Title
Ethnobotany of the Yoreme People and Environs

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Publication Date
2018

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA
RIVERSIDE

Ethnobotany of the Yoreme People and Environs

A Dissertation submitted in partial satisfaction
of the requirements for the degree of

Doctor of Philosophy

in

Plant Biology

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March 2018

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ABSTRACT OF THE DISSERTATION

Ethnobotany of the Yoreme People and Environs

by

Andrew Semotiuk

Doctor of Philosophy, Graduate Program in Plant Biology
University of California, Riverside, March 2018
Dr. Exequiel Ezcurra, Chairperson

The Yoreme people of northwestern Mexico have a vibrant body of traditional knowledge and practices (TKP) related to natural landscapes amidst drastic technological changes in the region. This apparent contrast presents an exemplar model system to conduct ethnobotanical studies on traditional knowledge and practice dynamics. Using a range of methods from in-person surveys, vegetation surveys, geographic data analysis, and biochemical assays, I sought to gain insight as to how TKP change and adapt. This research lead to four main findings within the concept that I call traditional knowledge and practice remodeling. (1) Traditional herbalists adapt to online shopping trends and are moving their storefronts online. (2) Local *pitaya*-product producers create value-added fruit products to stay relevant in an increasingly competitive market. (3) Ancestral use and phylogenetic studies can lead to hypotheses and assays on the mode and mechanism of action for local medicinal plants such as *Ibervillea sonorae*. Mechanistic studies show how *I. sonorae* inhibits α-glucosidase and stimulates insulin secretion *in vitro*. Mechanistic studies can help

strengthen cultural morale, help physicians plan treatment programs for patients who consume herbal medicine, and provide literature support for cultural initiatives and funding such as medicinal plant gardens. (4) While ethnobotanists often study TKP dynamics and even hold community events to strengthen TKP, little follow-up data is collected. Museum evaluation techniques should be implemented to strengthen the data pool of TKP conservation to refine the current and general ideas that time on the land with elders is the best way to transmit TKP. In all, my research has shown that TKP remodeling is driven by the needs and opportunities of community members. Given the large pool of talent in the Yoreme villages I visited and the innovative ideas of herbalists and artisan product producers, I propose that networking tools from social entrepreneurship incubators would help bolster new ideas and move them from an idea of a few individuals into a broad scale reality. This may also give more voice to those who want to preserve land and keep traditional practices active and vibrant.

Dedicated to the Yoreme people. May this research help them in their endeavors to care for their families, traditions, and natural world around them.

Acknowledgements

Dissertation in General

I would like to acknowledge many people on this ethnobotanical journey. The concept of *ethno-* in ethnobotany alludes to a large human component. This is certainly true with my graduate research where people from vastly different walks of life have helped and supported this work.

I would like to first thank my benevolent advisor, Exequiel Ezcurra, who has supported creative ideas from day one. He tells me that he does not want to stifle my creativity and waits for the ideas to flow. Then he forms them into a project that is reasonable and well planned. I am very grateful for this. I am also grateful for his form of positive pressure. He has a way of putting high expectations on his students in a constructive way. He speaks highly of them so that they strive for lofty goals. It is an effective technique, and I will use it with my future students. Further, I would like to thank my committee members Dr. Patricia Colunga-GarcíaMarín and Dr. G. Darrel Jenerette who, along with Dr. Exequiel Ezcurra, have helped guide me on my quest to study ethnobotany. I am grateful for their feedback, ideas, and council. This support has helped shape my view of approaching scientific questions during my time at UC Riverside.

In the UCR Department of Botany & Plant Sciences I would like to thank the faculty, staff, and fellow students. Linda Waling, Norm Ellstrand, and Amy Litt were instrumental in approving my extended expeditions. Deidra Kornfeld, Jammy Yang, Mariella Valdivia, Laura McGeehan, and Henry Gutierrez helped me iron out details of administrative paperwork and logistics. Fayek Negm always contributed good questions, ideas, and a hearty smile and laugh. My labmates Alejandra Martínez (especially for survey refinement in Spanish), Ben Wilder, Sula Vanderplank, Lorena Villanueva, Jocelyn Villa, Israel Jiménez, Vanessa Pérez, and Andrea Arévalo have all contributed their time, energy, ideas, and moral support. I also thank my qualifying exam committee members Tim Close, Scott Fedeck, Darrel Jenerette, Louis Santiago, and Giles Waines. I will miss all other people in the department who have taken part in my education here at UCR.

My research has taken me to multiple sites outside of UCR where great minds have helped shape my thinking and this project. These include researching in the laboratory of Dr. Luis Salazar at the Instituto Potosino de Investigación Científica y Tecnológica (IPICYT). He graciously invited me to his lab to do plant extraction and enzyme inhibition work. In his lab I refined molecular techniques with colleagues such as Emma Hernández, Julián Ávila, David Heras, and Angélica Montoya-Contreras among others. Across the city of San Luis Potosí, I was lucky to gain the guidance of Dr. Laura Yáñez at the Universidad Autónoma de San Luis Potosí (UASLP). As en expert plant anatomist, she guided me though methods and analysis of studies on *Ibervillea* xylem. Across the continent, in the lab of Dr. Alain Cuerrier at the Montreal Botanical Garden, I gained strategies for merging the physical sciences with the social sciences. I am very grateful for my time here seeing as it is a model environment for the merger of field studies with laboratory work alongside exemplar relationships with community groups. I thank Marie-Pierre Beauvais, Marion Carrier, Christian Norton, and Michel Rapinski for their great input and fruitful conversation. I would also like to thank the members of neighboring labs that gave a warm welcome including Audréanne Loiselle, Antoine Magnoux, Daniel Blouin, Maya Favreau, Mia Auger, and Nicolas Pinceloup. Thank you all for creating a superb learning environment in your respective laboratories.

In the field, I worked with many people who were instrumental in the formation of this project. I would like to thank Enrique Reyes for guiding me on plant collection trips, David Valenzuela Maldonado for accompanying me on many excursions all the while building hypotheses as we travelled, Atalio Juzacamea for inviting us to do a workshop in Tehuelibampo, Secundino Amarillas for instruction in the Yoreme language—Yoremnokki, the editor of the *Diario Yaqui* and Lupita Vásquez for connecting me to the Councilor of the Yoreme—Victoriano Moroyoki Buichileme, Victoriano for suggesting I visit the radio station of the *Comisión Nacional para el Desarrollo de los Pueblos Indígenas* (CDI), Manuel Espinoza for connecting me with the Yoreme communities of the municipality of Etchojoa, Carlos Díaz for leading a trip to *La Mesa Colorada* with the Macurawe (Guarijío), Simona Aldama for guidance within communities, Panchita Espinoza and her aunt Doña Linda for caring for me during work and when ill along with numerous community members and friends around Etchojoa, Benjamin Leyva Huicosa and Gael Leyva Huicosa for accompanying me on many trips to the field, Tirzo Ontamucha for including me in many municipal events, Eudelia Verdugo and Jesus Buaysehua for guidance and expertise in the *pitaya* forest, Jesus Sánchez of the Universidad de Sonora Herbarium for receiving and assisting with specimens, Luis Galeana for giving us an apartment to use in Hermosillo, the many *hierberos* of Sonora who opened up their shops and hearts about the wonder of herbs, Dolores and Gloria of the Ciudad Obregón municipal market, Mother Teresa of *Hogar Betesda* children's home in Navojoa who opened up their facility for traditional knowledge workshops, and countless others. Please accept my genuine gratitude.

There are many people to thank directly related to field work, but also indirectly. I would like to thank my family, Ernest, Nancy, and Eli, for listening to my anecdotes from various cultures and their patience as I assemble them into coherent concepts. I also thank my in-laws for their help navigating the urbanized regions of Mexico. And I especially thank my wife Jessica for her love and support during these pursuits and also for helping me establish and keep quality research contacts throughout North America.

Other helpful friends include Joel Castro who seemingly knows everyone related to agriculture in the Yaqui Valley. I thank Solomon and María del Carmen for a warm welcome and place to stay on some trips. I thank people such as Don Juan, Vicenta, Mercedes, and Linda for their passion about plants, gardens, and traditional knowledge. I thank Adam Green for teaching our lab and neighboring labs how to use the LaTeX document preparation system. I would also like to thank my friend and research colleague Latif Ahmad. We have discussed and worked on many projects and manuscripts together. Thank you for forming a great team. Thank you to everyone for contributing to this work!

Published Article of Chapter 2

The text of this dissertation chapter, in part or in full, is a reprint of the material as it appears in our article "The Eruption of Technology in Traditional Medicine: How Social Media Guides the Sale of Natural Plant Products in the Sonoran Desert Region" (*Economic Botany* 69:360-369). The co-author (Nancy L. Semotiuk) listed in that publication contributed to research planning and article revision. The co-author (Exequiel Ezcurra) listed in that publication directed and supervised the research which forms the basis for this dissertation chapter.

The acknowledgements given in that article are as follows: This work was funded by UC Mexus grants ST_13/06-12 and 14-7, and a Walla Walla University research grant. We thank these institutions for their financial support. We also thank Enrique

Reyes for his assistance with navigating the study region, and Patricia Colunga-GarcíaMarín for her help with the project proposal. Our acknowledgement also goes to local shopkeepers who passionately handle and sell local medicinal plants and took part in this study.

Published Article of Chapter 3

The text of this dissertation chapter, in part or in full, is a reprint of the material as it appears in "Pillar of Strength: Columnar Cactus as a Key Factor in Yoreme Heritage and Wildland Preservation" (*Ambio* 47(1):86-96). The co-author (Patricia Colunga-GarcíaMarín) listed in that publication contributed to research planning and article revision. The co-author (David Valenzuela Maldonado) listed in that publication contributed to research planning and data collection in the field. The co-author (Exequiel Ezcurra) listed in that publication directed and supervised the research which forms the basis for this dissertation chapter.

The acknowledgements given in that article are as follows: We thank the University of California Institute for Mexico and the United States (UC MEXUS) for funding as a Dissertation Research grant (DI 14-7). We give our utmost thanks to our local partners who assisted with networking and data collection, namely, Simona Aldama, Panchita Espinoza, Eudelia Verdugo, Jesús Buaysegua, Tirzo Ontamucha, Benjamín Leyva, Martín Espinoza, Miguel Molina, and Ishmael Ibarra. We also thank Latif Ahmad, Lorena Villanueva-Almanza, Darrel Jenerette, and Nancy Semotiuk for revision of early versions of this article, and Jessica Semotiuk for help with illustrations.

Chapter 4

We thank local herbalists and healers for sharing their knowledge and time, the asociación civíl Kawuy Bayajulay of Juchica, Sonora, David Valenzuela Maldonado for guidance and help in the field, María del Carmen Escobar Villanueva for the RIN-m5f cells, Jesús Sánchez of the University of Sonora Herbarium, and UC Mexus (DI 14-7) for project funding. We also thank colleagues who helped in the lab and by reviewing this manuscript, namely Adam R. Brown, Gloria Alicia López Niño, Nancy L. Semotiuk, Selene Paulina López de la Torre, and Travis A. Lee.

Chapter 5

We thank the University of California Institute for Mexico and the United States (UC Mexus) for funding in the form of a Dissertation Research grant (DI 14-7) and the University of California Riverside for funding of a Dissertation Year Program award. Mark Nesbitt for ideas on museum evaluation and Nancy Semotiuk for writing advice.

