slightly lower. Differences between months were minimal. Predicted intake rates of vitamin C were all within 10 μg of the optimal value of 45000 mg.

Nutrient-indexing predictions for a drought year included large amounts of hunting, beans, and maize, but no livestock. Eleven noncultivated plant species were included, the highest number of any of the four analyses: Agave (leaves), Amaranthus, Arbutus, Berberis, Dahlia, Hymenocallis, Jaltomata, Opuntia (fruit and cladodes), Prionosciadium, Prunus gentryi, and Tillandsia.

Predicted calcium rates were very close to recommended levels except slightly higher in September. Vitamin A levels were much higher than recommended in June, July, and August when several seasonal items were available. Vitamin C was suboptimal in all months except June, July, and August. Energy consumption fluctuated between 63% of recommended value in May to 163% in November. Protein was extremely high except in the period from May to September. Inclusion of seasonal resources in the diet resulted in increased amounts of maize except during March, October, and November; decreased hunting except in March and November; and decreased beans except in March, October, and November.

Discussion

The predicted diets differed from the actual consumption patterns in Nabogame at present. Maize, beans, and potatoes are the major staples, while squash and peaches are important on a seasonal basis. Wheat is of declining importance among the Mountain Pima. Beans were excluded from the optimal diet because wheat represented a slightly better source of lysine and because wheat fields were not included in the same total land constraint as the other crops. The former factor may be an artifact caused by overly optimistic estimates of wheat yields in good years.

Amaranthus leaves are a major food source during June and July, replacing beans and potatoes as the chief food accompanying maize tortillas. Agave stalks, excluded from all four predicted diets, are frequently comsumed when available, as are Jaltomata, Physalis, Opuntia, Physalis, Prionosciadium, and Prunus gentryi. Berberis, Arctostaphylos, Arbutus, P. serotina, and Agave leaves are consumed in lesser amounts. Hymenocallis, Tillandsia, and Dahlia are rarely consumed at present, although they may have been more important in the past. The people maintain and consume large herds of livestock, especially goats, despite the huge temporal and energetic costs involved.

The nutrient indexing method appears very successful in predicting the actual diet, giving results similar to those produced by the time minimization method but differing in several details. Its principle shortcomings are that it requires a huge database, it sometimes includes items like Hymenocallis in the optimal diet despite prohibitive overhead costs, and it is slow to distinguish between resources with similar nutritional value, e.g. hunting and livestock. It does represent a theoretical improvement over the time minimization method in removing the sharp boundaries between adequacy and fatality and permitting suboptimal intake rates for some nutrients. An example is vitamin C in drought year predictions. Reduced intake rates of this nutrient prevents excessive intake of protein.

Both models predict increased utilization of noncultivated plants during drought years, despite the infinite supply of land and game animals used in the analysis. This agrees with the numerous observations of such increases around the world, and with my own field data. Such increases were largely independent of the availabilities of these resources, provided they were positive, except to the extent that decreased yields resulted in lower harvest efficiencies. The increased occurrence of hunting and gathering in the Mountain Pima optimal diet during drought supports these observation. In fact the Pima did increase their utilization of wild foods during 1988, but the reliance was probably much greater in the past when outside markets were unavailable.

Discrepencies between good-year and drought-year predictions of the two models could be addressed using stochastic risk minimization methods. These represent an alternative optimization model which has proved useful in analyzing the subsistence strategies of traditional peoples (Winterhalder 1986). Amount of land devoted to particular crop plants must be determined months before it is evident whether the year will be good or not. Peaches, in any event, are perennials and their acreage cannot vary much from one year to the next. Unfortunately the data for the

Mountain Pima are inadequate to attempt such an analysis. Stochastic optimization methods require means and standard deviations for all parameters, which are lacking in the present study. Some estimates are available on the frequency of droughts in Mexico (Nichols 1987) but these are insufficient to permit a reliable stochastic analysis of my Mountain Pima data.

Meat, whether from hunting or livestock, appears more important as a source of vitamin A than for protein, while potatoes are the primary source of vitamin C and maize of calcium. Wheat represents the best source of carbohydrates and protein, and comprises 100% of the diet if no nutrient constraints are included. Wheat intake levels increase whenever seasonal resources permit diminution of reliance on other foods. Maize takes over this role during drought years when wheat is unavailable.

The assumptions made for the drought year study are necessary to reach a solution for the time minimization, and are admittedly artificial and lead to unreasonable results. This is less of a problem for the nutrient indexing model because of the flexibility in permitting suboptimal intake rates.

Critics of optimization theory (e.g. Martin 1983) frequently suggest taste as an alternative criterion for food selection. Purists among optimization theorists maintain that selection should optimize taste preferences. Many bad-tasting compounds are potentially toxic or have antinutritional properties. People do, however, make use of many resources they consider ill-tasting, including many which would be toxic without extensive processing (Johns & Kubo 1988). They also neglect good-tasting items if the costs involved are excessive. Two varieties of _Amaranthus hybridus_ are recognized in Nabogame, white-leaved "quelite de agua" and red-leaved "quelite de mayo". The latter is considered bitter and passed over by some Pima in preference to the former. When faced with a seasonal overabundance of similar resources people can afford to be selective.

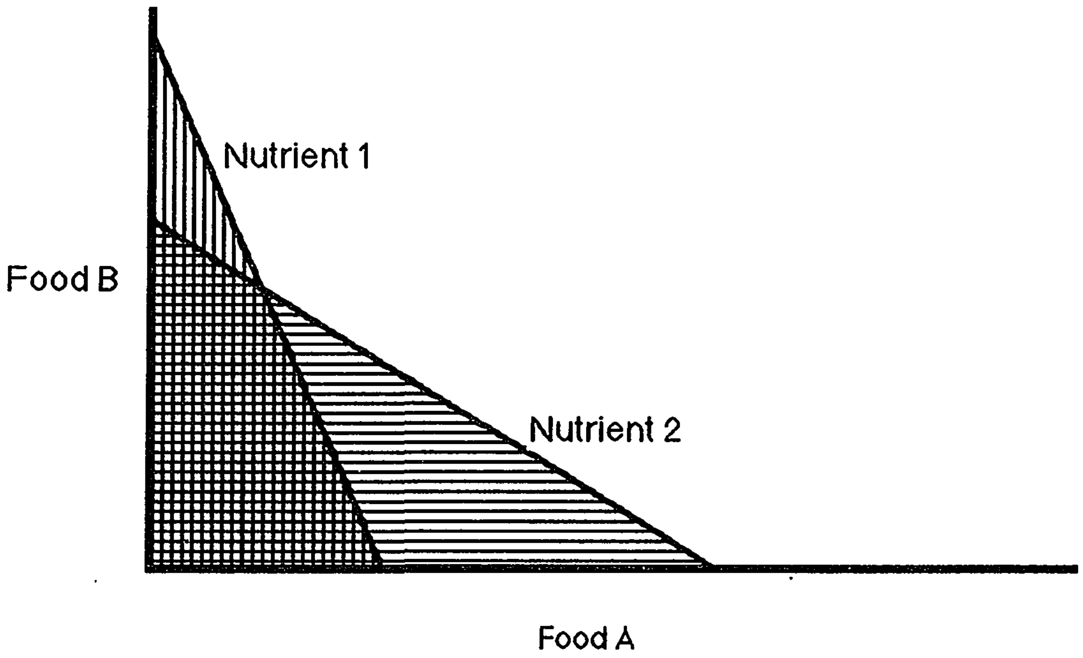
Noncultivated resources often have high energetic costs associated with their gathering and processing, especially if they are located a considerable distance from home. Cultivated crops also require a great deal of overhead, but the returns are much greater.

Optimization theory has been criticized as not reflecting the true concerns of or cognitive processes used by traditional peoples. The etic and emic analyses of the situation are in fact not as far apart as they might seem. The goals and constraints are parallel in the two systems, albeit phrased much differently. Energy maximation and/or time minimization are ubiquitous human concerns, usually stated in terms of increasing production and/or decreasing labor requirements. Nutrient and energy constraints are dictated by our biological makeup. When people consider certain foods as "good for strength" or "good protection against colds" they may in fact be expressing nutritional needs. Indeed, the elucidation of such rationalizations, the mechanisms by which cultures approach optimal use of resources, may prove an interesting area of research.

Some evidence indicates that physiological cravings for certain nutrients may result in consumption of foods high in these nutrients (Denton 1982). The same may be true for excess consumption as well. This may partially explain the fact that human and nonhuman foragers meet their nutrient requirements without explicit knowledge of nutritional biochemistry. The nutritional indexing model may better represent these phenomena than the older time minimization and energy maximation hypotheses.

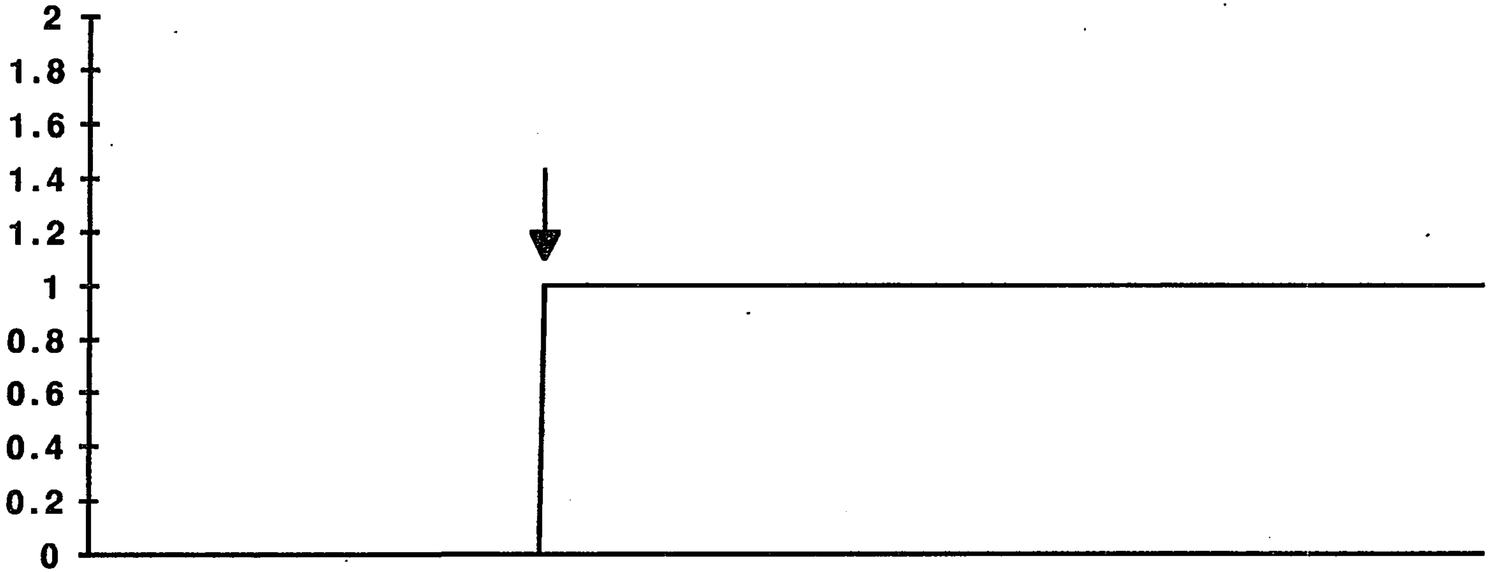
Optimization theory cannot answer all questions, even pertaining to food choices. For example, it cannot explain why the Mountain Pima consume <u>Amanita</u> but neglect morels and puffballs. It can, however, be very useful in suggesting testable hypotheses in a wide variety of situations.

Figure 5: Nutrient constraint functions, time minimization model



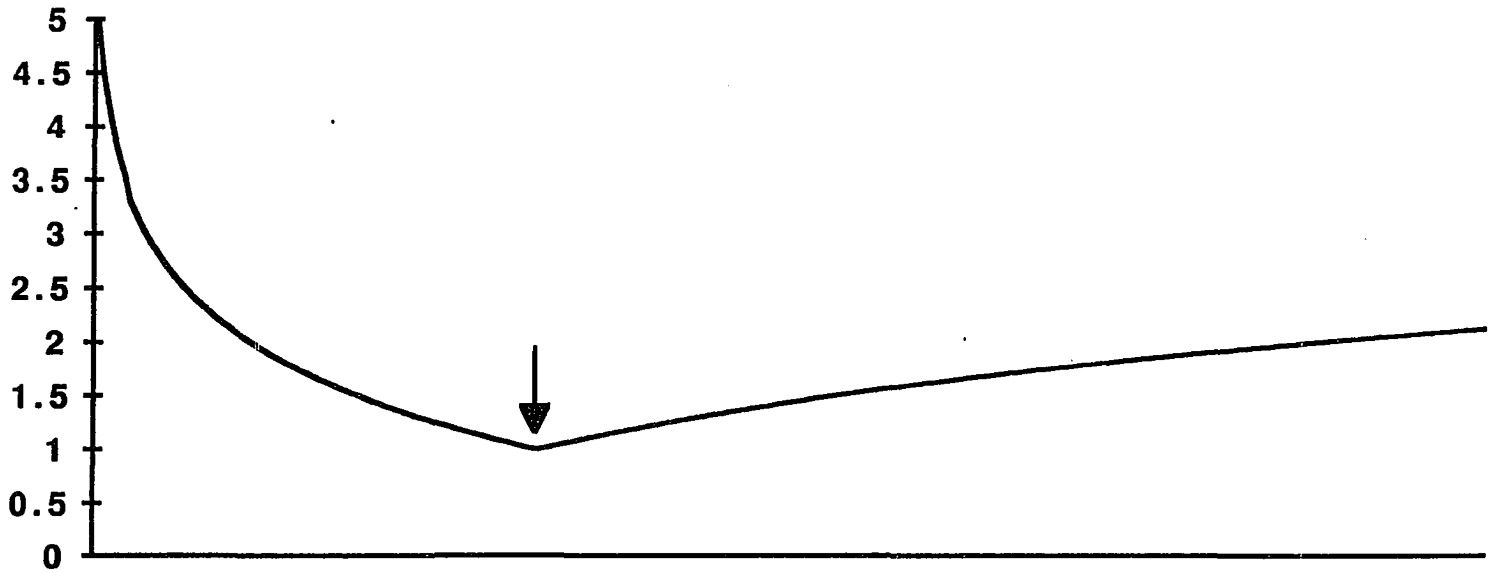
For each variable, values selected must lie in the unshaded region, representing intake rates saatisfying nutritional requirements.