Funding

Some project specific grants helped me throughout my studies. Of these I am very grateful to the family of Alan and Jennifer Wilson who set up the *Donald M. and*

Berenice D. Wilson Graduate Scholarship in honor of their father's admiration for heritage citrus landscapes of Riverside County. I am also grateful to UC Mexus for both a small grant and dissertation grant (ST_13/06-12 and DI 14-7), UCR Graduate Division for two quarters of support through the Dissertation Year Program fellowship, the Department of Botany and Plant Sciences for support as a teaching assistant, and my laboratory, the Ezcurra Lab, for support as a graduate student researcher.

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Chapter 1

Traditional Knowledge and Practice Remodeling of the Yoreme

1.1 Meanderings with the Yoreme Begin

The dust billowed back behind the early 1990s Chevrolet pickup as we approached Juchica, Sonora, Mexico. Miguel, from the *Comisión Nacional para el Desarrollo de los Pueblos Indígenas* (CDI, National Commission for the Development of Indigenous Peoples), agreed to introduce me to Siomara. Siomara, he tells me, is a young Yoreme (Mayo) healer and well connected community member. She will be a good contact for my attempt to work with the Yoreme people.

As we turned into the driving path to park along the goat corral, Siomara walked over to a wooden bench. Before we even exited the vehicle, she began to lambaste Manuel. "Why are you bringing me this *yori*" (literally 'one who disrespects' used to mean outsider who could be a foreign national or Mexican), she questions with a scowl of disapproval. "You know better than that. Get out of here!"

After Manuel explained that I was a student interested in plants, she decided to offer us a seat. As I spoke to her scowl, I thought this was for sure my first and last interview. Since it was my last, I wanted to cover all the ground possible and brought up the topic of *wereke* (*Ibervillea sonorae* (S. Watson) Greene, Cucurbitaceae) being depleted from the local ecosystem. The stone-like caudex of this local medicinal species in the squash family is used to treat diabetes. Unfortunately, this caudex is slow to grow and quick to be harvested. This slow growth combined with a sales market around Mexico has led to over-harvest. As Siomara felt the mutual interest in medicinal plants, her scowl turned into a gaze of earnest passion and determination. She told us how people with trucks and cars from out of the area would come and load up large amounts of the caudices only to be driven away with nothing but a plume of exhaust left behind. With this common interest in the local environment, she decided to show us around the village.

On our way to see the area, we passed under the large central mesquite tree *Prosopis glandulosa* Torr. where community meetings take place in its shade. The thornscrub habitat is lush with vegetation in spite of long bouts of dry and hot weather. This source of medicine, food, and cattle feed abruptly ends at edges of cultivated lands that lie dry half the year due to lack of irrigation water for double cropping. Simona tells me about her hopes of planting a medicinal plant garden to maintain the diversity of plants that are found in the remaining patches of thornscrub dotted around the landscape. Both Siomara and I became immersed in the common thread of medicinal plant gardens and habitat preservation. As we discussed, the tension left, and to my surprise she invited me to come back. I thanked her with an heavy accent in the Yoreme language—*Yoremnokki*, *"Lios emchi chiokore"* which gave her something to chuckle about, and another bond to create—her love of her mother tongue.

1.2 Yoreme Language—Yoremnokki

Schoolchildren chased each other laughing and shouting Spanish phrases then later calmed down after hearing the Yoremnokki commands of one of their aunts. Around Juchica and other Yoreme villages the mother tongue in the home is Yoremnokki, but Spanish dominates education and business outside of the home. Yoremnokki is part of the Cahita branch of languages. Its closest relative is Yoeme (otherwise known as Yaqui). The word *cahita* means "nothing" and has an unknown origin as the name of this language group. Given that the term cahita or, as written in Yoremnokki, *kaita*, is a common response when answering questions, I think the interpretation of the Spanish was a logical mistake. The term kaita is used as an English speaker would use the terms "no big deal," "no problem," or "not much." It is a way to downplay a pointed or specific question. I can imagine a Spanish explorer attempting to ask a question of specifically what language a Yoreme person was speaking and they respond, "Kaita"—nothing, no big deal, just talking normally. Although Yoremnokki (Mayo) and Yoemenokki (Yaqui) are two distinct languages of two distinct groups, namely, the Yoreme and the Yoeme, the languages are mutually intelligible. It is common to hear both Yoreme and Yoeme conversing at festivals where speakers of both are present. Additionally, both have the same goal—to get more youth speaking their language.

The language scene on earth as a whole, as with the Yoreme, seems bleak. It is estimated that 26% of the approximated 6 210 languages will be extinct in the next 100 years (Clingingsmith, 2017). What is more, language is intrinsically tied to ethnicity (Fought, 2006). Along these lines, local policy leaders measure the communities to a bar of 40 percent indigenous language speakers (GOB.mx, 2010). While one could argue that ethnicity, and thus some connectedness to a tribe is independent of language, in practicality, language helps establish ethnicity. For example, for the Yoreme people, securing various forms of government funding is basically impossible if communities or people do not speak Yoremnokki (Consultant interview, Personal communication, September 12, 2017). For this tangible reason following the rational method along with cultural and ethnic value, many indigenous community members and linguists seek to preserve languages along with biocultural diversity worldwide (Maffi, 2014).

Preserving languages is no small task. When looking at previous studies and projects, we can see that strategies such as policy and law may have an effect, but do not necessarily turn the trajectory of language use around (Brockman, Masuzumi, and Augustine, 1997). Society determines what is spoken and required to live with others. If communities such as Juchica as a whole would like to stimulate Yoreme usage, then the children must feel that it is required for their success in the world. They must have access to what others do not have access to. This may be ideas, it may be contacts, it may be products, it may be protection, or even health care. Whatever it may be, it needs to be more attractive than what they can get elsewhere in a Spanish-speaking environment. I suspect that the most attractive aspect is a sense of belonging. When Yoremnokki is spoken by an insider group then the speakers will have a sense of belonging and need to continue using their language in and around their Yoreme villages as was done in the past and, in many villages, currently.

1.3 Yoreme Villages

Juchica lies in southern Sonora in the municipality of Etchojoa. It is a village of 108 inhabitants (CDI, 2010b). Almost everyone has a herd of goats near their home. Siomara proudly recounts how her mother always said, "Keep the herd of goats healthy and vibrant. I may pass away, but you will keep my legacy with the herd." The herd is a central part of sustaining and caring for a family.

On any given day, before the sun shimmers though the windows of adobe and government-built, cinder-block houses, the horns of U.S.-import yellow school buses startle newcomers like me awake. These buses whisk young adults, parents, and grandparents away to work in fields, greenhouses, and factories. One or a few members from each family stay around home to care for the children and do household chores. Feeding goats, tending chickens, hand-washing laundry, and cooking over wood-fired stoves seems to be a never-ending job.

For those remaining in the village, breakfast of *taskarim* (wheat flour tortillas), *kabbam* (eggs), and the classic Yoreme tepari beans *yuri muni* (*Phaseolus acutifolius* A.Gray (Nabhan and Felger, 1978) winds down and people start to go about their day. On many occasions, there were community association meetings. After breakfast people would trickle in to gather under the central mesquite tree. Women arrived with colorful *cambaya* fabric of traditional Mexican designs on their head as a shade cloth. Men walked up in jeans and button-up shirts. Many sported the popular white cowboy-style hat of northern Mexico. This civil association named *Kawuy Bayajulay* (Mount in the Water) serves the Yoreme around Mount Bayajorit. Members attempt to tackle challenges of local villages. During meetings, various topics would come up. Alcoholism ranked high on the charts along with unemployment and childhood hunger. Later indigenous language use, cultural traditions, and deforestation were brought up and discussed earnestly. As ideas were given and problems addressed, the meeting shifted to more practical matters, such as who was bringing food for the next meeting, announcements of the next festival, and then people trickled out.

Aside from witnessing daily life, I was able to attend many of the Yoreme festivities. The Yoreme festivals comprise the most visible aspect of the culture. At these festivities, the music of the *maaso buikleerom* (deer dance singers) is always sounding. The seemingly tireless dancers, armed with *tenobarim* (moth cocoon rattles) on their ankles and a deer head on their head, dance from morning through the mid-day heat until late into the night. All around this symbol of reverence to the deer as an integral part of their lifestyle are booths with food, herbs, and trinkets for sale. Depending on the festival, a race such as the *kontis*, a dance such as the *matachín*, or the burning of the castle will occur. The castle is one of the most sensational events, where an extremely tall wooden structure laden with firecrackers is erected. Later, the bull (man with a firework laden A-frame on his back) is lit and he begins to run into crowds of giggling onlookers. As his flaming back cools down, the castle is lit to burn and twirl in a fashion that puts American Independence Day firework displays to shame. All these festivities are done around churches where each person, before and during, enters to honor Christ the savior and to touch representations of saints.

The Yoreme get criticism from outside onlookers for spending money on a mere party. While these onlookers see only a party, the Yoreme see a key aspect of culture. Professor of the Yoreme language, Secundino Amarillas Valenzuela, refuted these criticisms in his class with the point that the deer dance is a critical part of culture and identity. Yes, it costs; but it is important (Mayo Level 1 course, Personal communication, December 5, 2013). I saw the potential cost, I saw the pride of the Yoreme, and I began to wonder what would happen if the deer dance was taken away. Moreover, what would happen if the community association Kawuy Bayajulay was taken away? Would people just live in their town to take the big yellow bus to work each day? Would they have a sense of community? Would they identify as Yoreme? Would they form councils to tackled large challenges their villages are facing? I am not sure. But I am sure that each Yoreme takes great pride in the dance that gives them a sense of belonging on their own ancestral land.

1.4 Yoreme Place in Society

The Yoreme people are people of changes. They broke off from the larger and more general *Kaita* (Cahita) tribe and farmed along the riverbanks in what is now known as southern Sonora and northern Sinaloa (Berry and Doyon, 2001). Those of the Kaita in the north were known as the *Yoeme* or later called Yaquis, while the Yoreme inhabited the south and were later called Mayos. This descriptive name—Mayo means, people of the riverbank; and that is just what the Yoreme were, and were proud of being (Amarillas Valenzuela, 2010). They became distinct from the Yoeme and even began to trade with them as a separate people with separate identity.

Other changes began to come in as Europeans arrived. Land encroachment due to mines attracting Spanish immigrants and ranching changed the Yoreme lifestyle and led to armed uprisings and revolts against the Spanish and Mexican militaries (Crumrine, 1977; O'Connor, 1989). Currently, there is no large scale migration, new contact from across the world, and no war. Yet the changes continue. There is migration away from the riverbank and to the agricultural fields near the city of Caborca or the United States. The area is not a homogeneous melting pot. It is rather patchy with distinct Yoreme and mestizo sections and villages. In larger city centers such as Navojoa and Huatabampo, the contrast becomes quite marked as one spends some time in the area.

After one excursion to the field followed by meetings in Navojoa, I invited my Yoreme colleagues to eat. There was a well-known pizza restaurant where students and teachers often met. I had eaten there with another researcher many times. I thought, *This will be a good place where we can discuss our findings*—or so I thought. As we arrived, the hostess did not greet us. We sat at a table where, as every other time I had been there, the waitress had come to take our order. This time I had to go order at the counter. My colleagues were visibly nervous and I was pondering why they would be and why this seemingly normal day was starting to feel so strange.

Finally after a long awkward meal, Pricila asked me, “Do you always come here?”

I said that teachers and students do, so I thought we could discuss our research.

“It is very elegant,” she told me.

Hmm, I thought. Then said, "It is the same price as the fish we ate the other day,” wondering what the difference was.

Then Tito clued me in, as if hearing my unspoken question, “But Yoreme do not come here.” he said.

Siomara piped up, “We eat at the municipal market.”

Now it all became clear to me. The price of food was irrelevant. The decor, the location, the food, and flavor were mere distractions. It was separation in society and prejudicial barriers that made the difference.