Figure 6: Fitness as a function of intake rate, time minimization model



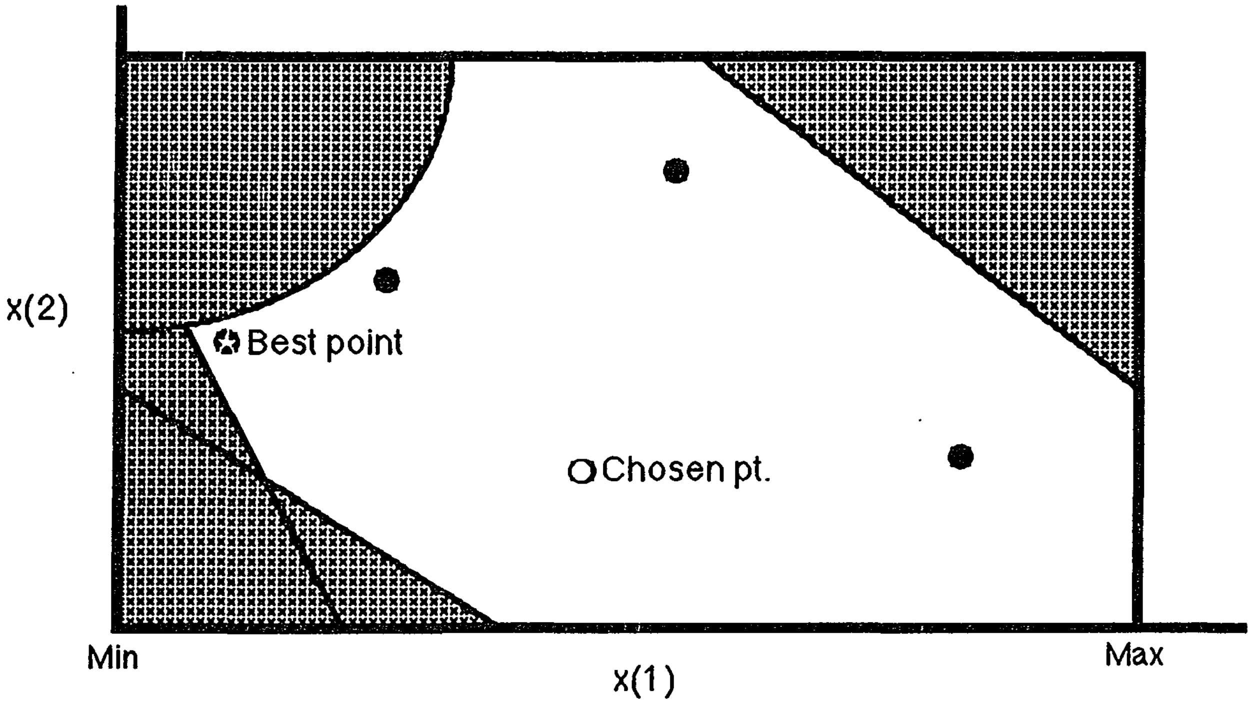
Intake (arrow indicates minimum requirement)

Figure 7: Nutrient indexing factor: 1+abs(ln(RDA/Intake))



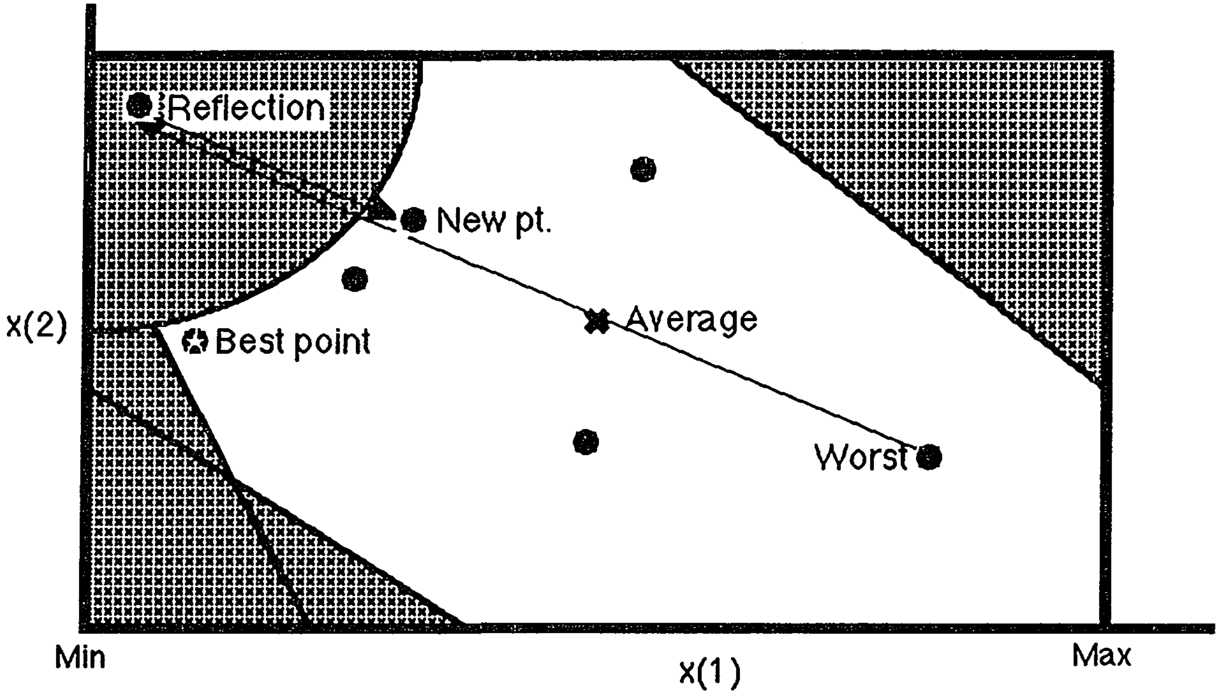
Intake (arrow indicates recommended daily allowance)

Figure 8: Program initialization, Box's complex method



A chosen point is entered by the user and a set of other points is chosen at random so the number of points equals twice the number of variables.

Figure 9: Selection of new point, Box's complex method



A reflection point is chosen on the opposite side of the average point and 1.3 times as far away. If it is outside the feasible region it is moved toward the average point. If this new point is better than the old worst point it replaces the worst point in the complex.

Table 9: Work patterns predicted by optimization study

	MONTH	VAR #	MAX	Efficiency	SHORTFALL	Good year Time min	Good year Time min	Bad year Time min	Bad year Time min	Good year Indexing	Good year Indexing	Bad year Indexing	Bad year Indexing
			h	h/kg		h	kg	h	kg	h	kg	h	kg
beans	Jan	51	2000.0	0.53	70%	0.0	0.0	2000.0	3773.6	0.0	0.0	1799.2	3394.7
hunting	Jan	24	2000.0	0.21	50%	29.3	139.5	3450.0	16428.6	0.4	1.9	1207.1	5748.1
livestock	Jan	11	2000.0	0.31	50%	0.0	0.0	0.0	0.0	799.3	2578.4	0.0	0.0
maize	Jan	33	2000.0	0.97	80%	265.0	273.2	704.5	726.3	247.6	255.3	831.0	856.7
potatoes	Jan	42	1000.0	0.28	120%	121.0	432.1	0.0	0.0	117.3	418.9	0.0	0.0
wheat	Jan	51	1000.0	0.42	100%	104.8	249.5	0.0	0.0	43.4	103.3	0.0	0.0
beans	Mar	52	2000.0	0.53	70%	0.0	0.0	2000.0	3773.6	0.0	0.0	1860.3	3510.0
hunting	Mar	25	2000.0	0.21	50%	24.3	115.7	3392.7	16155.7	0.3	1.4	1246.0	5933.2
livestock	Mar	11	2000.0	0.31	50%	0.0	0.0	0.0	0.0	799.3	2578.4	0.0	0.0
maize	Mar	34	2000.0	0.97	80%	264.7	272.9	705.4	727.2	246.5	254.1	806.9	831.9
potatoes	Mar	43	1000.0	0.28	120%	120.5	430.4	0.0	0.0	116.9	417.5	0.0	0.0
Tillandsia	Mar	20	2.0	4.00	0%	2.0	0.5	2.0	0.5	1.4	0.4	2.0	0.5
wheat	Mar	52	1000.0	0.42	100%	107.0	254.8	0.0	0.0	43.8	104.3	0.0	0.0
Agave-leaves	May	1	100.0	5.00	0%	0.0	0.0	0.6	0.1	0.0	0.0	5.2	1.0
Agave-stalks	May	2	20.0	2.00	0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
beans	May	53	2000.0	0.53	70%	0.0	0.0	785.1	1481.3	0.0	0.0	143.1	270.0
goatmilking	May	9	2000.0	0.67	90%	0.0	0.0	0.0	0.0	6.5	9.7	0.0	0.0
hunting	May	26	2000.0	0.21	50%	29.3	139.5	5000.0	23809.5	11.8	56.2	0.0	0.0
livestock	May	11	2000.0	0.31	50%	0.0	0.0	0.0	0.0	799.3	2578.4	0.0	0.0
maize	May	35	2000.0	0.97	80%	265.0	273.2	1122.4	1157.1	246.3	253.9	1474.6	1520.2
Opuntia-cladode	May	14	1209.0	1.10	90%	0.0	0.0	0.0	0.0	15.0	13.6	1186.9	1079.0
potatoes	May	44	1000.0	0.28	120%	121.0	432.1	0.0	0.0	108.0	385.6	0.0	0.0
wheat	May	53	1000.0	0.42	100%	104.8	249.5	0.0	0.0	36.7	87.4	0.0	0.0
Amaranthus	Jun	17	1000.0	0.50	20%	0.7	1.4	76.5	153.0	0.0	0.0	64.6	129.2
Arctostaphylos	Jun	13	10.0	2.20	100%	0.0	0.0	0.0	0.0	0.0	0.0	2.6	1.2
beans	Jun	54	2000.0	0.53	70%	0.0	0.0	524.3	989.2	0.0	0.0	43.7	82.5
hunting	Jun	27	2000.0	0.21	50%	0.0	0.0	5000.0	23809.5	16.4	78.1	39.6	188.6
livestock	Jun	11	2000.0	0.31	50%	0.0	0.0	0.0	0.0	799.3	2578.4	0.0	0.0
maize	Jun	36	2000.0	0.97	80%	262.5	270.6	1339.5	1380.9	248.2	255.9	1827.0	1883.5
potatoes	Jun	45	1000.0	0.28	120%	120.0	428.6	0.0	0.0	116.9	417.5	0.0	0.0
wheat	Jun	54	1000.0	0.42	100%	117.3	279.3	0.0	0.0	35.2	83.8	0.0	0.0
Amaranthus	Jul	16	1000.0	0.50	20%	0.7	1.4	25.6	51.2	0.0	0.0	67.2	134.4
beans	Jul	55	2000.0	0.53	70%	0.0	0.0	458.8	865.6	0.0	0.0	33.8	63.8
hunting	Jul	28	2000.0	0.21	50%	0.0	0.0	0.0	0.0	17.1	81.4	60.4	287.6
Jaltomata	Jul	22	3.2	0.80	20%	3.2	4.0	3.2	4.0	2.9	3.6	3.2	4.0

livestock	Jul	11	2000.0	0.31	50%	0.0	0.0	0.0	0.0	799.3	2578.4	0.0	0.0
maize	Jul	37	2000.0	0.97	80%	261.5	269.6	1956.2	2016.7	251.9	259.7	1814.3	1870.4
Physalis	Jul	21	20.0	0.80	40%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
potatoes	Jul	46	1000.0	0.28	120%	114.6	409.1	0.0	0.0	111.7	398.9	0.0	0.0
Prunus gentryi	Jul	3	780.0	2.50	0%	0.0	0.0	0.5	0.2	0.0	0.0	1.1	0.4
Prunus serotina	Jul	5	120.0	2.20	0%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wheat	Jul	55	1000.0	0.42	100%	118.7	282.6	0.0	0.0	35.3	84.0	0.0	0.0
beans	Aug	56	2000.0	0.53	70%	0.0	0.0	0.0	0.0	0.0	0.0	100.5	189.6
Berberis	Aug	4	14.0	2.30	70%	14.0	6.1	0.0	0.0	13.5	5.9	0.3	0.1
chayote	Aug	6	200.0	0.15	30%	1.3	8.7	86.5	576.7	0.0	0.0	24.9	166.0
hunting	Aug	29	2000.0	0.21	50%	0.0	0.0	220.4	1049.5	12.3	58.6	66.9	318.6
livestock	Aug	11	2000.0	0.31	50%	0.0	0.0	0.0	0.0	799.3	2578.4	0.0	0.0
maize	Aug	38	2000.0	0.97	80%	257.9	265.9	1463.1	1508.4	243.1	250.6	1457.5	1502.6
Opuntia-fruit	Aug	23	1506.0	1.30	90%	0.0	0.0	0.0	0.0	40.0	30.7	402.4	309.5
peaches	Aug	15	2000.0	0.15	30%	13.4	89.3	899.4	5996.0	0.0	0.0	412.9	2752.7
potatoes	Aug	47	1000.0	0.28	120%	99.9	356.8	0.0	0.0	80.5	287.5	0.0	0.0
wheat	Aug	56	1000.0	0.42	100%	121.9	290.2	0.0	0.0	46.9	111.7	0.0	0.0
beans	Sep	57	2000.0	0.53	70%	0.0	0.0	786.3	1483.6	0.0	0.0	91.7	173.0
Dahlia	Sep	8	600.0	4.50	0%	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.7
hunting	Sep	30	2000.0	0.21	50%	29.3	139.5	943.1	4491.0	0.2	1.0	116.1	552.9
Hymenocallis	Sep	10	900.0	6.30	0%	0.0	0.0	0.0	0.0	358.1	56.8	85.3	13.5
livestock	Sep	11	2000.0	0.31	50%	0.0	0.0	0.0	0.0	799.3	2578.4	0.0	0.0
maize	Sep	39	2000.0	0.97	80%	265.0	273.2	944.5	973.7	247.6	255.3	1299.9	1340.1
potatoes	Sep	48	1000.0	0.28	120%	121.0	432.1	0.0	0.0	117.3	418.9	0.0	0.0
Prionosciadium	Sep	18	1206.0	4.50	-50%	0.0	0.0	666.3	148.1	0.0	0.0	989.5	219.9
wheat	Sep	57	2000.0	0.42	100%	104.8	249.5	0.0	0.0	42.4	101.0	0.0	0.0
Arbutus	Oct	12	35.0	3.50	50%	0.0	0.0	35.0	10.0	0.0	0.0	34.8	9.9
beans	Oct	58	2000.0	0.53	70%	0.0	0.0	2000.0	3773.6	0.0	0.0	1901.1	3587.0
cowmilking	Oct	7	2000.0	0.67	90%	1.1	1.6	0.0	0.0	0.0	0.0	114.6	171.3
hunting	Oct	31	2000.0	0.21	50%	0.0	0.0	706.2	3362.9	15.7	74.8	192.2	915.2
livestock	Oct	11	2000.0	0.31	50%	0.0	0.0	0.0	0.0	799.3	2578.4	0.0	0.0
maize	Oct	40	2000.0	0.97	80%	261.4	269.5	706.2	728.0	245.0	252.6	804.7	829.6
potatoes	Oct	49	1000.0	0.28	120%	121.6	434.3	0.0	0.0	117.0	417.9	0.0	0.0
wheat	Oct	58	1000.0	0.42	100%	117.0	278.6	0.0	0.0	36.3	86.4	0.0	0.0
beans	Nov	59	2000.0	0.53	70%	0.0	0.0	2000.0	3773.6	0.0	0.0	1959.8	3697.7
hunting	Nov	32	2000.0	0.21	50%	29.3	139.5	349.9	1666.2	0.0	0.0	2209.9	10523.3
livestock	Nov	11	2000.0	0.31	50%	0.0	0.0	0.0	0.0	799.3	2578.4	0.0	0.0
maize	Nov	41	2000.0	0.97	80%	265.0	273.2	349.9	360.7	247.7	255.4	399.7	412.1
potatoes	Nov	50	1000.0	0.28	120%	121.0	432.1	0.0	0.0	117.3	418.9	0.0	0.0
squash	Nov	19	752.0	0.59	80%	0.0	0.0	523.0	886.4	31.0	52.5	513.5	870.3
wheat	Nov	59	1000.0	0.42	100%	104.8	249.5	0.0	0.0	43.3	103.1	0.0	0.0

Table 10: Nutrient intake rates predicted by optimization study

	MONTH	GOOD.MIN	BAD.MIN	GOOD.INX	BAD.INX
Total hours/year		12688.4	100445.8	2.6	361978.7
total land		34.5	129.9	30.2	132.1
A (RE, recommended)		135000.0	135000.0	135000.0	135000.0
A	Jan	135000.0	218798.1	135019.2	135000.0
A	Mar	135176.3	217176.5	135003.6	135000.0
A	May	135000.5	327266.6	137499.3	147643.0
A	Jun	135099.1	462319.2	136733.8	482029.6
A	Jul	135533.7	535564.1	139635.1	471768.1
A	Aug	135004.1	437896.6	135017.7	274200.9
A	Sep	135000.1	135000.0	135030.1	135000.4
A	Oct	135000.6	215702.5	135039.3	135000.0
A	Nov	135000.1	183340.8	135052.4	135000.0
C (mg, recommended)		45000.0	45000.0	45000.0	45000.0
C	Jan	45000.0	45000.0	45000.0	32895.2
C	Mar	45000.0	45000.0	45000.0	34229.9
C	May	45001.5	45000.0	45000.0	28819.9
C	Jun	45000.0	45000.0	45000.0	45000.0
C	Jul	45069.0	59155.4	45000.0	45000.0
C	Aug	45000.0	95911.3	45000.0	45000.0
C	Sep	45000.0	45023.2	45000.0	44968.0
C	Oct	45000.4	45001.2	45000.0	30809.1
C	Nov	45000.2	45000.0	45000.0	39413.2
Ca (mg, recommended)		1500000.0	1500000.0	1500000.0	1500000.0
Ca	Jan	1500000.0	1500000.0	1369393.4	1499999.6
Ca	Mar	1501710.1	1500000.2	1364794.2	1500000.1
Ca	May	1500001.8	1500000.0	1356040.9	1498778.8
Ca	Jun	1500737.0	1500000.5	1361360.8	1500030.1
Ca	Jul	1500000.4	1738886.5	1382525.0	1500000.0
Ca	Aug	1500002.2	1500000.2	1362921.3	1500000.0
Ca	Sep	1500000.1	1552404.6	1424102.1	1796951.2
Ca	Oct	1500000.0	1500000.0	1346906.1	1499378.5
Ca	Nov	1500000.2	1500000.2	1472880.0	1499978.6
protein (g, recommended)		75000.0	75000.0	75000.0	75000.0
protein	Jan	75000.0	6164819.7	75000.0	2527239.0
protein	Mar	75042.5	6065587.2	75000.0	2677795.6
protein	May	75000.0	5606346.4	75002.2	75000.0
protein	Jun	75000.0	4924340.2	75000.0	75000.0
protein	Jul	75002.5	271236.1	74999.5	75000.0
protein	Aug	75000.0	75008.1	75000.0	75000.0
protein	Sep	75000.0	852804.2	75000.0	75000.0
protein	Oct	75619.0	5999789.0	75000.0	1827112.5
protein	Nov	75000.7	5963561.1	75000.0	3949405.7

Table 11: Monthly workloads, caloric intakes, and food weights predicted by optimization study

	MONTH	GOOD.MIN	BAD.MIN	GOOD.INX	BAD.INX
food weight (g, max)		1050000.0	10500000.0	1050000.0	10500000.0
food weight	Jan	650543.2	1681323.4	773364.0	1083476.6
food weight	Mar	650567.8	1667989.5	772397.9	1112934.9
food weight	May	650551.5	1687603.2	764068.0	329235.5
food weight	Jun	653465.4	1611673.1	767689.6	348645.7
food weight	Jul	644386.9	525725.1	760811.0	347926.8
food weight	Aug	678154.4	3321056.0	718476.0	1636887.4
food weight	Sep	650543.3	801242.1	809665.4	470332.5
food weight	Oct	656415.0	1661813.0	766845.2	894717.1
food weight	Nov	650545.6	1750803.6	808193.5	1442110.6
kcal (recommended)		2925000.0	2925000.0	2925000.0	2925000.0
kcal	Jan	3741830.0	5641119.3	3046676.0	4475770.9
kcal	Mar	3771438.1	5618176.6	3045865.5	4571109.3
kcal	May	3741823.4	4694452.8	2924942.0	1850554.0
kcal	Jun	3910304.6	4488554.0	2925000.2	2091179.2
kcal	Jul	3904140.7	2925000.0	2926382.0	2069538.9
kcal	Aug	3903052.8	2925000.1	2937877.8	2321990.1
kcal	Sep	3741828.9	2925000.3	3088425.3	1866834.5
kcal	Oct	3909968.5	5605552.7	2924974.8	4253801.4
kcal	Nov	3741839.7	5336572.0	3069043.0	4789832.0
work (hours, maximum)		12500.0		12500.0	
work	Jan	1506.9	18570.2	2377.2	13839.0
work	Mar	518.5	6100.1	2007.3	3919.0
work	May	1327.7	11535.3	2708.6	6949.6
work	Jun	596.8	8097.8	2051.3	2954.4
work	Jul	115.8	6163.7	2552.5	5587.5
work	Aug	1577.1	5429.5	3041.3	5565.6
work	Sep	1239.0	3340.2	3048.1	2589.5
work	Oct	1241.2	8764.1	2706.7	6142.0
work	Nov	985.0	7999.5	2473.9	7028.5

Table 12: Wild plant species included in predicted diets

Good year		Drought year	
Time min	Indexing	Time min	Indexing
Amaranthus	*Hymenocallis*	*Agave (leaves)*	*Agave (leaves)*
Berberis	*Jaltomata*	*Amaranthus*	*Amaranthus*
Jaltomata	*Opuntia*	*Arbutus*	*Arbutus*
Tillandsia	*Physalis*	*Jaltomata*	*Berberis*
	Tillandsia	*Prionosciadium*	*Dahlia*
		Prunus gentryi	*Hymenocallis*
		Tillandsia	*Jaltomata*
			Opuntia
			Prionosciadium
			Prunus gentryi
			Tillandsia

Excluded from all:
Agave (stalks), Arctostaphylos, Prunus serotina

APPENDIX I

ANNOTATED LIST OF PLANTS COLLECTED IN NABOGAME, CHIHUAHUA, MEXICO.

Nearly all the following species are represented by vouchers at ARIZ and MEXU. For those taxa not represented by vouchers at ARIZ, location of voucher is given after the name. Secondary centers for duplicate deposition are ANSM, CHAPA, SD, and TEX. Smaller numbers of specimens have been sent to ASU, CAS, COL, COLO, DAV, DES, ENCB, F, FTG, GH, ID, K, KIRI, KU, MO, MONT, NCSC, NMC, NY, OBI, RM, SBBG, TAES, UC, UCR, UNL, UNM, US, VDB, and WS, and to Mesa State College, P.O. Box 2647, Grand Junction CO 81502. Family classification follows the system of Cronquist (1981) for dicots, Dahlgren et al. (1985) for monocots, and Smith (1977) for gymnosperms and seedless vascular plants.

LYCOPODIOPHYTA

Selaginellaceae

Selaginella arizonica Maxon. Cliff faces.

Selaginella lepidophylla (Hook. & Grev.) Spring. Cliff faces.

Selaginella rupincola Underw. Cliff faces, oak, pine, and cypress forests.

Selaginella wrightii Hieron. Sunlit creekbanks.

EQUISETOPHYTA

Equisetaceae

Equisetum hyemale L. var. *affine* (Engelm.) A. A. Eat. Streambanks.

POLYPODIOPHYTA

Adiantaceae

Argyrochosma limitanea (Maxon) Wind. var. *limitanea.* Cypress forest.

Bommeria hispida (Mett.) Underw. Oak forest.

Bommeria pedata (Sw.) Fourn. Oak forest.

Cheilanthes alabamensis (Buckl.) Kunze. Cypress forest.

Cheilanthes bonariensis (Willd.) Proctor. Oak forest.

Cheilanthes cuneata Link. Cypress forest.

Cheilanthes lendigera (Cav.) Swartz. Oak forest.

Cheilanthes sinuata (Sw.) Domin. Oak, cypress, and maple forests.

Cheilanthes wrightii Hook. Fallow fields.

Pellaea cordifolia (Sesse & Moc.) A.R. Smith. Cliff-faces.

Pellaea ternifolia (Cav.) Link. var. *ternifolia.* Oak forest.

Aspleniaceae

Asplenium palmeri Maxon. Cypress forest.

Thelypteris puberula (Baker) Morton. Cypress forest.

Dennstaedtiaceae

Pteridium aquilinum (L.) Kuhn var. *pubescens* Underw. Fields.

Ophioglossaceae

Ophioglossum engelmannii Prantl. Open oak forests.

Polypodiaceae

Elaphoglossum pilosum (H.B.K.) Moore. Maple forest.

Polypodium areolatum H.B.K. Oak forest.

Polypodium thysanolepis Klotz. var. *thysanolepis.* Pine and oak forests.

PINOPHYTA

Cupressaceae

Cupressus arizonica E. Greene. Cypress and maple forests.

Juniperus deppeana Steud. var. *robusta* Mart. Pine and oak forests.

Juniperus erythrocarpa A. Gray. Cliff faces and manzanita

thickets.

Juniperus flaccida Schlecht. var. *flaccida.* Oak forests.

Pinaceae

Pinus arizonica Engelm. Pine and cypress forests.

Pinus chihuahuana Engelm. Oak and pine forests.

Pinus engelmannii Carr. Pine and cypress forests

Pinus lumholtzii Rob. & Fern. Pine and cypress forests.

ANTHOPHYTA

DICOTYLEDONAE

Acanthaceae

Dyschoriste decumbens (A. Gray) Kuntze. Cypress forests.

Elytraria imbricata (Vahl.) Pers. Oak and pine forests.

Stenandrium pilosulum (Blake) Daniel. Fields.

Aceraceae

Acer grandidentatum Nutt. Maple forests.

Amaranthaceae

Alternathera caracasana H.B.K. Fields.

Amaranthus hybridus L. Fields. Very common weed in cultivated fields.

<u>Gomphrena nitida</u> Rothr. Fields.

<u>Guilleminea densa</u> Willd. Creekbanks.

<u>Iresine heterophylla</u> Standl. Creekbanks and cypress forests.

Anacardiaceae

<u>Rhus allophylloides</u> Standl. Cypress forests.

<u>Rhus trilobata</u> Nutt. var. <u>anisophylla</u> Jepson. Oak, pine, and cypress forests.

<u>Toxicodendron radicans</u> (L.) Kuntze var. <u>divaricatum</u> (E. Greene) Gillis. Forests.

Apiaceae

<u>Donnelsmithia juncea</u> (H.B.K.) Mathias & Const. Oak and pine forests.

<u>Eryngium heterophyllum</u> Engelm. Fields.

<u>Eryngium lemmonii</u> Coult. & Rose. Creekbanks in cypress forests.

<u>Eryngium longifolium</u> Cav. Sunlit springs.

<u>Hydrocotyle verticillata</u> Thunb. var. <u>triradiata</u> (A. Rich.) Fernald. Creekbanks.

<u>Lilaeopsis schaffneriana</u> (Schl.) Coult. & Rose. Emergent from mudflats along riverbank.

<u>Prionosciadium madrense</u> S. Wats. Fields and oak and pine forests.

Prionosciadium townsendii Rose. Cypress forests and sunlit springs.

Apocynaceae

Macrosiphonia hypoleuca (Benth.) Muell. Oak forests.

Mandevilla foliosa (Muell.-Arg.) Hemsl. Fields and oak, pine and cypress forests.

Aquifoliaceae

Ilex tolucana Hemsl. Cypress forests.

Araliaceae

Aralia humilis Cav. Oak and cypress forests.

Asclepiadaceae

Asclepias angustifolia Schweig. Fields, forests, and creekbanks.

Asclepias elata Benth. Fields.

Asclepias jaliscana Robins. Oak forests.

Asclepias glaucescen H.B.K. Fields.

Asclepias linaria Cav. Fields and oak forests.

Asclepias ovata Mart. & Gal. Fields and forests.

Asclepias quinquedentata A. Gray. Fields. Vouchered at MO.

Asclepias madrensis sp. nov. ined. Fields.

Gonolobus gonoloboides (Greenm.) Woods. vel aff. Cypress forests. Vegetative specimen. Voucher at MO.

Pherotrichis balbisii A. Gray. Oak forests.

Asteraceae

Acourtia dieringeri Cabrera. Oak forests.

Acourtia montana Rose. Pine and oak forests.

Acourtia thurberi (A. Gray) King & H. Rob. Fields and oak forests.

Ageratina hyssopina (A. Gray) King & H. Rob. Oak forests. Vouchered at TEX and MEXU.

Ageratina malacolepis (B.L. Rob.) King & H. Rob. Cypress forests.

Ageratina palmeri (A. Gray) Gage. Oak and maple forests.

Ageratina rothrockii (A. Gray) King & H. Rob. Cypress forests.

Ageratina stricta (A. Gray) King & H. Rob. Pine and cypress forests.

Ageratum corymbosum Pers. forma corymbosum. Fields and oak forests.

Ageratum corymbosum Pers. forma lactiflorum M.F. Johnson. Cliff faces and oak forests.

Alloispermum palmeri (A. Gray) Urbatsch & B. Turner var. lancifolium (B. Turner) B. Turner. Oak forests.

Ambrosia psilostachya DC. Fields and creekbanks.

Artemisia ludoviciana Nutt. Forests.

Aster potosinus A. Gray. Fields and cypress forests.

Aster spinosus Benth. Creekbanks.

Aster subulatus Michx. var. parviflorus (Nees) Sundberg. Creekbanks.

Baccharis salicifolia (Ruiz & Pavon) Pers. Sunlit creekbanks.

Baccharis thesioides H.B.K. Oak and pine forests.

Berlandiera lyrata Benth. var. monocephala B. Turner. Fields.

Bidens aurea (Ait.) Sherff. Fields and forests.

Bidens gentryi Sherff. Creekbanks and oak forests.

Bidens insolita Sherff. Fields.

Bidens odorata Cav. var. rosea (Sch.-Bip.) Melchert & B. Turner. Common in cultivated and fallow fields.

Brickellia betonicifolia A. Gray. Fields, creekbanks, and maple forests.

Brickellia eupatorioides (L.) Shinners var. chlorolepis (Woot. & Standl.) B. Turner. Fields and cypress forests.

Brickellia pringlei A. Gray. Creekbanks and pine forests.

Brickellia simplex A. Gray. Cypress forests.

Carminatia tenuiflora DC. Pine and cypress forests.

Carphochaete pringlei (S. Wats.) B. Turner. Oak and pine forests and manzanita thickets.

Carphochaete wislizeni A. Gray. Pine forests and manzanilla

thickets.

Chamomilla recutita (L.) Rausch. Fields. Probably escaped from cultivation. Vouchered at TEX and MEXU.

Chaptalia texana E. Greene. Pine and cypress forests.

Conyza canadensis (L.) Cronq. Fields and oak forests.