This almost invisible, but very palpable message is strong. It sends a message to children that although their ancestors through countless generations worked and cared for the land of an around Navojoa, they are not even welcome to eat a pizza there. Ironically, Navojoa is a Yoreme name which means *Home of the prickly pear cactus* (*Opuntia* spp.)—a major food source across Mexico.

1.5 Yoreme Education

I sat under the shade of the central mesquite tree brainstorming of places for traditional healer interviews and medicinal plant workshops. As I sat there making notes in my book, children orbited around the goat pasture and swung by me.

“Do you have any colors?” they asked.

“Why yes, of course. Here are some colored pens and some sheets of paper. Have fun coloring.” I responded.

Later, Pricila came to me and asked, “Andrés, can you teach the children to read? They do not learn anything in school.”

I knew right then that schools were the right place for the healer interviews and workshops. We talked to Siomara, and then were off to invite healers to the workshops.

We called the workshops *Im Sonorat Jariaka: Jumë Juya Jittua* (Exploring my Sonora: Wild Vegetation). During these workshops the children were bouncing with excitement. Not only that, but the healers were animated and feeding off the childrens' energy. It was a wonderful sight to see.

We held workshops at the local school *Escuela Primaria Indígenas del Mayo* in Juchica, *Netzahualcoyotl* the boarding school for indigenous children of remote communities in Buaysiacobe, and *Hogar Betesda* an orphanage in Navojoa. To go back to Pricila's original question of teaching the children to read at the local schools, I noticed that the teachers, parents, and students were all motivated. So I pondered, *What could the hangup be?* Then I reflected on the country schools in Canada and how they closed one by one. The issue can be described with an index of marginalization. Ability to travel to the school, access to services, number of children in the community, and more factor into this. But the end result is the same, reduced days of teaching due to weather and road conditions, reduced supplies, and reduced student stimulation since many times only a few children make up a whole grade level. This formidable problem is troublesome for the children of these communities. While equitable and proportional funding allotments as to those of schools in larger urban and non-indigenous centers is one crucial aspect, the challenge or retaining cohesive small communities while having low marginalization regarding access to education remains a large challenge. In all, my advisor Exequiel Ezcurra said it best when he simply stated, “All parents want their children to be educated.” In this respect, there is much work needed for the schools in the Yoreme villages.

1.6 Yoreme Economy

On average, indigenous peoples around Mexico earn less income than their non-indigenous counterparts. This trend holds true with the Yoreme of Sonora and Sinaloa (GOB.mx, 2015). With current development of lands and industrial processes, the value of a small herd for local ranchers just does not produce a large income. Further, jobs in greenhouses, fields, and factories do not pay much in comparison to many other jobs in larger urban centers like Hermosillo. Interestingly, when I asked about costs of living like property taxes and half-day daycare my friends were surprised that one would pay for these.

“Why would we pay for the land we own?” questioned one.

“Oh, I heard they do that in the city,” chimed in another.

“Daycare? There is no charge,” explains a mother.

After this group conversation I thought that there might be a low cost of living to live in a Yoreme village. Oh was I wrong. What I did not factor in was the level of marginalization that raises the price of many other goods and services. Distance to gas stations, water purification, groceries, and home goods adds transport cost in fuel and wear-and-tear of vehicles. What is more, is the price. Everything from food to cleaning products in villages, and small towns around have higher prices than the in the larger cities. But what really shocked me was the cost of goods at a second hand store on the outskirts of Etchojoa. Old, faded, and worn-out jeans were displayed with a price of $400 Mexican pesos or at that time $30 U.S. dollars. This when I had just seen brand new jeans in Ciudad Obregón for around $350 MXN or $27 USD and

I had bought the jeans I was wearing at K-Mart in the United States for $23 USD. I also saw tools for sale that looked like the ones my grandfather had stored away in an old barn. Prices were astronomical compared to new equivalents. These observations became quite the thought exercise for me to think about how much access to markets can lower costs on the level of a family. When one makes little and pays much even what income they do have does not go very far.

For these economic reasons many young Yoreme leave the villages for the city. But they are leaving something else behind. The Yoreme who stay and live on their land have something that the workers in the city desire. For example, the notion of working and saving so that one may own their own home and land. Then have some animals to take care of. Maybe they could even spend time with their grandchildren? This dream is the dream that many people push towards retirement that may or may not come to them. But the Yoreme in tight-knit villages already have this. What they pay in marginalization and high costs, they recoup by living in the present with their family, in their home, and on their land.

1.7 Yoreme Food

Professor David Valenzuela Maldonado and I marched through the *pitaya* thicket near Sirebampo, Sonora. We were guided by Eugenia. Eugenia is a Yoreme artisan who creates many value-added products out of the pitaya (*Stenocereus thurberi* (Engelm.) Buxb., Cactaceae). As we walked by the edge there were schoolchildren buying snacks at a little one-room store with a walk-up counter. They ran off and giggled with their chips, candy, and soda-pop. As we continue, we see little bits of red almost hovering above the ground. The little red fruits of the mammillaria cactus (*Mammillaria* Haw., Cactaceae) caught our eye in great contrast to the desert pavement.

Eugenia lit up with excitement saying, “Oh the mammillaria fruits! They are so tasty to eat!” Then she shifted to reminiscing to a time just 15 to 20 years ago. "We used to collect them after school. We would compete to see who collected the most then gobble them up. It turns out a doctor later told us that they have cancer fighting nutrients, but now the children buy junk food after school."

It is a shame to let so much childhood fun, exercise, and nutrition disappear. Currently, the traditional foods are still common. But just as mammillaria fruits get eclipsed by packaged junk food, the traditional drink of *banari*, a thick drink that could translate as *atole* or *atol*, is being replaced by soda-pop. Banari can be made with ingredients such as plantain and thickened with lime-treated corn. In the mornings families will eat taskarim (tortillas) with yori muni (local tepari) beans. They might have eggs or a beef-bone stew called *wakabaki* too. The bones from the butcher give enough remnant meat to add protein to the pot. But on really special occasions, a goat will be slaughtered and made into *chibabaki* or a type of goat stew. This protein rich delight has lots of meat since it does not rely on just remnants. It creates quite a fanfaire with smiles all around.

As we kept walking and talking, I reflected on the idea that easy pleasure from local junk food is, of course, not always that pleasurable in the end. And I also realized that more than the menu, a sense of community and camaraderie forms around a nice warm pot of beef-bone wakabaki, and this cannot be replaced in a package.

1.8 Traditional Knowledge and Practice Maintenance Proves Elusive

Traditional ways continue with a healthy vibrance in and around Yoreme communities. The dances and music are heard at festivals. All the while medicinal herbs are on display by local healers. Some give advice while others demonstrate how to prepare and apply the herbal medicine. All the scene is broadcast in the Yoremnokki (Yoreme langauge) on the local radio station XEETCH called *La Voz de los Tres Ríos* or The Voice of the Three Rivers making reference to the three groups served by radio broadcasts, namely, the Yaqui, Mayo, and Guarijío (Yoeme, Yoreme, and Macurawe). Amidst this seemingly vibrant activity, language use is declining. Sometimes over half of the indigenous population does not speak the language (GOB.mx, 2015). Also, some elders say that the interest in natural medicines, traditional foods, and ceremonies is declining in the younger generations. Yet here in Juchica and other communities I visited, the culture seems to be vibrant. It causes one to wonder how a vibrant culture stays vibrant. Victoria Reyes-García's group found that when local community members interact with the natural environment as they have done for millennia, they can develop their traditional knowledge and practices at a healthy progression (Gómez-Baggethun and Reyes-García, 2013). Whether people live in the country or city, all have access to plants in some form. I wanted to study human-plant interaction—ethnobotany as a way to see the development of traditional knowledge and practices in the context of societal changes.

1.9 Ethnobotany Hones in on Botanical Knowledge

The connection of plants and people creates a stage where integral parts of traditional knowledge and practices are seen. Plants provide such a pervasive part of human food, medicine, cosmetics, gardens, ideas of beauty, lore, and culture that they are an excellent subject for studies on traditional ways. The field of ethnobotany encapsulates these ideas of studying plants, peoples, and cultures. The prefix *ethno-* stems from the transliterated Greek *ethnos* for nation, culture, or, more generally, large group of people who live together, and the term botany stems from the Greek *botanē* for plant. Thus researchers in ethnobotany ask questions relating to how humans and plants interact. These questions entail both aspects of how humans influence plant life, and how plants affect human life. Ethnobotanists study multiple scales from broad ecological systems, to single plant uses. Further, they study humans and how plant trade affects society and food or medicines may affect human physiology. Some tangible benefits of these studies can come from crops, foods, medicines, and plant based industrial supplies, and many intangible benefits include access to seasonal work, whole-family inclusive projects, nutrition, gastronomic and culinary arts, nature awareness, appreciation for biological conservation, community identity, sense of agency, and resistance to negative social construction. Both economy and culture largely rely on supplies from the natural environment—specifically plant material. By studying these dynamics, the field of ethnobotany advances the human understanding of mechanisms related to the well-being of humans and the plants they depend on.

1.10 Yoreme and their Surroundings Provide an Excellent Model

The Mayo Valley exhibits wealth of traditional cultural expressions. These include dances, songs, festivals, native language use, foods, medicines, gathering, hunting and fishing practices, art, and oral traditions. At the same time, the lands of the valley are farmed with highly technical agricultural practices. This pushes the Mayo and adjacent Yaqui Valley into the leading wheat producing area of Mexico with yields soaring over world averages by 121% (20 Minutos, 2017). Additionally and in line with global trends, internet penetration in the valley is high and growing as it is all across Latin America (IWS, 2017b). Low cost phone plans and packages accessible to people with varied and uneven income have, most probably, contributed to this connectivity. Given the tensions between land and resource use, and indigenous practices worldwide, plus the expansion of digital technologies to remote peoples, the dynamic of this is important to study. My field site, the Mayo Valley, provides an ideal site to ask research questions about these dynamics in TKP remodeling.

1.11 Yoreme History and Environs

Yoreme history is marked by some major events. They settled along the banks of three main rivers, the Mayo, the Fuerte, and the Sinaloa (Berry and Doyon, 2001). They grew crops such as corn (*Zea mays* L.), squash (*Cucurbita* L.), and beans (*Phaseolus* L.) in the floodplains of these rivers. They relied on fish and seafood from the coast and resources from the native thornscrub vegetation stretching across to the base of the Sierra Madre Occidental mountain range. Temperatures are hot and dry with the rainy season in late summer. As a reference for climate compared to other parts of Mexico, see the maps of figures 1.2, 1.3, 1.4, and 1.5.

Upon contact with the Spanish, their history took radical turns. The first interactions with the military were tense and violent. The interactions with Jesuit missionaries, whom the Yoreme requested, were much more peaceful. This may have been due to the Jesuits' habits of working with local leaders, learning the language, and general peacefulness compared to military generals. Yet the discovery of silver in Álamos, Sonora caused waves of Spanish immigrants and lead to problems with land encroachment. Later, many Yoreme joined the Mexican revolution in hopes of securing land tenure for themselves and their communities. Of the men who returned, many found their community churches destroyed, lands taken, and women married off to mestizos. Land tenure was partially secured by Román Yocupicio who served as the governor of Sonora. He was Yoreme and through strategy and political wit, as opposed to previous armed uprisings, was able to secure some of the Yoreme lands (Crumrine, 1977; O'Connor, 1989). Although some land tenure was restored, the momentum of the valley was moving fast towards mechanized farming. The Green Revolution began and lands were being cleared and planed rapidly. By the 1950s and 60s much of the Mayo Valley was transformed into irrigated fields for cultivation of mechanized agriculture. The Yoreme presence remained strong in the region and CDI established a center in Etchojoa followed by the radio transmitter XEETCH some years later. During the time from the 1950s to present the ideas of acculturating native peoples has shifted to valuing traditions. This can be seen by programs and history from the start of INI (*Instituto Nacional Indigenista*, National Indigenous Institute) as it transformed into CDI. Considering the tumultuous past, this recent philosophy is refreshing.

> *Los indígenas tienen derecho a vivir bien con su propia identidad y con pleno respeto a sus derechos* (Abreu Sierra et al., 2012). (Indigenous people have the right to a good life with their own identity and with full respect for their rights.)

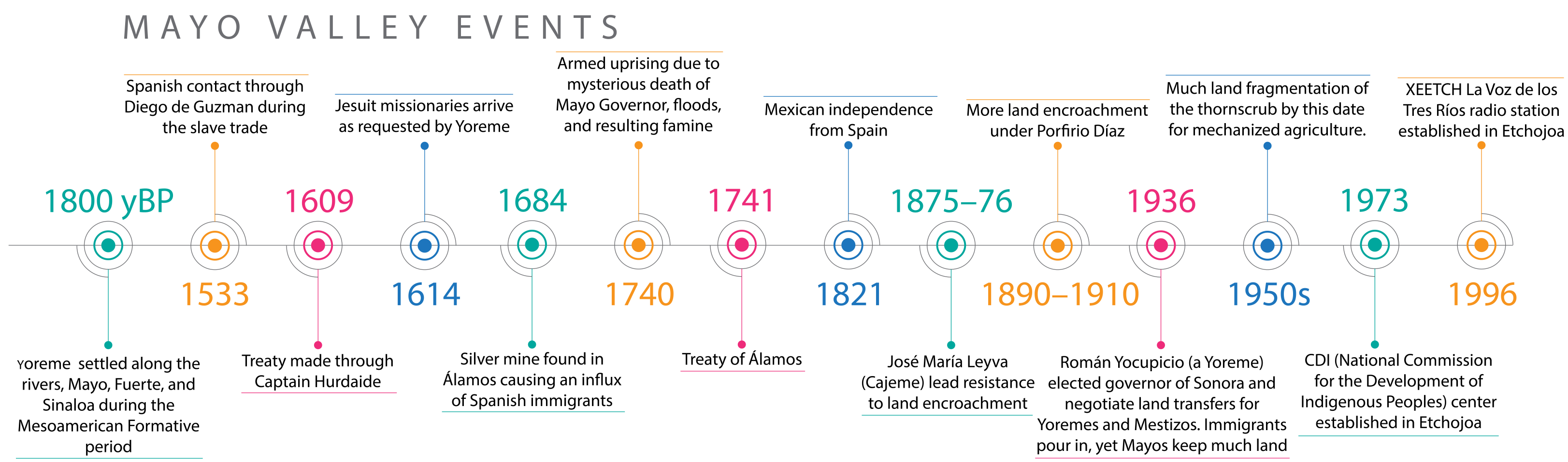


Figure 1.1: Major historical events have shaped Yoreme history. This timeline shows the events *en route* from *rancherías* to struggles throughout the colonial era to valoration of ethnic identity. Years are AD (CE) or years before present (yBP–defined as 1950 AD) (Crumrine, 1977; O'Connor, 1989; Abreu Sierra et al., 2012)

Physical Environment and Vegetation

Maps of temperature, rainfall, soil moisture, and bedrock were prepared using QGIS open source geographic information system software (QGIS Development Team, 2017). We acquired geographic data as shape (*.shp) files from Mexico's National Institute of Statistics and Geography (*Instituto Nacional de Estadística, Geografía, e Informática*—INEGI) at www.inegi.org.mx. The temperature and precipitation maps contained hard to read contour lines. In order to demonstrate qualitative trends in a readable way, we filled in gaps between contour lines using the color detecting eye dropper tool and the color filling paint bucket tool of Adobe Photoshop (Adobe, 2012). One challenge to this method is that the multiple manual operations provide increased risk of human error where a section could be mislabelled with a neighboring sections value. Therefore, these should not be used in the same way as maps generated from defined polygon vector values. Having stated that, they serve the purpose of showing trends in climate variables as one moves across a state or country. Since the main purpose is to describe these trends and not analyze climate variables, I feel that these maps are superior in conveying this than a contour map (See Fig. 1.2, 1.3, and 1.4).

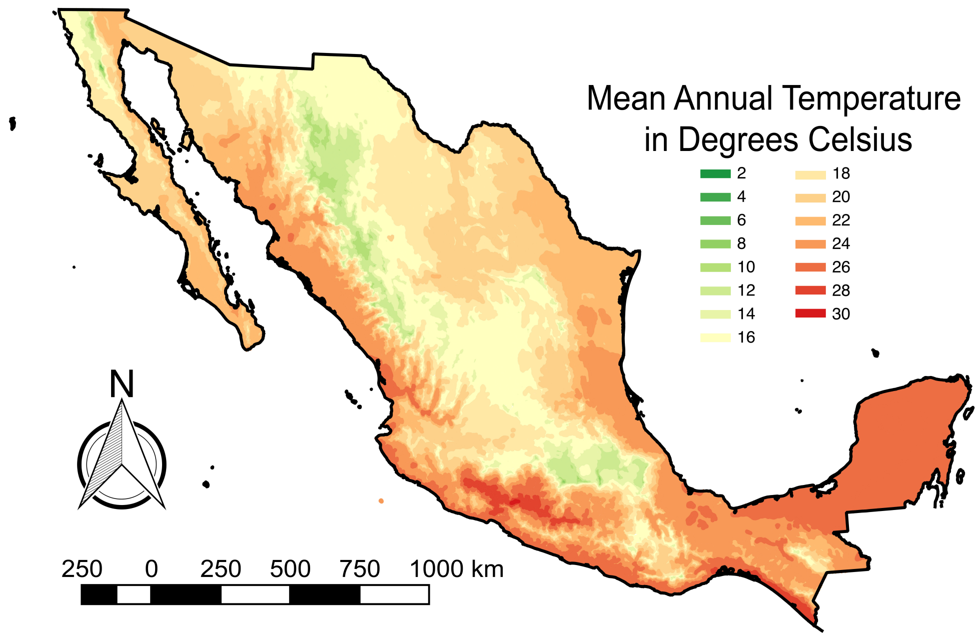


Figure 1.2: Mean annual temperatures across Mexico. The contours of temperatures reveal the transition regions from high to low temperature areas. Along the coast of mainland Mexico's northwest, the mean temperature transitions from high to a bit lower towards the base of the Sierra Madre mountain range and then steeply declines as higher elevations are reached. Raw data from INEGI (INEGI, 2005a), at 1: 1 000 000 scale

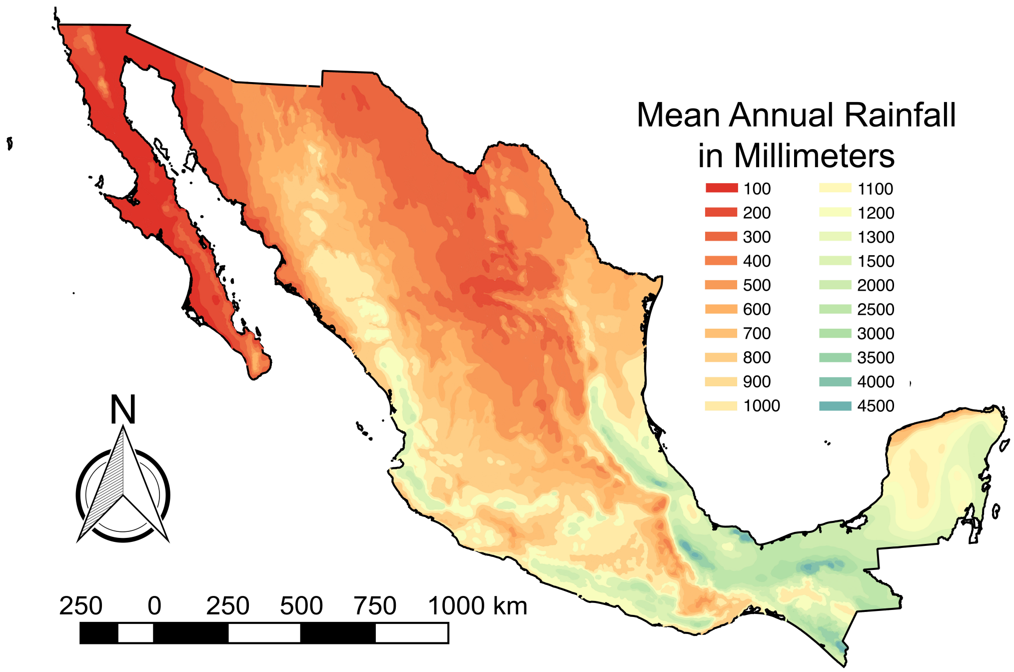


Figure 1.3: Mean annual rainfall across Mexico. The contours of rainfall reveal the transition regions from low to high rainfall areas. Along the coast of mainland Mexico's northwest, the mean rainfall transitions from 100 mm or less to over 1000 mm at the crest of the Sierra Madre mountain range. Raw data from INEGI (INEGI, 2005a), at 1: 1 000 000 scale

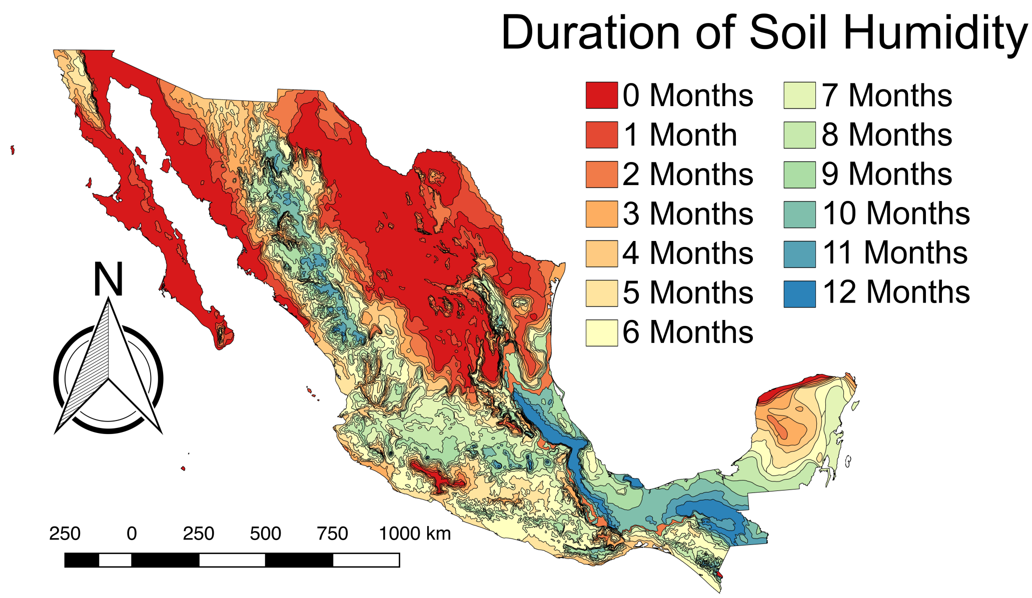


Figure 1.4: Duration of soil humidity is short along the coasts of Sonora and Sinaloa (northwestern coast of Mexico's mainland). This is in the habitat of many plants the Yoreme depend on. Raw data from INEGI (INEGI, 2005a), at 1: 1 000 000 scale