Cosmos bipinnatus Cav. Occasional escape from cultivation.

Cosmos linearifolius (Schultz-Bip.) Hemsl. Oak and cypress forests.

Cosmos parviflorus (Jacq.) Pers. Common weed in cultivated and fallow fields.

Cosmos pringlei Rob. & Fern. Oak and maple forests.

Cosmos thermale A. Nelson. Oak and maple forests.

Dahlia coccinea Cav. Oak and cypress forests.

Dahlia sherffii Sorenson. Cypress forests.

Dyssodia cancellata (Cass.) A. Gray. Fields. Vouchered at TEX and MEXU.

Erigeron basaseachensis Nesom. Maple forests.

Erigeron delphinifolius Willd. Oak forests.

Erigeron flagellaris A. Gray. Fields.

Erigeron fraternus E. Greene. Maple forests.

Erigeron fundus Nesom. Cypress and maple forests.

Erigeron oreophilus Greenm. Shaded streambanks.

Erigeron strigulosus E. Greene. Fields.

Eupatorium ovaliflorum Hook. & Arn. Oak and pine forests.

Eupatorium sonorae A. Gray. Cypress forests and shaded springs.

Galinsoga parviflora Cav. Fields and oak forests.

Gamochaeta americana (Mill.) Wedd. Oak forests.

Gamochaeta falcata (Lam.) Cabrera. Oak forests.

Gnaphalium sphacilatum H.B.K. Streambanks.

Gnaphalium stramineum H.B.K. Fields. Vouchered at TEX and MEXU.

Gnaphalium sp. nov. ined. Fields and oak and maple forests.

Gnaphalium viscosum H.B.K. Fields and cypress forests.

Gutierrezia wrightii A. Gray. Creekbanks and fields.

Heterosperma pinnatum Cav. Fields and forests.

Heterotheca subaxillaris (Lam.) Britt. & Rusby. Fields, forests, and creekbanks.

Hieracium albiflorum Hook. Oak forests.

Hieracium fendleri C.H. Schultz. Forests.

Hieracium pringlei A. Gray. Oak forests.

Hymenothrix palmeri A. Gray var. glandulosa (S. Wats.) B. Turner. Pine forests.

Hymenothrix palmeri A. Gray var. palmeri. Oak forests and manzanita thckets.

Hymenothrix wrightii A. Gray. Fields and cliff faces.

Jaegeria hirta (Lag.) Less. Cypress forests.

Laennecia eriophylla (A. Gray) Nesom. Manzanita thickets, and oak and pine forests.

Laennecia pimana Nesom & Lafer. Unplowed fields. Vouchered at TEX and MEXU.

Laennecia sophiifolia (H.B.K.) Nesom. Pine forests.

Lasianthaea podocephala (A. Gray) K. Becker. Fields and oak forests.

Leibnitzia occimadrensis Nesom. Cypress and maple forests.

Machaeranthera gracilis (Nutt.) Shinners. Fields.

Melampodium appendiculatum Robins. Fields and forests.

Melampodium longicorne A. Gray. Fields and cypress forests.

Melampodium perfoliatum (Cav.) H.B.K. Fallow fields.

Melampodium sericeum Lag. Fields.

Milleria quinqueflora L. Oak and cypress forests.

Montanoa leucantha (Lag.) Blake ssp. arborescens (DC.) V.A. Funk. Oak forests.

Pectis pimana Lafer. & Keil. Fields.

Pectis prostrata Cav. Fields and forests.

Perityle microcephala A. Gray. Cliff faces, manzanita thickets, and oak and pine forests.

Pinaropappus junceus A. Gray. Pine and cypress forests.

Pinaropappus roseus (Less.) Less. var. roseus. Fields and pine forests.

Porophyllum coloratum (H.B.K.) DC. Oak forests.

Porophyllum macrocephalum DC. Oak forests. Vouchered at TEX.

Psacalium decompositum (A. Gray) H. Rob. & Brett. Fields and oak forests.

Pyrropappus pauciflorus (D. Don) DC. Fields.

Schkuhria pinnata (Lam.) O. Kuntze var. guatemalensis (Rydb.) McVaugh. Fields and oak forests.

Senecio carlomasonii B. Turner & T. Barkley. Fields.

Senecio lemmonii A. Gray. Cypress forests.

Senecio masonii B. Turner. Oak and pine forests.

Senecio salignus DC. Fields.

Senecio sp. Oak forests. Vegetative specimen.

Simsia amplexicaulis (Cav.) Pers. Fields.

Solidago wrightii A. Gray. Cypress and maple forests.

Sonchus asper (L.) Hill. Cultivated fields. Uncommon.

Stevia glandulosa Hook. & Arn. var. gentryi Grashoff. Cliff faces.

Stevia ovata Willd. var. ovata. Fields and oak forests.

Stevia palmeri A. Gray var. palmeri. Fields, springs, and forests.

Stevia serrata Cav. var. serrata. Fields and oak forests.

Stevia viscida H.B.K. Fields.

Tagetes filifolia Lag. Oak and cypress forests.

Tagetes lucida Cav. Common in unplowed fields.

Tagetes micrantha Cav. Fields and oak forests.

Tagetes palmeri A. Gray. Oak forests.

Tagetes subulata Cerv. Oak forests.

Tagetes triradiata Greenm. Fields.

Tagetes wislizeni Greenm. Oak forests.

Taraxacum officinale L. Cypress forests. Rare.

Tithonia tubaeformis (Jacq.) Cass. Fields and open oak forests.

Tridax erecta A. Gray. Oak forests. Vouchered at TEX.

Verbesina parviflora (H.B.K.) Blake. Pine, oak, and cypress forests.

Vernonia serratuloides H.B.K. ssp. _serratuloides._ Fields.

Viguiera montana Rose. Oak forests.

Viguiera multiflora (Nutt.) Blake var. _multiflora._ Fields.

Wedelia chihuahuana B. Turner. Fields.

Wedelia greenmanii B. Turner. Oak forests and cliff faces.

Wedelia penningtonii B. Turner. Cypress forests.

Xanthocephalum eradiatum (Lane) Nesom. Fields.

Zinnia peruviana (L.) L. Oak forests.

Zinnia zinnioides (H.B.K.) Olorode & Torres. Fields and open oak forests.

Begoniaceae

Begonia gracilis H.B.K. var. _nervipilosa_ A. DC. Shaded creekbanks.

Berberidaceae

Berberis pimana Lafer. & Marr. Cypress and maple forests; occasionally on the northern (shaded) sides of large boulders (Laferrière & Marroquin 1990).

Betulaceae

<u>Alnus oblongifolia</u> Torr. Creekbanks in cypress forest.

Boraginaceae

<u>Lithospermum tubuliflorum</u> E. Greene. Fields.

Brassicaceae

<u>Arabis microcarpa</u> Rollins, sp. nov. ined. Fields, oak and cypress forests. Vouchered at GH.

<u>Brassica rapa</u> L. Streambanks and cultivated fields. Uncommon.

<u>Descurainia pinnata</u> (Walt.) Britt. ssp. <u>halictorum</u> (Cockerell) Detling. Fields.

<u>Dryopetalon runcinatum</u> A. Gray var. <u>laxiflorum</u> Robbins. Creekbanks.

<u>Lepidium densiflorum</u> Schrader. Fields and oak forests.

<u>Raphanus raphanistrum</u> L. Cultivated fields. Uncommon.

<u>Rorippa mexicana</u> (DC.) Standl. & Steyerm. Creekbank.

<u>Schoenocrambe linearifolia</u> (A. Gray) Rollins. Oak forests.

Buddlejaceae

<u>Buddleja parviflora</u> H.B.K. Oak forests.

<u>Buddleja sessiliflora</u> H.B.K. Oak forests.

Cactaceae

Echinocereus polyacanthus Engelm. var. polyacanthus. Fields and open oak forests.

Echinocereus sheeri (Salm-Dyck) Scheer var. sheeri. Shaded cliff faces in cypress and maple forests.

Echinocereus stoloniferus W.T. Marsh var. tayopensis (W.T. Marsh) N.P. Taylor. Fields, oak forests, and manzanita thickets.

Mammillaria barbata Engelm. vel aff. Fields and open oak forests.

Mammillaria sonorensis Craig vel aff. Cliff faces in cypress forest.

Opuntia durangensis Britt. & Rose. Fields, cliff faces, and open oak forests. Both red- and yellow-fruited specimens present.

Opuntia macrorhiza Engelm. vel aff. Fields and oak forests.

Opuntia robusta Wendl. vel aff. Fields, cliff faces and oak forests.

Caesalpiniaceae

Cassia leptadenia Greenm. Fields.

Campanulaceae

Heterotoma goldmanii Fern. Fields and creekbanks.

Lobelia anatina F.E. Wimmer. Maple forests.

Lobelia cardinalis L. var. *pseudosplendens* McVaugh. Springs and cypress forests.

Lobelia fenestralis Cav. Fields.

Lobelia laxiflora H.B.K. var. *angustifolia* DC. Creekbanks.

Lobelia laxiflora H.B.K. var. *nelsonii* (Fernald) McVaugh. Creekbanks. One specimen (*Laferrière 417*, ARIZ) is intermediate between the two varieties.

Triodanis biflora (A. Gray) E. Greene. Fields.

Caprifoliaceae

Lonicera cerviculata S.S. White. Creekbanks in oak and cypress forests.

Caryophyllaceae

Arenaria lanuginosa (Michx.) Rohrb. ssp. saxosa (A. Gray) Maguire. Forests.

Cerastium nutans Raf. Oak and maple forests.

Cerastium texanum Britton. Cliff faces. Vouchered at RM.

Drymaria effusa A. Gray. var. *effusa*. Fields and cliff faces.

Drymaria molluginea (Lag.) Didr. Fields.

Drymaria villosa Cham. & Schlecht. ssp. *palustris* (Cham. & Schlecht) J. Duke. Fields and cypress forests.

Silene scouleri Hook. ssp. *pringlei* (S. Wats.) Hitchcock & Maguire var. *eglandulosa* Hitchcock & Maguire. Cypress forests.

Chenopodiaceae

Chenopodium leptophyllum Nutt. Cultivated fields.

Teloxys ambrosioides (L.) W.A. Weber. Creekbanks. = Chenopodium ambrosioides L.

Teloxys graveolens (Willd.) W.A. Weber var. neomexicanum (Aellen) Aellen. Fields and pine forests.

Cistaceae

Helianthemum pringlei S. Wats. Fields and manzanita thickets.

Lechea tripetala (Moc. & Sess.) Britton. Oak forests.

Clusiaceae

Hypericum pratense Schl. & Cham. Fields and forests.

Hypericum punctatum Lam. Forests.

Cochlospermaceae

Amoreuxia palmatifida Moc. & Sesse. Open fields.

Convolvulaceae

Evolvulus alsinoides L. Cliff faces. Vouchered at ASU and MEXU.

Evolvulus arizonicus A. Gray. Forests and manzanita

thickets.

Evolvulus sericeus Sw. Fields and cliff faces.

Ipomoea capillacea (H.B.K.) G. Don. Fields and oak forests.

Ipomoea costellata Torr. Fields, creekbanks, and oak forests.

Ipomoea cristulata H. Hallier. Fields.

Ipomoea madrensis S. Wats. Fields and forests.

Ipomoea pubescens Lam. Oak forests.

Ipomoea purpurea (L.) Roth. Fields, creekbanks, and springs.

Ipomoea sescossiana Baill. Cypress forests. Vouchered at ASU.

Ipomoea tenuiloba Torr. var. lemmonii (A. Gray) Yatsk. & C. Mason. Fields, cliff faces, and cypress forests.

Ipomoea thurberi A. Gray. Fields.

Crassulaceae

Echeveria cragiana E. Walther. Pine forests.

Sedum alamosanum S. Wats. Cypress forests.

Sedum mellitulum Rose. Cliff faces.

Sedum vinicolor S. Wats. Cliff faces.

Villadia squamulosa (S. Wats.) Rose. Oak forests.

Cucurbitaceae

Apodanthera undulata A. Gray. Fields.

Cucurbita foetidissima H.B.K. Fields.

<u>Cyclanthera dissecta</u> (Torr. & Gray) Arn. Creekbanks in pine and cypress forests.

Cuscutaceae

<u>Cuscuta campestris</u> Yuncker. Parasite on herbs in fields.

Ericaceae

<u>Arbutus arizonica</u> (A. Gray) Sarg. Pine and cypress forests.

<u>Arbutus xalapensis</u> H.B.K. Pine and cypress forests.

<u>Arctostaphylos pungens</u> H.B.K. Oak forests and manzanita thickets.

Euphorbiaceae

<u>Acalypha neomexicana</u> Muell.-Arg. vel aff. Creekbanks and oak and cypress forests.

<u>Euphorbia adenoptera</u> Bertol. Fields.

<u>Euphorbia bilobata</u> Engelm. Oak forests.

<u>Euphorbia capitellata</u> Engelm. Springs.

<u>Euphorbia cyathophora</u> Murray. Fields.

<u>Euphorbia dentata</u> Michx. Fields and oak and cypress forests.

<u>Euphorbia gracillima</u> S. Wats. Creekbanks.

<u>Euphorbia graminea</u> Jacq. vel aff. Fields and pine forests.

<u>Euphorbia hirta</u> L. Fields and oak forests.

<u>Euphorbia hyssopifolia</u> L. Fields.

<u>Euphorbia indivisa</u> (Engelm.) Tidestrom. Oak forests.

Euphorbia plummerae S. Wats. Forests.

Euphorbia subreniformis S. Wats. Oak forests. Vouchered at SD.

Tragia nepetifolia Cav. Fields and oak forests.

Fabaceae

Aeschynomene americana L. var. _glandulosa_ (Poir.) Rudd. Creekbanks.

Astragalus nuttallianus DC. var. _austrinus_ (Small) Barneby. Creekbanks.

Cologania angustifolia Kunth. Pine forests and manzanita thickets.

Cologania broussonettii (Balb.) DC. Fields.

Cologania obovata Schlecht. Manzanita thickets and oak and pine forests.

Coursetia caribaea (Jacq.) Lavin var. _sericea_ (A. Gray) Lavin. Oak and pine forests.

Coursetia glabella (A. Gray) Lavin. Fields.

Crotalaria pumila Ortega. Fields and creekbanks.

Crotalaria sagittalis L. Fields and forests.

Dalea albiflora A. Gray. Fields.

Dalea exigua Barneby. Fields and oak and cypress forests.

Dalea filiformis A. Gray. Fields and oak and pine forests.

Dalea grayi (Vail) L.O. Williams. Oak forests and manzanita thickets.

Dalea leporina (Ait.) Bullock. Creekbanks and fields.

Dalea lumholtzii Rob. & Fern. Oak forests.

Dalea nelsonii (Rydb.) Barneby. Fields.

Dalea obreniformis (Rydb.) Barneby. Cultivated and fallow fields.

Dalea pinetorum Gentry. Oak forests.

Dalea pringlei A. Gray var. multijuga Barneby. Oak forests.

Dalea versicolor Zucc. ssp. versicolor var. calcarata (Gentry) Barneby. Cypress forests.

Desmodium angustifolium (H.B.K.) DC. var. angustifolium. Fields.

Desmodium angustifolium (H.B.K.) DC. var. gramineum (A. Gray) Schubert. Oak forests.

Desmodium hartwegianum Hemsl. Fields and oak forests.

Desmodium madrense Hemsl. Fields and oak and cypress forests.

Desmodium neomexicanum A. Gray. Fields and forests.

Desmodium procumbens (Mill.) Hitchc. var. exiguum (A. Gray) Schubert. Cypress forests.

Desmodium procumbens (Mill.) Hitchc. var. procumbens. Oak forests.

Desmodium prostratum Brandegee. Forests.

Desmodium psilophyllum Schlecht. Riverbanks in maple and cypress forests.

Eriosema pulchellum (H.B.K.) G. Don. Fields and forests.

Erythrina flabelliformis Kearn. Oak forests.

Eysenhardtia orthocarpa (A. Gray) Wils. var. orthocarpa. Creekbanks and steep hillsides.

Galactia wrightii A. Gray. Oak forests.

Indigofera densiflora Mart. & Gal. Fields.

Indigofera sphaerocarpa A. Gray. Oak forests. Vouchered at MONT.

Lotus alamosanus (Rose) Gentry. Creekbanks in pine and cypress forests.

Lotus greenei (Woot. & Standl.) Ott. Oak forests.

Lupinus huachucanus M.E. Jones. Pine and maple forests.

Macroptilium gibbosifolium (Ort.) A. Delgado. Creekbanks and oak forests.

Phaseolus acutifolius A. Gray var. tenuifolius A. Gray. Cypress forests.

Phaseolus leptostachyus Benth. Fields and oak forests.

Phaseolus parvulus E. Greene. Maple and cypress forests.

Phaseolus pauciflorus G. Don. Fields, manzanita thickets, and oak and pine forests.

Phaseolus ritensis M.E. Jones. Oak and pine forests.

Tephrosia cinerea (L.) Pers. vel aff. Pine forests.

Tephrosia nicaraguensis Benth & Oerst. Oak forests.

Trifolium amabile H.B.K. var. amabile. Fields and cypress forests.

Trifolium pinetorum E. Greene. Fields. Vouchered at MONT.

Trifolium wormskioldii Lehm. Creekbanks and fields.

Vicia pulchella H.B.K. Fields and oak forests.

Zornia reticulata Sm. Fields.

Zornia venosa Mohl. Fields

Fagaceae

Quercus chihuahuensis Trel. Forests.

Quercus chuhuichupensis Muller. Oak forests and manzanita thickets.

Quercus coccolobaefolia Trel. Oak and pine forests.

Quercus mcvaughii Spellenberg, sp. nov. ined. Oak forests. This is the "northern phase of Q. crassifolia H.B.K." discussed by McVaugh (1974).

Quercus depressipes Trel. Pine and oak forests.

Quercus durifolia von Seemen. Oak and pine forests.

Quercus epileuca Trel. Oak and pine forests.

Quercus urbanii Trel. Oak and pine forests.

Quercus viminea Trel. Oak and pine forests.

Quercus x knoblochii Muller. Oak and pine forests. Hybrid between Q. viminea and Q. cocolobifolia.

Garryaceae

Garrya laurifolia Benth. ssp. laurifolia. Cypress and maple forests.

Garrya wrightii Torr. Oak and cypress forests.

Gentianaceae

Centaurium nudicaule (Engelm.) Robinson. Fields.

Gentianella microcalyx (Lemm.) Gill. Cypress forests.

Geraniaceae

Geranium albidum Hands & Small. Creekbanks in cypress forests.

Geranium subulato-stipulatum Kunth. Creekbanks in oak and cypress forests.

Geranium wislizeni S. Wats. Creekbanks in oak, cypress, and maple forests.

Gesneriaceae

Achimenes grandiflora (Schiede) DC. Shaded cliff faces in cypress forests.

Lamiaceae

Agastache mearnsii Woot. & Standl. Oak and cypress forests.

Agastache pallida (Lindl.) Cory var. *coriacea* R. Sanders. Oak forests.

Hedeoma patens M.E. Jones. Fields and oak and cypresss forests.

Hyptis seemannii A. Gray. Cliff faces and fields.

Lepechinia caulescens (Ort.) Epling. Fields.

Mentha piperita L. vel aff. Under *Baccharis salicifolia* along creekbank.

Monarda austromontana Epling. Fields.

Prunella vulgaris L. Creekbanks and cypress forests.

Salvia azurea Lam. Oak and pine forests.

Salvia galinsogifolia Fern. Springs and oak and maple forests.

Salvia goldmanii Fern. Creekbanks and oak forests.

Salvia greggii A. Gray. Oak and cypress forests.

Salvia hispanica L. Creekbanks, fields, and cypress forests.

Salvia lemmonii A. Gray. Oak and cypress forests.

Salvia reptans Jacq. var. *glabra* (A. Gray) K.M. Peterson. Fields and oak forests.

Salvia subincisa Benth. Cypress forests.

Salvia tiliaefolia Vahl. Fields and oak forests.

Stachys bigelovii A. Gray. Cypress forests.

Stachys coccinea Jacq. Fields and forests.

Lentibulariaceae

Pinguicula macrophylla H.B.K. Maple forests.

Loranthaceae

Phoradendron bolleanum (Seemen) Eichl. Parasitic on *Arbutus* spp. and *Juniperus deppeana.*

Phoradendron engelmannii Trel. Parasitic on *Quercus* spp.

Lythraceae

<u>Cuphea llavea</u> Lex. Creekbanks and cypress forests.

<u>Cuphea wrightii</u> A. Gray. Fields and open oak forests.

<u>Rotala ramosior</u> (L.) Koehne. Streambanks.

Malpighiaceae

<u>Ascicarpa hirtella</u> Rich. Oak forests.

Malvaceae

<u>Anoda cristata</u> (L.) Schlecht. Fields and streambanks.

<u>Malva parviflora</u> L. Fields and oak forests.

<u>Sida alamosana</u> Rose. Cliff faces.

<u>Sida neomexicana</u> A. Gray. Fields and pine and oak forests.

Mimosaceae

<u>Acacia angustissima</u> (Mill.) Kuntze. Fields and forests.

<u>Calliandra humilis</u> Benth. var. <u>humilis.</u> Fields and cypress forests.

<u>Calliandra humilis</u> Benth. var. <u>reticulata</u> (A. Gray) L. Benson. Fields.

<u>Mimosa dysocarpa</u> Benth. Pine and oak forests.

<u>Mimosa grahamii</u> A. Gray var. <u>grahamii.</u> Fields and oak and cypress forests.

Nyctaginaceae

Boerhaavia coccinea Mill. Fields.

Mirabilis longiflora L. Fields and oak forests.

Oleaceae

Forestiera pubescens Nutt. Oak, cypress, and maple forests.

Fraxinus papillosa Lingelsheim. Forests.

Fraxinus pennsylvanica Marsh. ssp. velutina (Torr.) Miller. Oak and pine forests.

Osmanthus americanus (L.) Benth & Hook. Maple forests.

Onagraceae

Epilobium fendleri Hausskn. Springs and creekbanks.

Gaura hexandra Sesse & Moc. var. gracilis (Woot. & Standl.) Raven & Gregory. Fields.

Gongylocarpus rubricaulis Cham. & Schlecht. Fields and oak forests.

Oenothera kunthiana (Spach) Munz. Sunlit creekbanks.

Oenothera pubescens Spreng. Fields.

Oenothera rosea Ait. Fields.

Orobanchaceae

Conopholis alpina Liebm. var. mexicana (S. Wats.) Haynes. Pine forests.

Oxalidaceae

Oxalis albicans H.B.K. ssp. *albicans.* Common in sunny locations.

Oxalis alpina (Rose) Kunth. Fields.

Oxalis decaphylla H.B.K. Fields and forests.

Oxalis hernandesii DC. Fields, oak forests, and manzanita thickets.

Oxalis latifolia H.B.K. Fields and maple forests.

Passifloraceae

Passiflora bryonioides H.B.K. Cliff faces and manzanita thickets.

Passiflora quercetorum Killip. Cypress forests.

Phytolaccaceae

Phytolacca americana L. Fields and creekbanks.

Plantaginaceae

Plantago argyraea Morris. Fields.

Plantago hirtella Kunth. Cypress forests.

Podostemaceae

Podostemon ceratophyllum Michx. Aquatic.

Polemoniaceae

Ipomopsis pinnata (Cav.) V. Grant. Fields and pine and oak forests.

Loeselia glandulosa (Cav.) G. Don. Oak forests. Common.

Polygalaceae

Monnina wrightii A. Gray. Fields and forests.

Polygala sinaloae S.F. Blake vel aff. Fields and pine and oak forests.

Polygala glochidiata H.B.K. Fields and oak forests.

Polygala hemipterocarpa A. Gray. Fields and oak forests.

Polygala obscura Benth. var. _obscura._ Fields and forests.

Polygonaceae

Polygonum lapathifolium L. Sunlit creekbanks.

Polygonum mexicanum Small. Sunlit creekbanks.

Polygonum persicaria L. Sunlit creekbanks.

Polygonum punctatum Ell. Shaded springs in cypress forest.

Pterostegia drymarioides Fisch. & Meyer. Creekbanks.

Rumex obtusifolius L. Fields and forests.

Rumex violascens Rech. Creekbanks.

Portulacaceae

Portulaca oleracea L. Cultivated fields.

Portulaca suffrutescens Engelm. Fields.

Talinum marginatum E. Greene. Cliff faces.

Primulaceae

Samolus floribundus H.B.K. Cypress forests.

Ranunculaceae

Clematis drummondii Torr. & A. Gray. Fields, often over *Opuntia* spp.

Delphinium wislizeni Engelm. Fields and cypress forests.

Ranunculus circinatus Sibth. var. *subrigidus* (W. Drew) L. Benson. Aquatic.

Ranunculus macranthus Scheele. Streambanks.

Thalictrum pinnatum S. Wats. Fields and open pine and oak forests.

Rhamnaceae

Ceanothus coeruleus Lag. Maple forests.

Ceanothus depressus Benth. Oak forests.

Ceanothus lanuginosus (Jones) Rose. Pine and cypress forests.

Rhamnus scopulorum (M.E. Jones) C.B. Wolf. Oak and cypress forests.

Rosaceae

Cercocarpus montanus Raf. var. paucidentatus (S. Wats.) F.L. Martin. Riverbank.

Holodiscus dumosus (Nutt.) Heller var. australis (Heller) Ley. Cypress forests.

Potentilla thurberi A. Gray. Fields and oak forests.

Prunus gentryi Standl. forma gentryi. Creekbanks, cypress and maple forests.

Prunus gentryi Standl. forma flavipulpa Lafer. Creekbanks.

Prunus serotina Ehrh. ssp. virens (Woot. & Standl.) McVaugh var. virens. Pine and cypress forests.

Rubus arizonicus Focke vel aff. Maple forests.

Rubiaceae

Bouvardia ternifolia (Cav.) Schlecht. Fields and oak forests.

Crusea diversifolia (H.B.K.) Anderson. Fields.

Crusea longiflora (Willd.) Anderson. Fields, forests, and manzanita thickets.

Crusea wrightii A. Gray var. wrightii. Fields.

Galium hystricocarpum Greenm. Oak forests and cliff faces.

Galium mexicanum Kunth ssp. asperrimum (A. Gray) Demp. Pine, cypress, and maple forests.

Galium microphyllum A. Gray. Cliff faces and creek banks.

Houstonia wrightii A. Gray. Fields and creekbanks.

Mitracarpus hirtus (L.) DC. Fields and cliff faces.

Salicaceae

Salix bonplandiana H.B.K. Streambanks.

Salix lasiolepis Benth. Creekbanks in pine and cypress forests.

Salix taxifolia H.B.K. Riverbank.

Saxifragaceae

Heuchera sanguinea Engelm. Shaded cliff faces in cypress forest.

Scrophulariaceae

Brachystigma wrightii (A. Gray) Pennell. Fields and open forests.

Buchnera pusilla H.B.K. Fields.

Castilleja lithospermoides H.B.K. Pine forests.

Castilleja tenuiflora Benth. Creekbanks, forests, and manzanita thickets.

Escobedia crassipes Pennell. Oak forests.

Lamourouxia viscosa H.B.K. Fields.

Mecardonia vanelloides (H.B.K.) Pennell. Creekbanks.

Mimulus glabratus H.B.K. Springs and creekbanks in cypress forests.

Mimulus guttatus DC. Shaded creekbanks.

Mimulus pallens E. Greene. Creekbanks.

Mimulus pennellii Gentry. Creekbanks.

Penstemon campanulatus (Cav.) Willd. Manzanita thickets and oak and cypress forests.

Penstemon linearioides A. Gray var. *linearioides.* Fields.

Penstemon pinifolius E. Greene. Oak forests.

Penstemon wislizeni (A. Gray) Straw. Pine and oak forests.

Schistophragma intermedia (A. Gray) Pennell. Oak forests.

Seymeria bipinnatisecta Seemen. Pine and oak forests.

Veronica peregrina L. Creekbanks.

Solanaceae

Browallia angustifolia R. VanDevender & P. Jenkins, sp. nov. ined. Oak forests and open cliff faces.

Jaltomata procumbens (Cav.) J.L. Gentry. Fields and oak forests.

Physalis caudella Standl. Cultivated fields.

Physalis minima L. Fields and oak forests. = *P. lagascae* Roemer & Schultes.

Physalis microcarpa Urban & Eckman. Fields and oak forests.

Physalis philadelphica Lam. Cultivated fields.

Physalis pubescens L. Fields and cypresss forests.

Solanum nannodes Corr. vel aff. Cypress forests and as a weed in potato fields.

Solanum nigrescens Mart. & Gal. Fields, oak forests, and manzanita thickets.

<u>Solanum rostratum</u> Dunal. Fields near riverbank.

Tiliaceae

<u>Triumfetta discolor</u> Rose. Fields and pine and cypress forests.

Valerianaceae

<u>Valeriana sorbifolia</u> H.B.K. var. <u>sorbifolia.</u> Cypress forests.

Verbenaceae

<u>Glandularia bipinnatifida</u> (Nutt.) Nutt. Cypress forests.

<u>Priva mexicana</u> (L.) Pers. Oak and pine forests.

<u>Verbena carolina</u> L. Fields.

<u>Verbena neomexicana</u> (A. Gray) Small. Fields, oak forests, and manzanita thickets.

<u>Verbena perennis</u> Woot. Fields and oak and pine forests.

Violaceae

<u>Viola adunca</u> J.E. Smith. Pine, cypress, and maple forests.

Vitaceae

<u>Vitis arizonica</u> Engelm. Shaded creekbanks.

MONOCOTYLEDONAE

Agavaceae

Agave polianthiflora Gentry. Pine and oak forests.

Agave shrevei Gentry ssp. matapensis Gentry. Cliff faces and oak forests.

Manfreda singuliflora (S. Wats.) Rose. Creekbanks in oak forests.

Yucca madrensis Gentry. North-facing slopes in oak forests (Laferrière 1990a).

Alliaceae

Allium rhizomatum Woot. & Standl. Fields near creekbanks.

Milla biflora Cav. Fields and cliff faces.

Amaryllidaceae

Hymenocallis pimana Lafer. Unplowed fields and sun-lit creekbanks (Laferrière 1990b).

Antheriaceae

Echeandia durangensis Cruden. Creekbanks and oak forests.

Echeandia flavescens (Schultes & Schultes) Cruden. Creekbanks and oak forests.