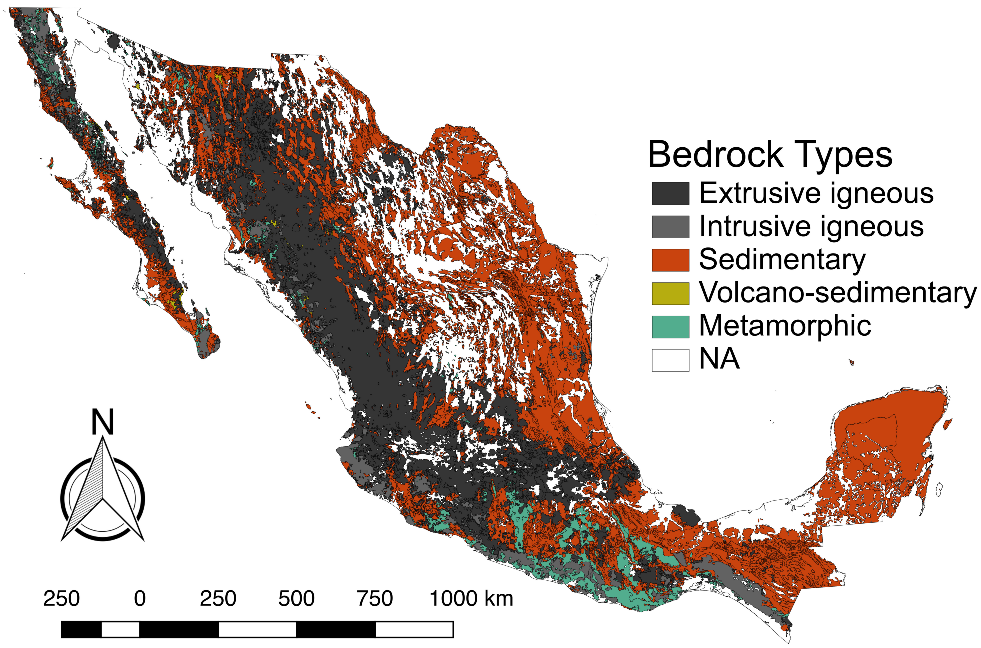


Figure 1.5: Underlying rock shows the igneous formation of the Sierra Madre Occidental and western Mexico as compared to the high rate of sedimentary rock in eastern Mexico. Raw data from INEGI (INEGI, 2005b), at 1: 1 000 000 scale

The sonoran desert ends around the city of Guaymas which lies north of the Yoreme territory. The Yoreme mainly inhabit the thornscrub vegetation type. The thornscrub is distinguished by the increasing presence of low trees and shrubs as elevations raise from the coast up the Sierra Madre mountain range where the tropical deciduous forest begins. The thornscrub consists of drought deciduous trees 3–6 meters in height with undergrowth of shrubs. Cacti are plentiful with both short cactus such as *Mammillaria* Haw. and taller columnar cacti such as *Stenocereus thurberi* (Engelm.) Buxb. and *Pachycereus pecten-aboriginum* (Engelm. ex S.Watson) Britton & Rose. The vegetation cover provides ecosystem services of and habitat for erosion control, wild game, food, medicinal plants, native rangeland, pollinators, and endemic species. But through experience any investigator will feel the refreshing gift—if you will of the heat reduction service the greenery provides. At any given time of year, when one steps from a concrete ladden city into the thornscrub an instant relief from the incessant heat is felt. For an idea of the transition zones and patchines of vegetation types see the vegetation map (Fig. 1.6).

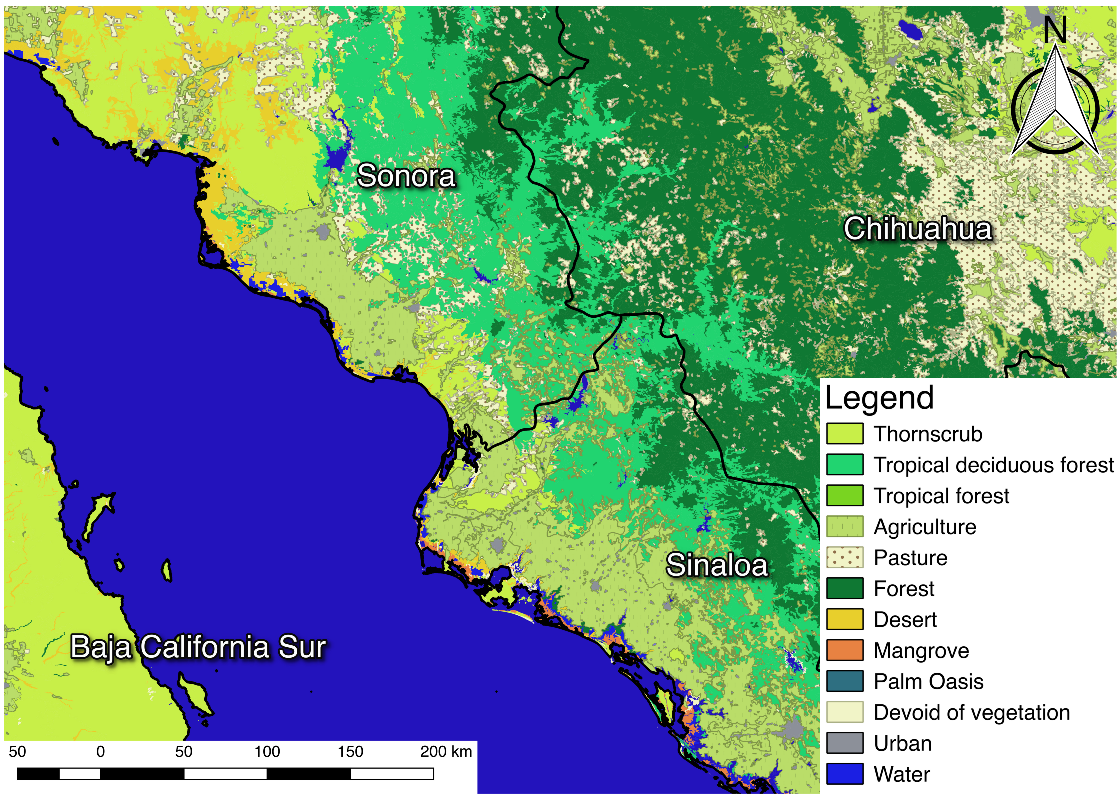


Figure 1.6: Vegetation of southern Sonora and northern Sinaloa shows the change from desert to thornscrub along the coast and thornscrub to tropical deciduous forest towards the Sierra Madre mountain range. One can also see the prominence of agriculture mixed with patches of native vegetation. Raw data from INEGI (INEGI, 2011), at 1: 1 000 000 scale

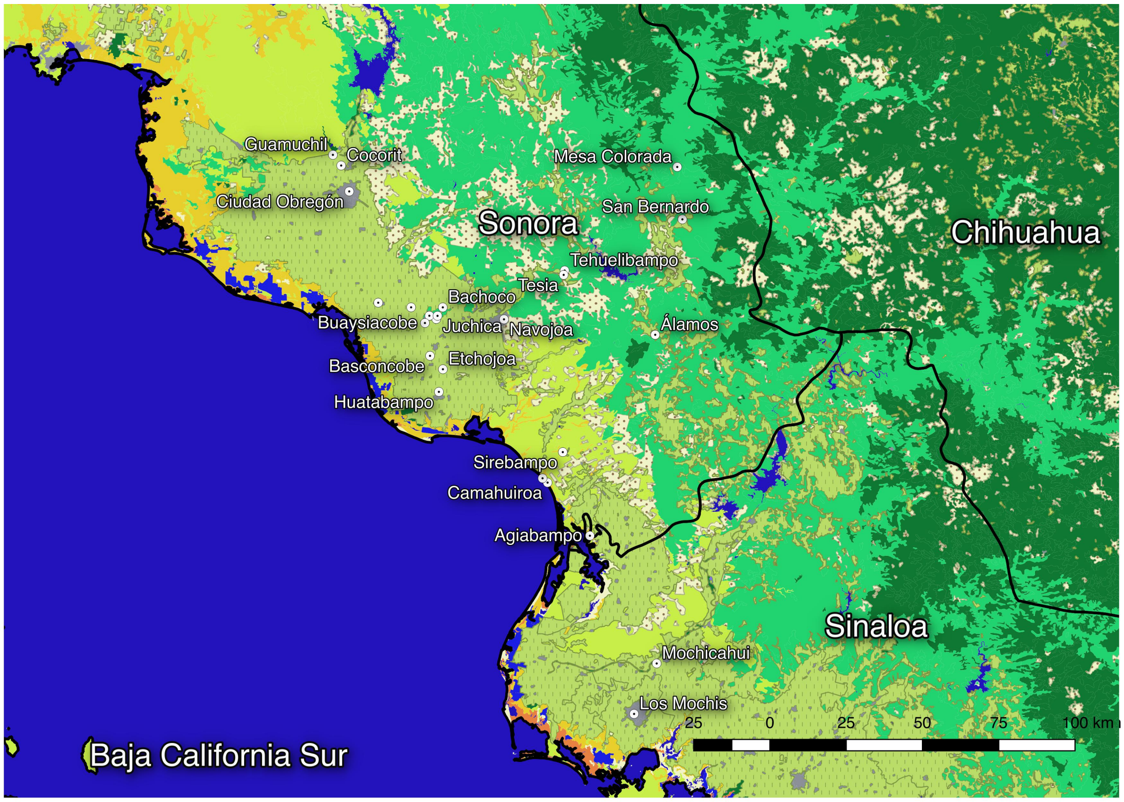


Figure 1.7: Zoomed out map of towns visited during research trips to southern Sonora and northern Sinaloa

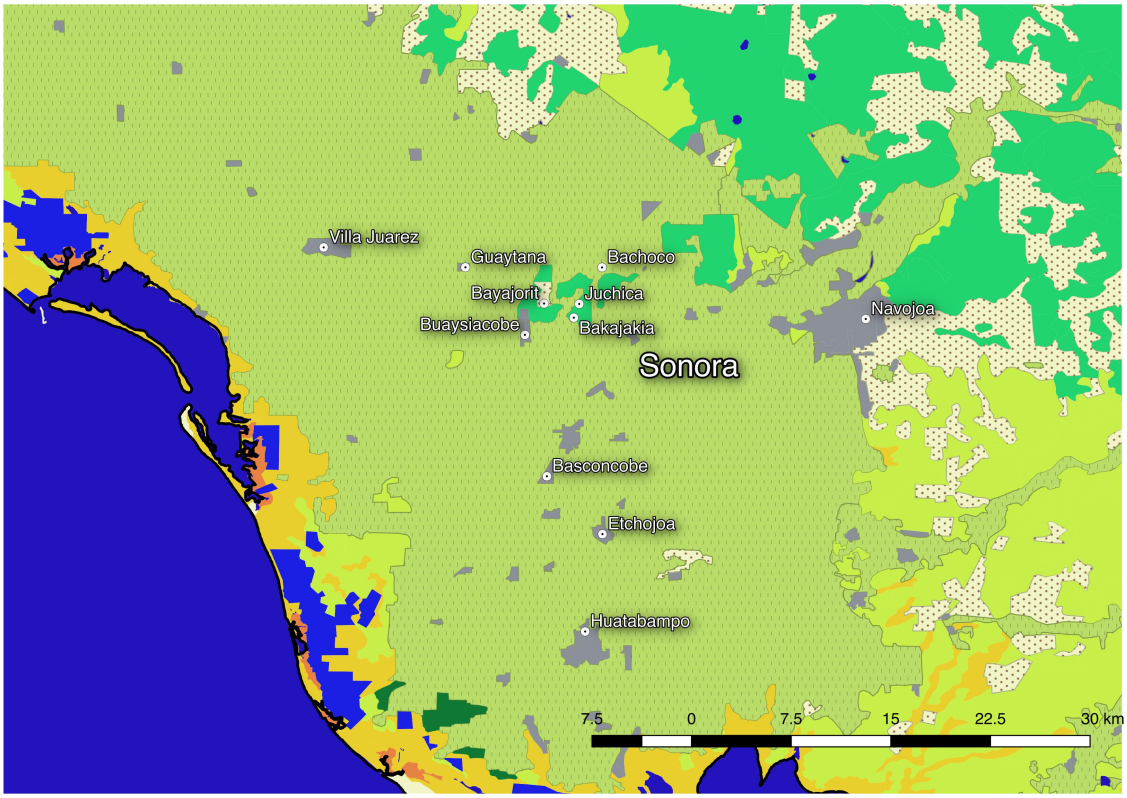


Figure 1.8: Zoomed in map of towns visited during research trips to southern Sonora in the municipality of Etchojoa

1.12 The Río Mayo has a Rich History of Botanical Research

Some names continuously appear in plant collections and herbarium records from the region. Edward Palmer of the U.S. Department of Agriculture and later Smithsonian Institute made notable collections in Sonora and many other areas of Mexico and the U.S. (Smithsonian Institute Archives, n.d.). Ira Loren Wiggins also made ample collections in southern Sonora in the 1930s and 1940s (JSTOR Global Plants, n.d.). However the one who popularized the Mayo Valley along with its thornscrub vegetation and culturally rich peoples was Howard Scott Gentry with his book *Río Mayo*

Plants of Sonora-Chihuahua (updated posthumously to *Gentry's Río Mayo Plants*) (Gentry et al., 1942).