Echeandia mexicana Cruden. Pine forests.

Bromeliaceae

Tillandsia erubescens Schlecht. Epiphytic on most trees; occasionally on shaded cliff faces in moist canyons.

Tillandsia recurvata L. Epiphytic on various trees.

Calochortaceae

Calochortus fuscus Schultes. Cypress forests.

Calochortus venustulus E. Greene var. *madrensis* (S. Wats.) Reveal & Hess. Fields and open oak forests.

Commelinaceae

Commelina coelestis Willd. Fallow fields and oak and pine forests.

Commelina dianthifolia Del. Oak, pine and cypress forests.

Tradescantia amplexicaulis Clarke. Oak, pine, and cypress forests. = *Tripogandra amplexicaulis* (Clarke) Woods.

Tradescantia linearis Benth. Oak, pine, and cypress forests. = *Aneilema linearis* (Benth.) Woods.

Tradescantia pinetorum E. Greene. Fallow fields and oak forests. = *Aneilema pinetorum* (E. Greene) Woods.

Cyperaceae

Bulbostylis capillaris (L.) Clarke. Cultivated fields, oak and pine forests.

Carex agrostoides MacKenzie. Cypress forests.

Carex chihuahuensis MacKenzie. Creekbanks.

Carex endlichii Kukenth. Cypress forests.

Carex leucodonta Holn. Pine forests.

Carex longicaulis Bock. Pine forests.

Carex turbinata Liebm. Maple forests.

Cyperus amabilis Vahl. Fallow fields.

Cyperus bipartitus Torr. Springs and creekbanks.

Cyperus dipsaceus Liebm. Fields and pine forests.

Cyperus esculentus L. Common in cultivated fields; also pine and oak forests.

Cyperus hermaphroditus (Jacq.) Standl. Fields and forests.

Cyperus niger Ruiz & Pavon. Springs and creek banks.

Cyperus seslerioides H.B.K. Oak forests and manzanita thickets.

Cyperus squarrosus L. Fallow fields.

Eleocharis parvula (Roem. & Schult.) Link. Creekbanks.

Eleocharis rostellata (Torr.) Torr. Creekbanks.

Fimbristylis annua (All.) Roem. & Schult. Creekbanks and oak forests.

Fimbristylis autumnalis (L.) Roem. & Schult. Fields, creekbanks, and springs.

Fimbristylis puberula (Michx.) Vahl. Oak forests.

Hypoxidaceae

Hypoxis mexicana Schultes. Fields and manzanita thickets.

Iridaceae

Nemastylis tenuis (Herb.) Baker. Unplowed fields.

Sisyrinchium palmeri Greenm. Oak forests and manzanita thickets.

Sisyrinchium scabrum Schlecht. & Cham. Fields and cliff faces.

Tigridia pavonia (L. f.) DC. Cypress forests.

Juncaceae

Juncus articulatus L. Creekbanks.

Juncus confusus Coville. Creekbanks.

Juncus interior Wieg. Creekbanks and cypress forests.

Melanthiaceae

Schoenocaulon megarhizum M.E. Jones var. _megarhizum._ Cypress forests.

Zigadenus virescens (H.B.K.) Macbr. Maple forests.

Nolinaceae

Dasylirion wheeleri S. Wats. var. _durangense_ (Trel.) Lafer. Cliff faces and oak forests.

Dasylirion wheeleri S. Wats. var. _wheeleri._ Cliff faces and oak forests. The two varieties of this species intergrade in Nabogame (Laferrière 1991a).

<u>Nolina</u> sp. Pine and oak forests.

Orchidaceae

<u>Bletia gracilis</u> Lodd. var. <u>roezlii</u> (Reichb.) L.O. Williams. Pine and oak forests.

<u>Corallorhiza involuta</u> Greenm. Maple forests.

<u>Epipactis gigantea</u> Dougl. Riverbank.

<u>Govenia liliacea</u> (Lex.) Lindl. Oak and cypress forests.

<u>Habenaria clypteata</u> Lindl. Pine and cypress forests.

<u>Habenaria guadalajara</u> S. Wats. Fallow fields.

<u>Hexalectris grandiflora</u> (A. Richard & Galeotti) L.O. Williams. Pine forests.

<u>Malaxis fastigata</u> (Reichb.f.) Kuntze. Cypress forests.

<u>Malaxis myurus</u> (Lindl.) Kuntze. Cypress forests.

<u>Spiranthes aurantiaca</u> (Llave & Lex.) Hemsley. Unplowed fields.

<u>Spiranthes lancelolata</u> (Aubl.) Leon. Oak forests.

<u>Spiranthes michuacana</u> (Lex.) Hemsley. Fields.

<u>Spiranthes rubrocalosa</u> Rob. & Greenm. Fields.

<u>Triphora trianthophora</u> (Sw.) Rydb. Oak forests.

Poaceae

<u>Aegopogon cenchroides</u> Humb. & Bonpl. Cliff faces and oak forests.

<u>Aegopogon tenellus</u> (DC.) Trin. var. <u>abortivus</u> Beetle.

Cypress forests.

Aegopogon tenellus (DC.) Trin. var. tenellus. Oak forests and cliff faces.

Agrostis scabra Willd. Cypress forests.

Aristida adscensionis L. Fields and oak and pine forests.

Bothriochloa barbinodis (Lag.) Herter. Fields.

Bouteloua curtipendula (Michx.) Torr. Fields and cypress forests.

Bouteloua gracilis (H.B.K.) Steud. Creekbanks.

Bouteloua hirsuta Leg. Creekbanks.

Bouteloua radicosa (Fourn.) Griffiths. Fields.

Bouteloua repens (H.B.K.) Scribn. & Merr. Oak forests.

Bromus anomalus Fourn. Creekbanks and forests.

Chloris submutica H.B.K. Fields.

Chloris virgata Swartz. Creekbanks.

Cynodon dactylon (L.) Pers. Fields.

Digitaria sanguinalis (L.) Scop. Fields and creekbanks.

Echinochloa colonum (L.) Link. Creekbanks.

Echinochloa crusgalli (L.) P. Beauv. Creekbanks, cultivated fields, and cypress forests.

Echinochloa muricata (P. Beauv.) Fern. Creekbanks.

Eleusine indica (L.) Gaertn. Cultivated and noncultivated fields.

Eleusine multiflora Hochst. Fields.

Elyonurus barbiculmis Hack. Oak forests.

Eragrostis intermedia A.S. Hitchc. Fields, cliff faces, and cypress forests.

Eragrostis mexicana (Hornem.) Link. Fields.

Eriochloa acuminata (Presl.) Kunth var. acuminata. Fields.

Eriochloa lemmonii Vasey & Scribn. Oak forests.

Hackelochloa granularis (L.) Kuntze. Fields.

Heteropogon melanocarpus (Ell.) Benth. Fields.

Hilaria swallenii Cory. Fields.

Muhlenbergia alamosae Vasey. Oak forests

Muhlenbergia annua (Vasey) Swallen. Creekbanks.

Muhlenbergia argentea Vasey. Oak forests.

Muhlenbergia dumosa Scribn. Creekbanks.

Muhlenbergia durangensis Herrera vel aff. Pine forests.

Muhlenbergia elongata Beal. Fields.

Muhlenbergia emersleyi Vasey. Cliff faces.

Muhlenbergia leptoura (Piper) A.S. Hitchc. Springs.

Muhlenbergia montana (Nutt.) A.S. Hitchc. Pine and cypress forests.

Muhlenbergia polycaulis Scribner. Maple forests.

Muhlenbergia rigens (Benth.) A.S. Hitchc. Cypress forests.

Muhlenbergia schmitzii Hackel. Springs.

Muhlenbergia scoparia Vasey vel aff. Pine forests.

Oplismenus burmannii (Retz.) P. Beauv. Cypress forests.

Panicum bulbosum H.B.K. Fields and forests. Very common.

Panicum hirticaule Presl. Fields and creek banks.

Paspalum convexum Willd. Fields and creekbanks.

Paspalum distichum L. Creekbanks.

Paspalum setaceum Michx. var. stramineum (Nash) D. Banks. Fields.

Paspalum squamulatum Fourn. vel aff. Cypress forests.

Pereilema crinitum Presl. Fields and cypress forests.

Piptochaetium fimbriatum (H.B.K.) A. Hitchc. Pine forests.

Poa annua L. Creekbanks.

Polypogon elongatus H.B.K. Creekbanks.

Polypogon viridis (Gouan) Breistr. Creekbanks.

Rhynchelytrum repens (Willd.) C.E. Hubbard. Fields.

Schizachyrium cirratum (Hack.) Woot. & Standl. Forests.

Schizachyrium hirtiflorum Nees. Oak forests.

Setaria geniculata (Lam.) P. Beauv. Fields.

Setaria glauca (L.) P. Beauv. Creekbanks and cypress forests.

Setaria griesbachii Fourn. Fields and oak forests.

Setaria macrostachya H.B.K. vel aff. Fields.

Sorghastrum nutans (L.) Nash. Creekbanks and oak and cypress forests.

Sporobolus indicus (L.) R. Br. Fields and oak forests.

Trachypogon secundus (Presl.) Scribn. Fields and pine forests.

Tripsacum lanceolatum Fourn. Cliff faces and oak and pine forests.

Pontederiaceae

Heteranthera limosa (Sw.) Willd. Aquatic.

Heteranthera peduncularis Benth. Aquatic.

Potamogetonaceae

Potamogeton foliosus Raf. Aquatic.

Potamogeton pusillus L. Aquatic.

Smilacaceae

Smilax moranensis Mart. & Gal. var. *moranensis.* Maple forests.

APPENDIX II

MOUNTAIN PIMA PLANT AND FUNGAL NAMES

The following list includes all Mountain Pima names for which I have reasonable confidence. In each case the Pima name is followed by the name used in the local dialect, and the scientific name. The symbol "j" in Pima names refers to the German ch or Spanish j; "y" indicates palatization of the preceding consonant; "ch" and "sh" have the same meanings as in English; "+" refers to an open front vowel. An apostrophe represents a glottal stop. Accent is on the first syllable unless noted. Final vowels in Mountain Pima can fluctuate, especially between "e" and "i", or be dropped entirely. Such fluctuation extends to Spanish names as pronounced by the Mountain Pima, such as "saraviqui" or "matariki". Nonfinal "e" occurs only in words borrowed from Spanish or Tarahumara (D. Saxton, personal communication).

aajas = ajo = _Allium sativum_

a'loki = juve = _Cosmos parviflorus_

anís = anís = _Tagetes filifolia_

ara = calabazilla chiquita = _Apodanthera undulata_

ara = calabazilla grande = _Cucurbita foetidissima_

ba'iva = palo dulce = _Eysenhardtia orthocarpa_ baashoma = batamote = <u>Baccharis salicifolia</u>

babulyi = calabaza = <u>Cucurbita pepo</u>

ban ga'a = tàscate = <u>Juniperus deppeana</u>

bautama hioshgama = flor de piedra = <u>Selaginella lepidophylla</u>

bava hioshgara = flor de reliz = <u>Achimenes grandiflora</u>

bavi = frijol = <u>Phaseolus vulgaris</u> or <u>P. coccineus</u>

bavish = bavisa = <u>Cosmos pringlei</u>

bi'igama huko = pino finito = <u>Pinus lumholtzii</u>

bipshi hioshgama = flor de chuparosa = <u>Lobelia cardenalis</u> or <u>Stachys coccinea</u>

bopkama sha'i = oreja de conejo = <u>Hieracium fendleri</u>

boapkokama = tonolochi = <u>Passiflora</u> spp.

bopkama tu'a = encino blanco = <u>Quercus chihuahuensis</u>

bopshok shù'udara = huevo de ratón = <u>Crotalaria pumila</u>

chilokó'ot = chilicote = <u>Erythrina flabelliformis</u>

divi'uka = lima = <u>Rhus trilobata</u>

dogo t++lyigo = espiga de trigo = <u>Salvia hispanica</u> or <u>Prunella vulgaris</u>

duji = nopal de zorra = <u>Opuntia macrorhiza</u>

duurshañi k= durazno = <u>Prunus persica</u>

ga'a = sabino = <u>Cupressus arizonica</u>

gagyap+lyi = encino chapito or encino chinito or encino vajito = <u>Quercus chihuichupensis</u>

h+'+k sha'i = hierba aigre = <u>Begonia gracilis</u>

h+kt+lyi = bayburín = *Cuphea llavea*

h+kt+lyi = hierba aigre or zacate aigre = *Oxalis* spp.

haap+ky+lyi = encino de hojas anchas = *Quercus cocolobaefolia*

hada ko'o kaskavélgara = herba de la víbora = *Zornia venosa*

haramkulyi = mala mujer = *Desmodium hartwegianum, Priva mexicana*, or *Triumfetta discolor*

haramkulyi = toji = *Phoradendron* spp.

hauk u'ushi = sauco = *Sambucus mexicana*

hyopdyama = madroño = *Arbutus* spp.

hiishulyi = jamón = *Echeveria craigiana*

ho'i = junco = *Ceanothus buxifolius*

hoda hioshgara = flor de piedra = *Heuchera sanguinea*

hoyi = jamol = *Yucca madrensis*

hoyi = savaliqui = *Yucca grandiflora*

huko = pino colorado = *Pinus arizonica*

humpalyi = ahuasiqui = *Prunus gentryi*

huun = maiz = *Zea mays*

huun viikogar = hongo de maiz = *Ustilago zeae*

ibimaki = ? = *Dalea versicolor*

iol = manzanilla = *Artostaphylos pungens*

kaava boporo = redadura de nopal = *Clematis drummondii*

kaba hira = cola de caballo = *Equisetum hyemale*

kachana = dalia or cachana = *Dahlia* spp.

karnavála = carnehual = ferns

kiki = quiqui = orchids

ko'ovalyi = coronilla = Berlandiera lyrata

koko hoyi = hierba del sapo = Eryngium heterophyllum

kokonchara = palo de cuervo = Dryopetalon runcinatum

koksham = matarikė = Acourtia thurberi

komichi = saraviqui amargo = Prionosciadium madrense

kordón = cordoncillo = Elytraria imbricata

kuusi = cusi = Quercus viminea

lali contrayėrva = contrahierba chiquita = Gomphrena nitida

lali miisholya = gatuña chiquita = Mimosa dyssocarpa

lali tomáata = Physalis minima or P. microcarpa

maalva = malva = Malva parviflora

mansani = manzanilla del rio = Gnaphalium viscosum

manshani = manzanilla = Chamomilla recutita

maravii = maravilla = Mirabilis spp.

matashmayi = tarėchari = Agave polianthiflora

mayi = chugilla or churiqui = Agave shrevei

miishuktara = gatuña = Mimisa grahamii

mo'oshgama = capulin = Prunus serotina

mortasa = mortal = Pherotrichis balbisii

musha = estafiete = Ambrosia psilostachya

nakshura = baatayaqui = Montanoa leucantha

nava = nopal temporal = Opuntia robusta

navája sha'i = zacate de navaja = Bouteloua spp.

nor sha'i = hierba de la flecha = Panicum bulbosum o'ob u'ushi = palo aigre or palo amarillo or palo dulce = *Berberis pimana*

oichka u'uvàra = sauzo de la casa = *Salix babylonica*

pashko'o nava = nopal de duraznillo = *Opuntia durangensis*

pashma = hierba del pasmo = *Baccharis thesioides*

pashóota = pasote = *Teloxys ambrosioides*

piichai = fresno = *Fraxinus* spp.

pitáya = pitaya = *Mammillaria sonorensis*

rosál = rosal = *Oenothera rosea*

ruuda = ruda = *Bidens gentryi* or *Tagetes palmeri*

shampwál = sampual = *Tagetes erecta*

shamundam = pipichau = *Acourtia dieringeri*

shereki = sotol = *Dasylirion wheeleri*

shevó'oya = cebollín = *Allium rhizomatum*

shi'iva = cebollín = *Hymenocallis pimana*

shiipugi = tusi = *Anoda cristata*

shipura = encino colorado = *Quercus durifolia*

shishpura = ruína = *Acacia angustissima*

shiitulyi = redadera = *Ipomoea* spp.

sho'olyi ga'a = táscate negro or táscate chino = *Juniperus erythrocarpa*

shohar u'ushi = parra = *Vitis arizonica*

shojara = barril = *Quercus epileuca*

sojara = haya = *Acer grandidentatum*

t++lyigo = trigo = *Triticum aestivum*

t++m+ra = ortigilla = *Tragia nepetifolia*

t+p+lyi = matarike = *Psacalium decompositum*

t+pura = carnero = *Alnus oblongifolius*

t+t+'ibwi = tuna novembreña = red-fruited *Opuntia robusta*

tapy+k+lyi = saraviqui = *Prionosciadium townsendii*

to'ora = grulla = *Cyperus esculentus*

tomáata = tomatillo = *Physalis caudella* or *P. philadelphica*

tostón = tostón = *Cosmos bipinnatus*

toynkama = orégano chiquito = *Hedeoma patens*

toynkama = orégano grande = *Monarda austromontana*

tu'i shogi = cholla = *Mammillaria* spp. or *Echinocereus* spp.

tu'ulyi = sauzo = *Salix* spp.

tu'ya = quelite = *Amaranthus hybridus*

tuk ga'a = táscate negro or táscate chino = *Juniperus erythrocarpa*

tumuraga = hiedra = *Toxicodendron radicans*

tuushkulyi = tulusín = *Jaltomata procumbens*

twa huko = pino blanco = *Pinus engelmannii*

u'ush hioshgara = flor de encino = *Tillandsia* spp.

v+v+gi hioktoktam = contrahierba = *Zinnia peruviana, Euphorbia cyathophora,* or *Guillerminea densa*

vakashin+ñir = lengua de vaca = *Rumex obtusifolius*

verdoláaga = verdolaga = *Portulaca oleracea*

vervéen = vervena = *Verbena* spp.

viikoga = hongo = fungus

viva = tobaco = Nicotiana tabacum

viva viikorgara = hongo del juve = Cuscuta campestris

vohi huungara = maiz del oso = Conopholis alpina

wa'a hioktama sha'i = girasol del campo = Tithonia tubaeformis

wam ga'a = sabino colorado = Juniperus flaccida

waja = chuale = Chenopodium leptophyllum

wopseksurel = cascabel = Crotalaria pumila

yerbanis = yerbanis = Tagetes lucida

APPENDIX III

MOUNTAIN PIMA ANIMAL NAMES

Each Pima name is followed by the local Spanish name and the English equivalent. See page 206 for an explanation of Pima pronunciaiton.