Later both Thomas Van Devender and David Yetman published *Mayo Ethnobotany: Land, History, and traditional knowledge and practices in Northwest Mexico*. This book built upon Gentry's work by highlighting uses, names, and cultural significance of plants around the Mayo Valley (Yetman and Van Devender, 2002). Prominent collections from the region were done by researchers such as Alberto Búrquez, Richard Felger, Raymond Turner, and Andrew Sanders (SEINet, 2018). These works along with others have advanced the botanical knowledge and background research of the area. This foundational work helped me begin my investigation of the dynamics between traditional practices and current land and technological development in the Mayo Valley.

1.13 Traditional Ways and Industrial Development are at Odds in the Valley

Southern Sonora plays a huge part in Mexico's grain export market. It was the northern field site of Norman Bourlaug's experimental grain varieties at the CIMMYT field station (CIMMYT, 2016). It also converted Mexico from being a wheat importer to being a wheat exporter (Opalko and Opalko, 2015). This upswing in development comes at a cost to traditional ways of life. Land that was once home to arrays of medicinal and edible plants along with wild game for hunting, and also homes of people, are now golden fields of grain. And where grain once was, houses and yards take over. Where yards used to be green, larger and denser homes place concrete where little gardens once flourished. This happens all over the world and here in Sonora, I wanted to find out how tradition knowledge and practices related to plants from the natural environment may be held, preserved, and taught amidst these societal and landscape changes.

Chapter 2

The Eruption of Technology in Traditional Medicine: How Social Media Guides the Sale of Natural Plant Products in the Sonoran Desert Region

First published online 20 November 2015[1]

2.1 Keywords

Ethnobotany; selection; medicinal plants; social media marketing; Sonora

[1]Chapter two was published as presented here in 2015 in *Economic Botany* 69(4): 360–369, written by Andrew J. Semotiuk, Nancy L. Semotiuk & E. Ezcurra, and reproduced in accordance with the permissions and conditions of the journal *Economic Botany*.

2.2 Abstract

Because the adoption of technology into traditional systems has unknown effects, we examined the hypothesis that social media aids shopkeeper selection of herbs or herbal preparations that the public is exposed to. Medicinal plant shopkeepers in southern Sonora, Mexico, were interviewed about their customer base and marketing strategy. The majority, 85%, of their customers had low to middle incomes as ranked by the shopkeepers, of which seven of seventeen incorporate social media marketing into their marketing strategy. Shopkeepers preferentially selected herbal preparations over loose herbs for online marketing. The results indicate that the incorporation of social media marketing aids a shift from herbs to herbal preparations in Sonoran traditional medicine markets. In short, social media use may act as a conditioning factor used by shopkeepers to promote herbal preparations and, in doing so, may provide a critical tool for the long-term survival of traditional plant markets, but at the risk of also contributing to the loss of the culture of home remedies and traditional domestic preparation of natural products.

2.3 Resumen

Porque la adquisición de tecnologías modernas en sistemas tradicionales tiene efectos desconocidos, examinamos la hipótesis que las redes sociales asisten a la población en la selección de vendedores o marchantes de hierbas y preparaciones de hierbas. Los marchantes de plantas medicinales en el sur de Sonora, México, fueron entrevistados acerca de su base de clientes y su estrategia de mercadotecnia. La mayoría, 85%, de los clientes fueron identificados como de ingreso bajo a medio por los propios marchantes, de la cuales siete de diecisiete incorporan redes sociales por medio del In-

ternet en su estrategia de mercadotecnia. Los marchantes entrevistados seleccionaron preferencialmente preparaciones de hierbas más que hierbas sueltas para sus ventas en línea. Los resultados indican que la incorporación de redes sociales para apoyar las ventas impulsa un cambio de hierbas a preparaciones de hierbas en mercados de medicina tradicional en Sonora. En resumen, el uso de redes sociales puede funcionar como un factor condicionante usado por los marchantes para promover preparaciones de hierbas, y, al hacerlo, puede proveer una herramienta critica para la sobrevivencia de los mercados de plantas tradicionales en el largo plazo, pero al riesgo de también contribuir a la pérdida de una cultura de remedios de hogar y de preparación tradicional domiciliaria de productos naturales.

2.4 Introduction

The harvest and sale of medicinal plants is a core part of the traditions and healthcare of many people. "For many millions of people, herbal medicines, traditional treatments, and traditional practitioners are the main source of healthcare, and sometimes the only source of care" (WHO, 2002). Medicinal plant vendors are a predominant source of wild-crafted herbal medicines for traditional healers and those who prepare traditional remedies in their own homes. These medicinal plant markets have a particularly robust presence in Mexico, where the culture of traditional medicine use is strong and there is a high market demand from people seeking traditional remedies and treatments (Smith, 2003; Euromonitor International, 2014).

For centuries, Mexico has enjoyed a rich plaza culture where people congregate in a common area, such as a central plaza market, which creates a sense of community and provides strong networks for the distribution of locally produced food and other goods, including wild-crafted medicinal plant materials gathered from local and territorial regions near the market (Luquín, L. H., 2005; Sistema de Información Cultural, 2009; Guillaumin, 2010; Sánchez, 2010; Towell and León, 2010). While doing initial fieldwork in southern Sonora, we noted a developing trend in the use of social media networks for marketing purposes by medicinal plant shopkeepers. The use of social media marketing creates a second storefront for these vendors to supply home practitioners with products. Online social networks and smart phones offer business owners an enormous potential for engaging customers, which was not possible even a few years ago. Since Facebook introduced its Spanish language version in 2008, it has dominated the social media landscape in Mexico (eMarketer, 2012) and, by doing so, is bringing the plaza culture online.

The proliferation of low-cost Internet access has opened up opportunities for businesses to deal directly with individual customers and with a larger customer base in a way that was previously unimaginable. Social media marketing is considered a hybrid aggregate of the promotional mix of advertising, the Internet, direct marketing, and e-commerce (Mangold and Faulds, 2009). Compared to traditional media, which uses one-way company-to-consumer marketing messages such as advertisements, social media is interactive, allowing customers to talk to businesses and to each other. While there are no generally accepted classifications of social media, they are considered to be those "activities, practices, and behaviors among communities of people who gather online to share information, knowledge, and opinions using conversational media" (Safko and Brake, 2009). Probably the best known social media are social networks such as Facebook. A site like Facebook.com allows one person to communicate with hundreds, even thousands of people about his or her products. Today it is recognized that "a sound social media strategy combines engagement through social networks like Facebook with building social capabilities into a brand's own sites" (Foux, 2010). This move to use social media provides Mexican shop owners with a low-cost way to incorporate online tools to help sell their traditional medicinal plants. By creating and cultivating an online community of customers, traditional plant vendors can develop trust that leads to more sales. When social media is used to market ancestral medicinal plants, these products become available for sale to a larger customer base than ever before.

Vendors and customers have traded online since the inception of ARPANET, a precursor to the Internet. Some of these trades involved marijuana (*Cannabis sativa* L.) exchanged between students in Silicon Valley who had access to such networks (Walsh, 2011). Later, people started purchasing psychoactive plants such as *Salvia divinorum* Epling & Játiva and plants used for *ayahuasca*, namely *Banisteriopsis caapi* (Spruce ex Griseb.) Morton and *Psychotria viridis* Ruiz & Pav. from online companies (Walsh, 2011). As Internet penetration increases (IWS, 2015; Pew Research Center, 2015), we find traditional herbalists moving online. This brings up many questions about the future of marketing herbs online around the world. Bussmann has found that confusion between species in local physical markets can pose serious risks to customers, especially pregnant women. His team identifies the need for vendor education and deeper studies on the supply chain of herbs in local and potential online markets (Bussmann, Paniagua-Zambrana, Rivas Chamorro, et al., 2013; Bussmann, Paniagua-Zambrana, and Huanca, 2015). In addition to human health, the health of a species' habitat may be affected as vendors reach out to wider markets. Lee found that local market demand may decrease the ecological health of popular species in Southwest China (Lee, Xiao, and Pei, 2008). Yet at the same time, Monteiro asserts that healthy, prosperous physical markets can keep the persistence and prevalence of traditional knowledge systems active in markets of Brazil (Monteiro et al., 2010). There are scores of questions regarding habitat, harvest, sale, and traditional knowledge preservation that can and should be studied as traditional herb vendors move online.

This move to online sales illustrates the union of modern technology with the time-honored use of medicinal plant resources from the natural environment. The interplay between human and natural systems, known as social-ecological systems, evolves through multiple factors (Folke, 2006; Vervoort et al., 2014). On one hand, it has been proposed that the assumption that western technology can help or save a culture is insulting and detrimental (Escobar, 2011; López, 2012); on the other hand, some traditional practitioners seek to preserve their ancestral practices and knowledge using modern technology such as websites and social media (Cowan et al., 2012; Owiny, Mehta, and Maretzki, 2014). Still others suggest that rather than stagnating in tradition or assimilating in modern society, many traditional practitioners have a dynamic approach where they mix old and new ways (Berkes, 2012). Despite various ideas on the best way to respect, preserve, and value traditional practices, the understanding of this interplay between traditional and technological societies remains unclear.

One important factor that may contribute to the shift in the current dynamics between local tradition and technology is the recent adoption of social media marketing by herbal medicine vendors. Around the world, 15% of mobile device users seek health and medical advice online, in addition to speaking with a health practitioner (Pew Research Center, 2014). Consumers are tapping into a new source of health information by going online, suggesting that the mixing of tradition and technology may have a profound effect on both the marketing of herbal medicines and the product availability of those medicines.

The present study was designed to test the general hypothesis that social media aids herbal product placement and that availability to consumers varies between the physical and online storefronts. For this study, we interviewed medicinal plant vendors in the cradle of the Green Revolution in southern Sonora, Mexico, where the intermixing of tradition and technology is particularly strong. To observe the placement of products, we measured both the physical and cyber shelf space given to herbs and herbal preparations. This approach enabled a direct assessment of the effect of new marketing strategies on shelf space and availability of local medicinal herbs and herbal preparations.

2.5 Materials and Methods

2.5.1 Location and Study Site

In and around Mexican municipal markets, medicinal plant vendors are found alongside vendors of staple food items (like meat, produce, and grains) and alongside artisanal craft and clothing vendors. The municipal markets in southern Sonora (Fig. 2.1) are illustrative of Mexico's centuries-old plaza culture where people come together to buy and sell, and this includes medicinal plants (Luquín, L. H., 2005; Sistema de Información Cultural, 2009; Guillaumin, 2010; Sánchez, 2010; Towell and León, 2010). The government constructs these markets in city centers to house small shops, and numerous stores open for business all around them (Luquín, L. H., 2005; Sistema de Información Cultural, 2009; Sánchez, 2010; Towell and León, 2010). Markets in the cities of Ciudad Obregón, Navojoa, and Hermosillo offer ideal research sites as they provide access to investigate the flow of wild plants from the natural environment to consumers, as well as the circumstances of this interchange.

The habitats supplying these markets are dominated by Sonoran Desert communities, thorny tropical deciduous forests, and scrub (Yetman, Van Devender, et al., 1995;

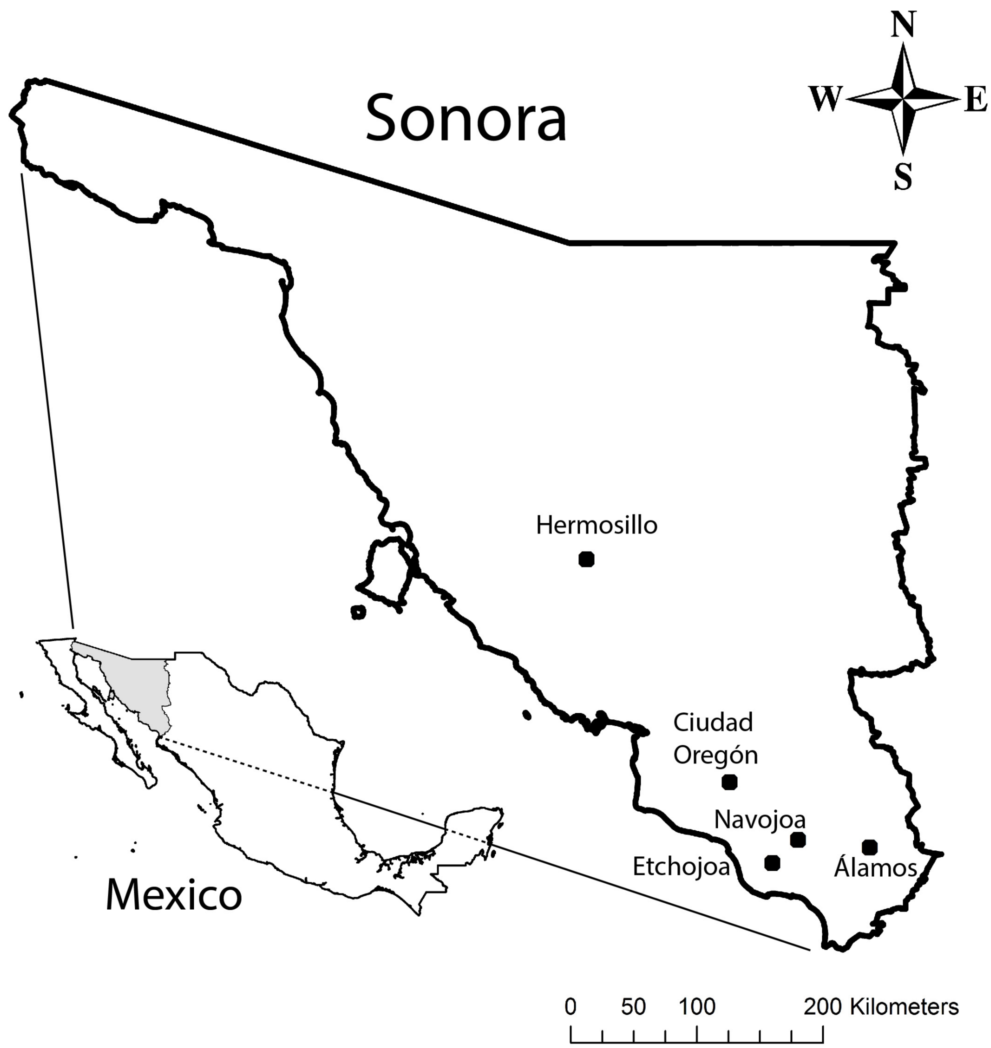


Figure 2.1: Map showing the study site locations in relation to Mexico and the state of Sonora. The enlarged region shows cities surveyed for medicinal plant shops (GIS data from Conabio (2010))

Figure 2.2: Representative photographs of the medicinal plant shops typical in the study area with (A) side view and (B) front view

Arizona-Sonora Desert Museum, 2014). These areas have an arid climate from Hermosillo southwards to Ciudad Obregón, gradually transitioning southeast of Navojoa into a semiarid one (INEGI, 2010b). The mean annual rainfall is 390 mm in Navojoa, 299 mm in Ciudad Obregón, and between 200 and 300 mm in Hermosillo with the heaviest rains occurring in late summer in all areas (Ayuntamiento de Cajeme, 2010; Ayuntamiento de Hermosillo, 2010; Ayuntamiento de Navojoa, 2010).

Vendor shops are usually stands (about 25 m^2) within large, covered municipal buildings, although sometimes larger one-room stores are located nearby (Fig. 2.2). The herbal products are typically displayed as loose herbs piled in open containers, placed in clear containers with lids, or packed in clear plastic bags. Herbal preparations are typically placed in bags, bottles, or plastic jars and displayed on a shelf or in small boxes (Fig. 2.3).

We selected three study sites based on the presence of medicinal plant vendors in the markets. Ciudad Obregón is the principal city in the Municipality of Cajeme,

Figure 2.3: Representative samples of herbs and herbal preparations from medicinal plant shops in the study region. (A) Herbs, (B) herbal preparations

which has ca. 410,000 inhabitants (INEGI, 2010a). This city lies in the Yaqui Valley where it grew during the agricultural development of the Green Revolution (Hewitt de Alcántara, 1974). Navojoa is the principal city in the Municipality of Navojoa, which has some 158,000 inhabitants (INEGI, 2010a). The city of Navojoa is surrounded by agricultural fields cleared out of the original thornscrub (Yetman, Van Devender, et al., 1995). Hermosillo is the principal city in the Municipality of Hermosillo, which has around 785,000 inhabitants (INEGI, 2010a). The city is surrounded by Sonoran Desert scrub, and the main agricultural activities are ranching and some cultivated field crops in irrigated areas (Encyclopaedia Britannica, 2014).

2.5.2 Informant Interviews

Medicinal plant shopkeepers were asked to participate in a plant products survey. The shopkeepers were asked questions verbally in Spanish, which is the dominant language in the markets, and answers were written down by the investigator. All interviews and surveys used in the present study were approved by the University of California Riverside Human Research Review Board (Protocol Number HS-14-103) and followed the International Society for Ethnobiology Code of Ethics for the facilitation of ethical conduct and equitable relationships (International Society of Ethnobiology, 2006). The Spanish and English versions of the vendor survey are available as Appendix B.

2.5.3 Sampling

In this study, three central markets were sampled in the southern region of Sonora: Navojoa, Ciudad Obregón, and Hermosillo. Within each city, interviews were conducted at markets where local people use, exchange, and sell locally sourced medicinal plants. Shopkeeper informants participated and provided information on a voluntary basis. Surveys were conducted among nine female and eight male shopkeepers selected on the basis of the prevalence of medicinal herbs or herbal products on display. All shops in and around central municipal markets participated with the exception of one vendor in Ciudad Obregón. Surveys were attempted in both Etchojoa and Álamos, but there were no stands or shops selling herbal medicines in these towns.

2.5.4 Shop Comparison

To compare the shelf space of physical and cyber storefronts, shelf product display areas were measured. The resulting display zones were normalized to total storefront area. As for online shelf spaces, product displays were considered as photos and product display quantities were normalized to the total number of product display photos. Interviewees were also asked about the socioeconomic level of their customer base (classified as Low, Middle, and High), and their responses were ranked.

2.5.5 Data Analysis

Product data were grouped into three storefront categories according to whether they were from (a) an online storefront, (b) physical storefront of a shop that also markets online, or (c) from a physical storefront of a shop that does not market online. Products also were classified into two categories: (i) bulk and (ii) prepared products. Our data analysis design was planned to test whether the proportion of prepared products compared to that of bulk-sale products was different in traditional stores that do not market online compared to those stores that use online marketing. Because our dependent variable, the proportion of prepared products in each store, is a ratio of two counts, we first used a Generalized Linear Model for proportions (also known as a logit model for binomial data). The residuals in the models were tested for over-dispersion, and the model parameters were corrected if necessary using "quasi-binomial" modeling (R Core Team, 2013). The significance of the differences between the three types of stores was calculated by means of a t-test on the model's parameters (in order to further confirm our results, we also calculated the proportion of processed products offered in each different storefront as a simple continuous variate, and tested these proportions across the different types of stores using one-way ANOVA, with similar results to the more complex logit model).

For the analysis of customers ranked into socioeconomic groups, we first counted the number of stores that declared receiving customers from (a) low-income social groups, (b) middle-class customers, and (c) high-income customers. We then compared the proportion of stores that declared receiving customers from each social group relative to the total number of stores, also using a logit model. If, overall, the proportions differed significantly, we calculated for each group its binomial mean and standard error, and compared each social group against the others using a t–test. All statistical analyses were scripted and run in the R programming language (R Core Team, 2013). Both original data and computer code are available from the authors.

2.6 Results

We encountered 11 medicinal plant shops in Ciudad Obregón, 4 in Navojoa, and 3 in Hermosillo, 17 of which agreed to participate, with one in Ciudad Obregón declining. Shops generally consisted of stands set up in a larger municipal marketplace. Of the 17 participating shops, 5 were outside the municipal marketplace on nearby streets. Seven of the 17 shops incorporated social media marketing into their marketing mix, 6 used Facebook pages, and 1 used a blog. Figure 2.4 demonstrates a representative