baabadu = rana = frog

baahuki = tejón = badger, raccoon, or ringtail

baksh+lyi ko'o = culebra = garter snake

bana = coyote = coyote

bapkushi = ardilla roja or ardilla voladora = Nayarit squirrel

boohi = oso = bear

booshogyi = ratón = mouse

byuhulyi = rochaca = spiny lizard

chiki = venado = deer

chonti = chonte = oriole

chukalyi = chiva = goat

coconyi = cuervo = crow

d++gi = rata = rat

garsa = borra = egret

gigichulyi = golondrina = barnswallow

gogoshi = perro = dog

h+'d+ra = huico = whiptail lizard

h+mpachikachkama = curpión = alligator lizard

h+m+ktash ko'o = coralio = coral snake and mimics

haadalyi = vibora de cascabel = rattlesnake

hohokolyi' = paloma = mourning dove

hoopishi = murciélago = bat

huná'adagi = solomanquez = skink

kaavalyi = borrego = sheep

kamalyón = camelión = horned lizard

kashu = zorra = fox

kava = cavallo = horse

koolyishi = gato del monte = wildcat

kukwulyi = lechusa = screech owl

kwak+lyi = sapo = toad

maakave = paloma del campo = white-winged dove

maavicha = león = mountain lion

mijit = gato = cat

mushiva = vagre = catfish

muulyi = tortuga = mud turtle

muumkama = sajolote = salamander

muuvlyi = mosca = fly

mwilchikama ko'o = chirionera = ground snake

naalyichi = sanguijuela = leech

nakmil = mariposa = butterfly

nakshil = alacrán = scorpion

nui = chupilote or abra = vulture

paroshi = liebre = jackrabbit

pishkalyi = curta = flicker

puyi = churea or paysano = roadrunner

s+'+ = lobo = wolf

shaamkulyi = chachámori = banded rock rattlesnake

shaapishi = sardina = unidentified fish

shakalyi = carpintero = downy woodpecker

shilyoon toshkolyi = javelín = peccary

shoovolyi = matalote = unidentified fish

shuulyi = cholugo = coatimundi

t++kulyi = ardilla prieta = Arizona gray squirrel

t+w+gi shw+ga = ? = millipede

teesh+lyi = gogorníz = montezuma quail

tohoroki = rochaca = spiny lizard

toova = huíjolo or cócono = turkey

torhibulyi = pescado chino = unidentified fish

tu'uva = conejo = rabbit

tub+hi = tuza = pocket gopher

tutkura = tecolote = borreal owl

tutupa = chichimoco = chipmunk

tuvil = gusano = worm

u'upa = zorillo = skunk

uhiba = gavilán = hawk

vipishi = chuparosa = hummingbird

vwashkiga = pato = duck

APPENDIX IV

LISTING OF QUICKBASIC PROGRAM USED IN OPTIMIZATION STUDY

```
10 '$DYNAMIC:'NABOGAME.BAS by Joseph E. Laferriere.
Modification of Box's (1965) complex method adapted to
analyze food intake patterns from Nabogame, Chihuahua,
Mexico
20 ON ERROR GOTO 1430: RANDOMIZE VAL(RIGHT$(TIME$, 2)):
DEFDBL U-Z: DEFSTR A-H: DEFINT I-T: N = 59: K = 118
30 OPTION BASE 1: DIM X(59), W(59), U(59), XC(59), XO(59):
DIM XR(59), Z(118), A(59), Y(10): DIM V(118, 59): DIM
XM!(27, 6), XAA(5, 2), ANUT(6), AMON(9), UT(6)
40 COLOR 7, 1: CLS : PRINT "MAIN MENU": PRINT "Enter 0 for
complete nutrients": PRINT "      1 for without protein":
PRINT "      2 for energy only"
50 PRINT "      3 for without Ca": PRINT "      4 for
without A": PRINT "      5 for without C": PRINT "      6
for without gut constraints"
60 INPUT MNU: IF MNU > 6 THEN BEEP: GOTO 60
70 CLS : PRINT "OBJECTIVE MENU": PRINT "Enter 1 for time
minimization": PRINT "      2 for energy maximization":
PRINT "      3 for nutrient index"
80 INPUT OBJECT: IF OBJECT < 1 OR OBJECT > 3 THEN BEEP:
GOTO 80
90 AM = "Drought year (y/n)?": GOSUB 500: DROUGHT = AZZ
```

```
100 CLS : PRINT "INITIALIZATION MENU": PRINT "Enter 1 for
upper bias": PRINT "      2 for lower bias": PRINT "      3
for random scatter": PRINT "      4 for edge effect"
110 INPUT IBIAS: IF IBIAS < 1 OR IBIAS > 4 THEN BEEP: GOTO
110
120 'Initialization menu allows several options which
permit faster program operation. Random scatter (option 3)
is the standard method.
130 'The presence of numerous constraints in the time
minimization problem make the upper bias method work 400-
500 times as fast because of larger initial complex.
140 'For all except option three, variables close to their
max/min axes are set close to these values. This also
speeds up program initialization
150 IF DROUGHT = "n" THEN RESTORE 1480 ELSE RESTORE 1490
160 FOR MNUX = 0 TO MNU: READ AMNX: NEXT: IF OBJECT = 2
THEN AMNX = AMNX + ".MAX" ELSE IF OBJECT = 3 THEN AMNX =
AMNX + ".INX"
170 OPEN "i", 2, AMNX: GOSUB 550
180 RESTORE 1510: FOR I = 1 TO 6: READ ANUT(I): NEXT: FOR I
= 1 TO 9: READ AMON(I): NEXT: FOR I = 1 TO 2: FOR J = 1 TO
5: READ XAA(J, I): NEXT J, I
190 FOR I = 1 TO 27: READ Y: FOR J = 1 TO 6: READ II:
XM!(I, J) = II * (1 + Y * (DROUGHT = "y")): NEXT J, I
200 IF DROUGHT = "y" THEN FOR J = 1 TO 6: READ II: XM!(27,
```

```
J) = .3 * II: NEXT: XAA(5, 1) = 25.87: XAA(5, 2) =
9.739001: 'substitution of bean coefficients for wheat
210 RESTORE 1830: FOR I = 1 TO 6: READ UT(I): NEXT: IF
DROUGHT = "y" THEN UT(6) = 10 * UT(6): 'allowing for
increased stomach capacity during famine binges
220 CLS : GOSUB 560: IF IC OR JC THEN PRINT "Initial point
not feasible": BEEP: GOSUB 1150
230 ON OBJECT GOSUB 730, 770, 810: Z(1) = Z
240 COLOR 1, 2: CLS : LOCATE 25, 1: PRINT "x=exit+save",
"p=print", "r=restart", "last reboot="; TIME$; : LOCATE 1,
1
250 FOR I = 2 TO K: COLOR 2, 1: PRINT : PRINT "Initial
point"; I, : COLOR 1, 2: FOR J = 1 TO N: ON IBIAS GOSUB
1360, 1380, 1400, 1410
260 NEXT: MJ = 0
270 IF 10# * X(6) > X(15) THEN X(6) = X(15) / 10.1:
'setting chayote less than peaches
280 IF X(11) < 6.25 * X(9) THEN X(9) = X(11) / 6.3:
'setting goatmilking less than livestock because of
overhead requirements
290 MJ = MJ + 1: IF MJ > K THEN ERROR 98
300 GOSUB 600: IF IC = 0 THEN FOR J = 1 TO N: V(I, J) =
X(J): XC(J) = ((I - 1) * XC(J) + X(J)) / I: NEXT:  ELSE FOR
J = 1 TO N: X(J) = (X(J) + XR(J)) / 2: NEXT: GOTO 290
310 ON OBJECT GOSUB 730, 770, 810: Z(I) = Z: NEXT: COLOR 7,
```

```
1: PRINT "Sorting points": GOSUB 530: PRINT : IF Z(1) =
Z(K) THEN PRINT "All points have same function value" ELSE
GOSUB 510: JZ = 0
320 WHILE Z(K) - Z(1) > ABS(Z(1)) / 1000000000000000#: MJ =
0: ZM = Z(1): FOR L = 1 TO N: XO(L) = (K * XC(L) - V(K, L))
/ (K - 1): XR(L) = 2.3 * XO(L) - 1.3 * (V(K, L)): X(L) =
XR(L): NEXT: IC = 0: JC = 0
330 GOSUB 560: IF JC = 0 THEN 370
340 FOR J = 1 TO N: IF ASC(MID$(HH, J, 1)) THEN XR(J) =
W(J): X(J) = XR(J)
350 IF ASC(MID$(HH, J + N, 1)) THEN XR(J) = U(J): X(J) =
XR(J)
360 NEXT: GOTO 330: 'if max/min limits on variables not
met, reset to max/min.
370 IF IC = 0 THEN 400 ELSE MJ = MJ + 1: FOR L = 1 TO N:
XR(L) = (XR(L) + XO(L)) / 2: X(L) = XR(L): NEXT: 'if
explicit constraints violated move point toward center of
complex
380 IF MJ > 100 THEN ERROR 99: 'reinitialize if caught in
loop
390 GOTO 330
400 ON OBJECT GOSUB 730, 770, 810: IF Z < Z(K) THEN 430
ELSE MJ = MJ + 1: FOR L = 1 TO N: XR(L) = (XR(L) + XO(L)) /
2: X(L) = XR(L): NEXT: 'if new point not better than old
worst pt, move toward center
```

```
410 IF MJ > 100 THEN ERROR 99
420 GOTO 330
430 Z(K) = Z: FOR L = 1 TO N: XC(L) = XC(L) + (XR(L) - V(K,
L)) / K: V(K, L) = XR(L): NEXT: MM2 = K: WHILE Z(MM2 - 1) >
Z(MM2) AND MM2 > 2: SWAP Z(MM2), Z(MM2 - 1): FOR L = 1 TO
N: SWAP V(MM2, L), V(MM2 - 1, L): NEXT: MM2 = MM2 - 1: WEND
440 IF Z(2) < Z(1) THEN SWAP Z(2), Z(1): FOR L = 1 TO N:
SWAP V(2, L), V(1, L): NEXT: GOSUB 510: IF UN / 100 = UN \
100 THEN GOSUB 520: IF UN / 5000 = UN \ 5000 OR (OBJECT = 3
AND UN \ 500 = UN / 500) THEN ERROR 99
450 'Previous line sorts new best point, saves it to disk
periodically in case of power failure, and occasionally
reinitializes program to enlarge complex
460 WEND: PRINT : IF JZ = 0 THEN ERROR 99 ELSE H =
"Iteration terminated"
470 COLOR 7, 4: PRINT H: UN = UN - 1: GOSUB 510: GOSUB 520:
COLOR 7, 1
480 AM = "Paper copy (y/n)?": GOSUB 500: IF AZZ = "y" THEN
GOSUB 1220
490 AM = "Run again (y/n)?": GOSUB 500: IF AZZ = "y" THEN
GOSUB 1140: GOTO 240 ELSE END
500 PRINT AM; : AZZ = "": WHILE AZZ <> "y" AND AZZ <> "n":
AZZ = INKEY$: WEND: PRINT AZZ: RETURN
510 UN = UN + 1:  COLOR 0, 2: PRINT : PRINT "Best point #";
UN, "Min value ="; Z(1): COLOR 7, 1: RETURN
```

```
520 OPEN "o", 1, AMNX: FOR L = 1 TO N: WRITE #1, W(L),
U(L), A(L), V(1, L): NEXT: CLOSE : RETURN
530 MM = K: WHILE MM > 1: MM = MM \ 2: KK = K - MM: J = 1:
WHILE J <= KK: I = J: WHILE I > 0: LL = I + MM: IF Z(I) -
Z(LL) > 0 THEN SWAP Z(I), Z(LL): FOR L = 1 TO N: SWAP V(I,
L), V(LL, L): NEXT
540 I = I - MM: WEND: J = J + 1: WEND: WEND: RETURN
550 FOR I = 1 TO N: INPUT #2, W(I), U(I), A(I), X(I): XC(I)
= X(I): XR(I) = X(I): V(1, I) = X(I): NEXT: CLOSE : RETURN
560 JC = 0: HH = STRING$(K, 0)
570 FOR II = 1 TO N: IF X(II) < W(II) THEN MID$(HH, II, 1)
= "*": JC = 1: PRINT "min "; A(II),
580 IF U(II) < X(II) THEN MID$(HH, N + II, 1) = "*": JC =
1: COLOR 7, 4: PRINT "MAX "; A(II), : COLOR 7, 1
590 NEXT: 'check for violation of max/min limits
600 YW = 0: IC = 0: GOSUB 1050: FOR IM = 1 TO 9:
610 FOR IZ = 1 - 5 * (OBJECT = 3) TO 6: Y(8) = 0: Y(9) = 0:
IF IZ = MNU XOR MNU = 2 THEN 630
620 GOSUB 1070: IF YM < UT(IZ) THEN IC = IM: PRINT
ANUT(IZ); "-"; AMON(IM),
630 NEXT: 'nutrient and gut constraints (the former
inactive for nutrient balancing objective function)
640 ON IM GOSUB 840, 870, 880, 920, 930, 950, 980, 1000,
1020
650 YW = YW + X(11) + X(7) / 30 + X(23 + IM) + X(32 + IM) +
```

```
X(41 + IM) + X(50 + IM) + X(11): IF DROUGHT = "n" AND YW >
12500 THEN IC = 1: PRINT "work-"; AMON(IM),
660 NEXT: 'work constraints
670 IF DROUGHT = "n" AND Y(3) >= 3616 THEN IC = 1: PRINT
"wheat total",
680 IF X(19) >= Y(1) * .2 THEN IC = 1: PRINT "squash <
maize",
690 IF 10# * X(6) > X(15) AND X(15) > .01 THEN IC = 1:
PRINT "chayote < peach",
700 IF DROUGHT = "n" AND 36.14 < Y(1) / 146 + Y(2) / 320 +
X(15) / 3750 THEN IC = 1: PRINT "max land",
710 IF X(11) < 6.25 * X(9) AND X(9) > .01 THEN IC = 1:
PRINT "goat overhead",
720 GOSUB 1100: RETURN: 'constraints
730 GOSUB 1050
740 Z = Y(1) / .702 + Y(2) / 2.5 + Y(3) / .91 + .4 * X(9) +
11 * X(11) + 3 * (X(24) + X(33) + X(42) + X(51))
750 FOR LL = 1 TO N: Z = Z + X(LL): NEXT
760 GOSUB 1100: RETURN: 'time minimization objective fn
770 Z = 3 * (X(24) * XM!(24, 2) + X(33) * XM!(25, 2) +
X(42) * XM!(26, 2) + X(51) * XM!(27, 2)) + 11 * X(11) *
XM!(11, 2)
780 FOR IOBJ = 1 TO 23: Z = Z + X(IOBJ) * XM!(IOBJ, 2):
NEXT
790 FOR IOBJ = 1 TO 9: Z = Z + XM!(24, 2) * X(23 + IOBJ) +
```

```
XM!(25, 2) * X(32 + IOBJ) + XM!(26, 2) * X(41 + IOBJ) +
XM!(27, 2) * X(50 + IOBJ): NEXT
800 Z = -Z: RETURN: 'energy maximization objective fn
810 Z = 1: FOR IM = 1 TO 9: FOR IZ = 1 TO 5: YM = 0: Y(8) =
0: Y(9) = 0: IF IZ = MNU XOR MNU = 2 THEN 830
820 GOSUB 1070: Z = Z * (1 + ABS(LOG(UT(IZ) / YM)))
830 NEXT IZ, IM: RETURN: 'nutrient index objective fn
840 YW = .75 * Y(3)
850 RETURN: 'seasonal additions to work and consumption,
Jan
860 YM = YM + XM!(20, IZ) * X(20): RETURN: 'Mar
870 YW = X(20): RETURN: 'Mar
880 YW = .215 * Y(1) + .097 * Y(3) + X(14) + X(1) + X(2) +
X(9): RETURN
890 YM = YM + XM!(14, IZ) * X(14) + XM!(1, IZ) * X(1) +
XM!(2, IZ) * X(2) + XM!(9, IZ) * X(9)
900 Y(8) = 10.68 * X(9): Y(9) = 4.92 * X(9): RETURN: 'May
910 YM = YM + XM!(16, IZ) * X(16) + XM!(13, IZ) * X(13):
RETURN: 'Jun
920 YW = .073 * Y(3) + X(16) + X(13): RETURN
930 YW = .162 * Y(1) + .11 * Y(3) + X(17) + X(22) + X(21) +
X(3) + X(5): RETURN
940 YM = YM + XM!(17, IZ) * X(17) + XM!(22, IZ) * X(22) +
XM!(21, IZ) * X(21) + XM!(3, IZ) * X(3) + XM!(5, IZ) *
X(5): RETURN: 'Jul
```

```
950 YW = .242 * Y(1) + .213 * Y(2) + X(23) + X(4) + X(15) +
X(6): RETURN
960 YM = YM + XM!(23, IZ) * X(23) + XM!(4, IZ) * X(4) +
XM!(15, IZ) * X(15) + XM!(6, IZ) * X(6): RETURN: 'Aug
970 YM = YM + XM!(8, IZ) * X(8) + XM!(18, IZ) * X(18) +
XM!(10, IZ) * X(10): RETURN: 'Sep
980 YW = .505 * Y(2) + X(8) + X(18) + X(10): RETURN
990 YM = YM + XM!(12, IZ) * X(12) + XM!(7, IZ) * X(7): Y(8)
= 27.83 * X(7): Y(9) = 9.135 * X(7): RETURN: 'Oct
1000 YW = .234 * Y(1) + X(12) + X(7): RETURN
1010 YM = YM + XM!(19, IZ) * X(19): RETURN: 'Nov
1020 YW = .147 * Y(1) + X(19): RETURN: 'Nov
1030 FOR IZX = 1 TO 2: Y(7 + IZX) = Y(7 + IZX) + XAA(1,
IZX) * X(23 + IM) + XAA(2, IZX) * X(32 + IM) + XAA(3, IZX)
* X(41 + IM) + XAA(4, IZX) * X(50 + IM): NEXT: Y(8) = Y(8)
/ 5500: Y(9) = Y(9) / 3500: IF Y(8) > Y(9) THEN Y(8) = Y(9)
1040 YM = YM * Y(8):  RETURN: 'protein balance
1050 Y(1) = 4 * X(33): Y(2) = 4 * X(42): Y(3) = 4 * X(51)
1060 FOR IM = 2 TO 9: Y(1) = Y(1) + X(32 + IM): Y(2) = Y(2)
+ X(41 + IM): Y(3) = Y(3) + X(50 + IM): NEXT: RETURN: 'work
for planting + harvesting crops
1070 YM = XM!(24, IZ) * X(23 + IM) + XM!(25, IZ) * X(32 +
IM) + XM!(26, IZ) * X(41 + IM) + XM!(27, IZ) * X(50 + IM) +
XM!(11, IZ) * X(11)
1080 ON IM GOSUB 850, 860, 890, 910, 940, 960, 970, 990,
```

```
1010: IF IZ = 1 THEN GOSUB 1030
1090 RETURN: 'seasonal workload
1100 AZZ = INKEY$: IF AZZ = "x" THEN H = "Iteration
terminated": RETURN 470
1110 IF AZZ = "p" THEN H = "Interim point": GOSUB 1220
1120 IF AZZ = "r" THEN ERROR 99
1130 RETURN: 'program interruption
1140 FOR LO = 1 TO N: X(LO) = V(1, LO): NEXT
1150 INPUT ; "subscript to change"; IZ
1160 IF IZ > N THEN BEEP: GOTO 1150 ELSE IF IZ > 0 THEN
PRINT "    "; A(IZ); " ="; X(IZ), : INPUT "new value"; AZZ:
IF AZZ > "" THEN X(IZ) = VAL(AZZ): GOTO 1150 ELSE 1150
1170 PRINT : GOSUB 560: PRINT : IF IC OR JC THEN PRINT
"Point not feasible": GOTO 1200
1180 ON OBJECT GOSUB 730, 770, 810: PRINT "value="; Z: AM =
"Accept point (y/n)?": GOSUB 500
1190 IF AZZ = "y" THEN Z(1) = Z: FOR LO = 1 TO N: V(1, LO)
= X(LO): XC(LO) = X(LO): XR(LO) = X(LO): NEXT: RETURN
1200 AM = "Try again (y/n)?": GOSUB 500: IF AZZ = "y" THEN
1150
1210 AM = "Quit ?": GOSUB 500: IF AZZ = "y" THEN END ELSE
RETURN: 'changing of values from keyboard
1220 LPRINT AMNX, "Nabogame data", : RESTORE 1500: FOR IMNU
= 0 TO MNU: READ AXX: NEXT: LPRINT AXX
1230 LPRINT DATE$, TIME$, "point #"; UN: LPRINT H, "Minimum
```

```
value ="; Z(1)
1240 FOR L = 1 TO N: IF V(1, L) - W(L) < .01 OR U(L) - V(1,
L) < .01 THEN LPRINT "*";
1250 LPRINT L; A(L); "="; V(1, L), : X(L) = V(1, L): NEXT:
LPRINT
1260 LPRINT CHR$(12): LPRINT AMNX, "Nabogame data", DATE$,
TIME$, "point #"; UN: LPRINT H, "Minimum value ="; Z(1)
1270 GOSUB 1050: FOR IZ = 1 TO 6: FOR IM = 1 TO 9: YM = 0:
Y(8) = 0: Y(9) = 0: IF IZ = MNU OR (IZ = 2 AND MNU = 2)
THEN 630
1280 YM = YM + XM!(24, IZ) * X(23 + IM) + XM!(25, IZ) *
X(32 + IM) + XM!(26, IZ) * X(41 + IM) + XM!(27, IZ) * X(50
+ IM) + XM!(11, IZ) * X(11)
1290 ON IM GOSUB 850, 860, 890, 910, 940, 960, 970, 990,
1010: IF IZ = 1 THEN GOSUB 1030
1300 LPRINT ANUT(IZ); "-"; AMON(IM); "="; YM,
1310 NEXT IM, IZ: 'printout of nutrient constraint values
1320 FOR IM = 1 TO 9: ON IM GOSUB 840, 870, 880, 920, 930,
950, 980, 1000, 1020: YW = YW + X(11) + X(7) / 30 + X(23 +
IM) + X(32 + IM) + X(41 + IM) + X(50 + IM) + X(11): LPRINT
"work="; AMON(IM); YW,
1330 NEXT: 'work values
1340 LPRINT "Total land ="; Y(1) / 146 + Y(2) / 163 + Y(3)
/ 320 + X(6) / 3750
1350 RETURN
```

```
1360 IF U(J) - V(1, J) < 1 THEN X(J) = U(J) + RND * (U(J) -
W(J) > 1) ELSE IF V(1, J) - W(J) < 1 THEN X(J) = W(J) + RND
ELSE X(J) = V(1, J) + RND * (U(J) - V(1, J))
1370 RETURN: 'upper bias initialization
1380 IF U(J) - V(1, J) < 1 THEN X(J) = U(J) + RND * (U(J) -
W(J) > 1) ELSE IF V(1, J) - W(J) < 1 THEN X(J) = W(J) + RND
ELSE X(J) = V(1, J) - RND * (V(1, J) - W(J))
1390 RETURN: 'lower bias
1400 X(J) = W(J) + RND * (U(J) - W(J)): RETURN: 'random
scatter
1410 IF U(J) - V(1, J) < 1 THEN X(J) = U(J) + RND * (U(J) -
W(J) > 1) ELSE IF V(1, J) - W(J) < 1 THEN X(J) = W(J) + RND
ELSE X(J) = W(J) + RND * (U(J) - W(J))
1420 RETURN: 'edge bias, random except for extreme values
1430 IF ERR = 53 THEN PRINT "File "; AMNX; " not found":
INPUT "Name of starting file "; A: OPEN "i", 2, A: RESUME
NEXT
1440 IF ERR = 99 THEN RESUME 240
1450 IF ERL = 820 THEN Z = Z * 1000: RESUME NEXT: 'to catch
division by zero in balancing factor equation
1460 IF ERR = 98 THEN OPEN "i", 2, AMNX: GOSUB 550: RESUME
240
1470 ON ERROR GOTO 0
1480 DATA GOOD,GOOD-PRO,GOOD-CAL,GOOD-CA,GOOD-A,GOOD-C
1490 DATA BAD,BAD-PRO,BAD-CAL,BAD-CA,BAD-A,BAD-C: 'names
```

for data files

```
1500 DATA "All nutrients included","Energy only","No
protein constraints","No Ca constraints","No A
constraiants","No C constraints","No lys/met+cys
constraints"
1510 DATA protein,kcal,Ca,A,C,gut
1520 DATA Jan,Mar,May,Jun,Jul,Aug,Sep,Oct,Nov
1530 DATA 11.09,3.875,5.2,16.75,10.97:'lys,hunt,maize,papa,
wheat, livestock
1540 DATA 4.49,5.375,.245,26.05,5.505: 'met+cys
1550 DATA 0,0,362,250,35,0,-133: 'Agave-leaves; drought
reduction factor plus nutrient compositions and gut space
factor
1560 DATA 0,0,490,0,0,0,-333: 'Agave-stalks
1570 DATA 0,2,181,116,512,40,-267: 'ahuasiqui
1580 DATA .7,60,281,1300,0,427,-290: 'Berberis
1590 DATA 0,0,153,100,585,46,-303: 'capulin
1600 DATA .3,8,2730,200,500,800,-4444: 'chayote
1610 DATA .9,305,5542,885,3964,0,-1495: 'cowmilking
1620 DATA 0,21,335,487,4,9,-148: 'dahlia
1630 DATA .9,186,3951,885,328,0,-1491: 'goatmilking
1640 DATA 0,6,163,156,0,0,-106: 'Hymenocallis
1650 DATA .5,142,587,58,14,2,-319: 'livestock
1660 DATA .5,3,209,28,49,22,-190: 'madrono
1670 DATA 1,3,267,22,68,31,-303: 'manzanilla
```

```
1680 DATA .9,6,118,0,0,224,-606: 'nopal
1690 DATA .3,5,1726,78,400,74,-4444: 'peaches
1700 DATA .2,11,532,-5720,5540,822,-1333: 'quelite-Jul
1710 DATA .2,11,532,-5720,5540,822,-1333: 'quelite-Jun
1720 DATA -.5,3,164,318,0,29,-148: 'saraviqui
1730 DATA .8,15,746,3322,0,0,-1130: 'squash
1740 DATA 0,8,286,170,375,115,-167: 'Tillandsia
1750 DATA .4,20,576,125,313,75,-833: 'tomatillo
1760 DATA .2,16,284,1463,313,663,-833: 'tulusin
1770 DATA .9,12,81,180,31,194,-513: 'tuna
1780 DATA .5,123,856,45,86,8,-481: 'hunt
1790 DATA .8,115,5395,4900,500,0,-687: 'maize
1800 DATA 1,85,4385,400,0,370,-2381: 'papa
1810 DATA 1,630,16760,1450,0,0,-1587: 'wheat
1820 DATA 378,5674,1220,0,52,-1258: 'beans
1830 DATA 75000#,2925000#,1500000#,135000#,45000#,-1050000:
'minimum nutrients
```

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