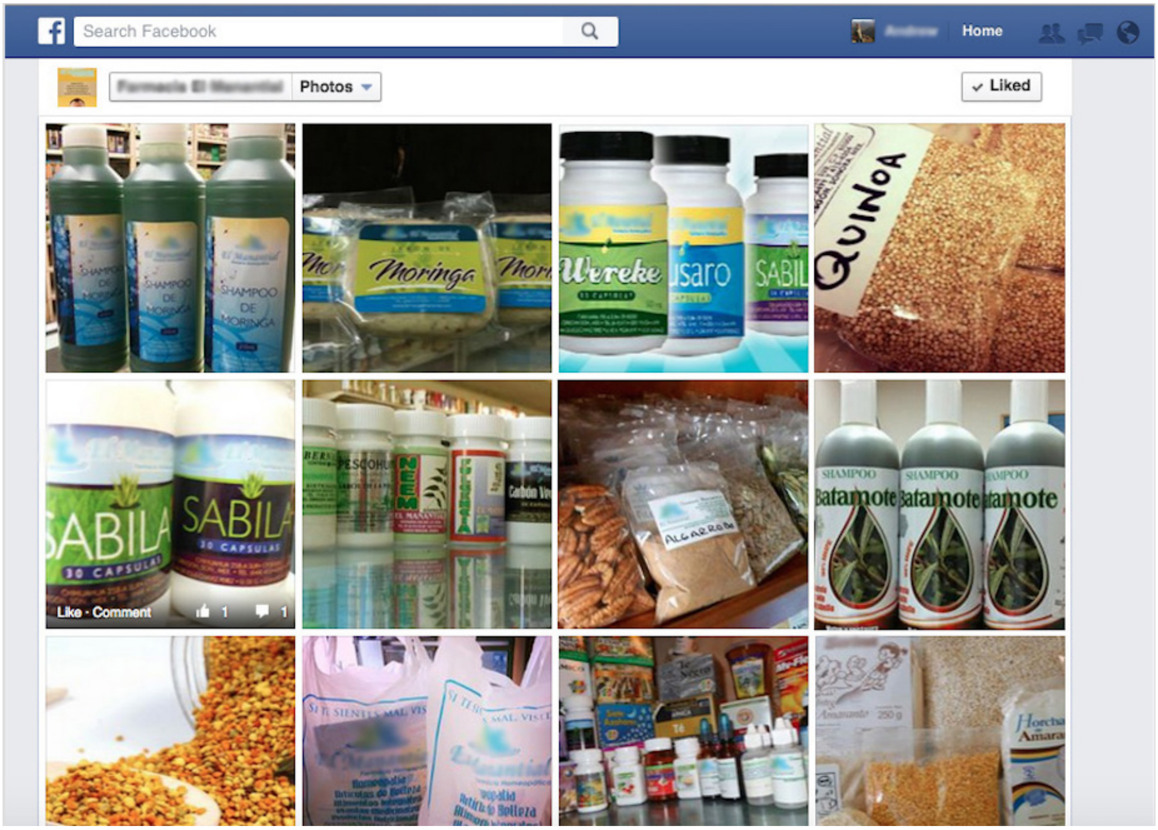


Figure 2.4: Representative image of products marketed online using social media

image of products marketed online with informant information blurred out. All of the businesses rely on local suppliers, and these suppliers make biweekly rounds offering bulk material gathered from wild areas in the countryside. Correspondingly, shop owners resell bulk plant material as loose herbs, and/or process it and sell their herbal preparations. They reported that the major customer base, 85% on average, is made up of low- to middle-income people who seek natural remedies to treat health ailments. All stores reported receiving low- and middle-income customers but only 42% of the stores reported receiving high-income customers. That is, higher-income customers were perceived as being significantly less frequent ($t = 5.1; P < 0.0001$).

Product sales can be influenced by promotion and marketing. Social media marketing brings information and products closer to the consumer (Bernhardt, Mays, and

Hall, 2012). To determine the potential influence of shopkeeper marketing strategies, we examined the relationship between Internet marketing and the product availability of herbs and herbal preparations. There was a marked and highly significant difference in the proportion of prepared and bulk products sold by the different shopkeepers, according to their type of store ($\chi^2 = 113.7, DF\,2, P < 0.0001$). Online shelf space exhibited almost all herbal preparations, whereas shopkeepers who did not use Internet marketing filled their shelf space with mainly bulk herbs. This significant difference ($t = 2.7, P = 0.001$; Fig. 2.5) reveals a starkly different product availability via these two marketing methods. Further, physical storefronts of shopkeepers who also market online showed a trend to less herbal preparations compared to their own online storefronts and more bulk herbs, but the difference was not significant ($t = 1.7, P = 0.1$; Fig. 5). Taken together, these shifts in shelf space demonstrate a trend toward turning herbs into herbal preparations as shopkeepers move their marketing strategies online.

2.7 Discussion

The present study offers two new findings. First, shopkeepers in southern Sonora who sell wild medicinal plants are incorporating social media marketing into their marketing plans. Second, herbal preparations are preferentially marketed online, more so than bulk herbs.

Through social media marketing, individuals can promote their products using online social channels and tap into a much larger community of potential buyers. With more than one thousand million users (Facebook Newsroom, 2014), Facebook is the largest social networking site in the world. A growing number of small businesses use Facebook to engage with, share deals, and seek feedback from consumers and

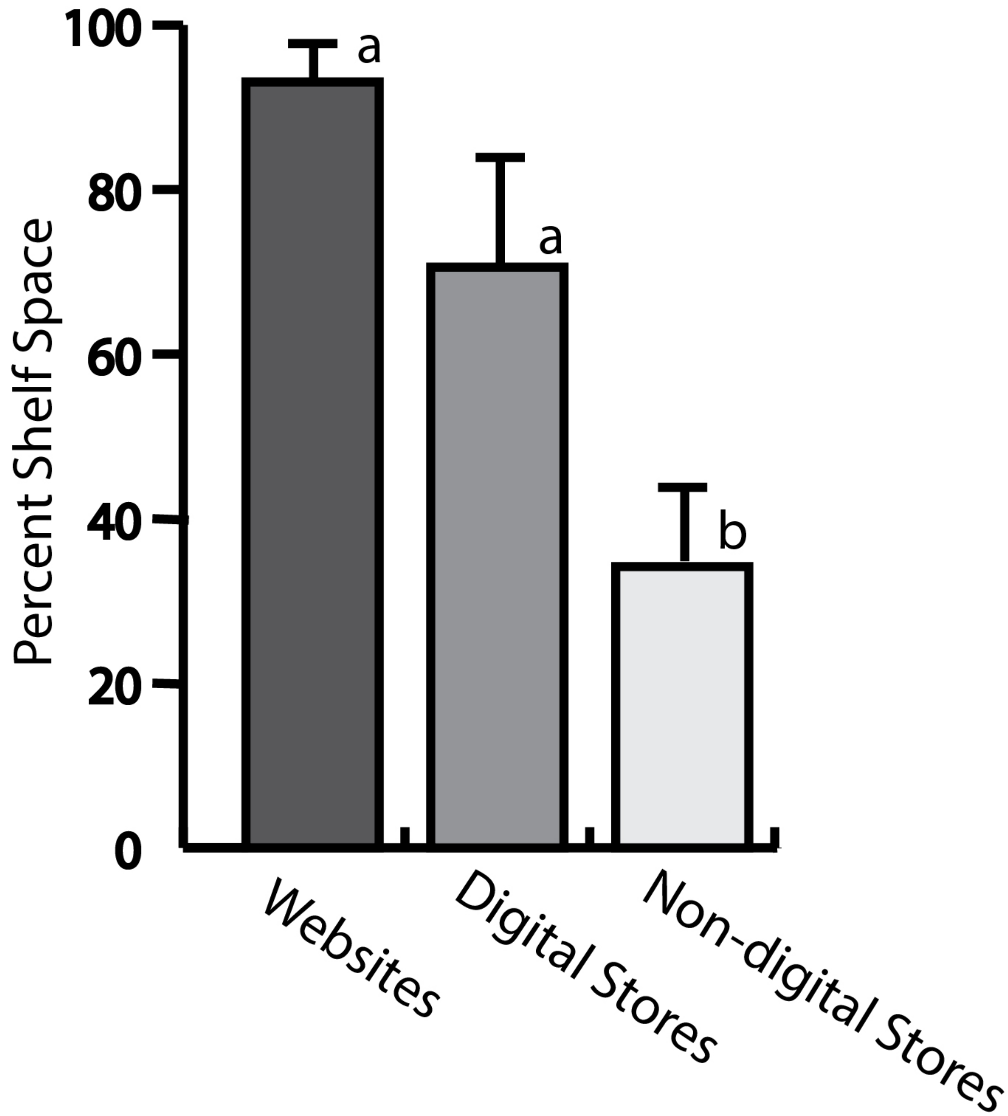


Figure 2.5: Proportion of shelf space occupied by herbal preparations as opposed to unprocessed natural products for Internet websites (Websites), storefronts in shops that also advertise using digital media (Digital Stores), and storefronts in shops that do not advertise in digital media (Non-digital Stores). While Internet sites market almost exclusively prepared products, in traditional market stores prepared products show a minority presentation. Different letters indicate significant ($P < 0.05$) differences in the proportion of processed/unprocessed natural products according to Student's t-test. Bars labeled "a" differ significantly from bars labeled "b". The error intervals above each bar indicate $\pm$ standard error (see text for statistical details)

fans. Mexican medicinal plant vendors in this study used social media, predominantly Facebook, to talk to their customers and advertise their products. Because Facebook relies on members adding friends, who add their friends to create a network of trusted allies, marketers have the potential of reaching groups of consumers with similar interests. Humans are social by nature, and the conversational marketing that is such a striking feature of social media brings the plaza culture of Mexico to the online environment. So while the term "social media" might be relatively new, the experience is not (Wenger, White, and Smith, 2009). Social media facilitates information sharing and knowledge distribution. With social media, information in the form of words, images, pictures, videos, and audio tracks is easily shared. Meerman Scott (2013) said, "Social media differ from so-called mainstream media in that anyone can create, comment on, and add to social media content."

Mexico has a strong tradition of herbal and natural medicinal plant use. A large percentage of the population seeks herbal and traditional remedies (Euromonitor International, 2014). Cost savings are an important reason for people to use traditional medicine, which is easily available and affordable in low-income countries (WHO, 2002). Information supplied by the shop owners in this study also showed that low- to middle-income people make up their main customer base.

Our concern is that the affordability of wild plants combined with a broader marketing approach may lead to the over-harvesting of wild plants. Krigas, Menteli, and Vokou (2014) recently showed that endemic and endangered flora of Greece are marketed and sold online to a large multinational customer base. This may affect the survival of endemic flora promoted online. Additionally, the predominance of herbal preparations over bulk sale in Internet-marketed products leads to a narrowed assortment of options for Internet customers, who buy prepared products instead of preparing them at home using a much wider array of recipes, processes, and uses.

In future work we aim to assess the risk of this selection of specific species of plants harvested within the region and marketed online.

2.8 Conclusion

The sale of local traditional plants in city centers connects modern society with natural resources, and it also increases the awareness of traditional medicinal knowledge. While some purport the benefits, and some cite the harm of combining traditional and modern systems, our study finds that traditional plant markets are highly resilient and can survive in the middle of one of the most technologically intense agricultural areas of Latin America, evolving and adapting to take advantage of digital media marketing strategies and social networks.

However, our study also shows that the offer and supply of traditional resources changes as shopkeepers move online, because digital media pushes human selection away from bulk sale of unprepared natural products onto herbal preparations. In short, social media use may act as a conditioning factor used by shopkeepers to promote herbal preparations, and in doing so may provide a critical tool for the long-term survival of traditional plant markets, but at the risk of also contributing to the loss of the culture of home remedies and traditional domestic preparation of natural products.

Chapter 3

Pillar of Strength: Columnar Cactus as a Key Factor in Yoreme Heritage and Wildland Preservation

First published online 5 September 2017[1]

3.1 Keywords

Yoreme; Ethnobotany; Pitaya; *Stenocereus thurberi*; Sonora, Mexico; Land-use change

3.2 Abstract

The persistence of traditional cultures and modes of land use within rapidly changing, globalized societies is a central issue in understanding ecological and cultural change in the Anthropocene. Located in the heart of the Green Revolution, the Yoreme

[1]Chapter three was published as presented here in 2017 in *Ambio* 47(1):86–9669, written by Andrew J. Semotiuk, Patricia Colunga-GarcíaMarín, David Valenzuela Maldonado, & E. Ezcurra, and reproduced in accordance with the permissions and conditions of the journal *Ambio*.

(Mayo) people of the Mayo Valley in Mexico still obtain a significant proportion of their sustenance from wild ecosystems in the midst of this intensive technological and agricultural development. They live in and around the pitaya (*Stenocereus thurberi* (Engelm.) Buxb.)–dominated thornscrub. In this study, we hypothesize that the pitaya supports Yoreme heritage and sustenance amidst anthropogenic changes to the landscape, and we asked three specific questions. What is the land use status of the *S. thurberi* habitat? What are its potential uses? Does *S. thurberi* provide economic value? To address these questions we conducted interviews, vegetation surveys, and land-use analysis based on geographic information systems. We found that (a) land conversion of the pitaya-rich thornscrub is occurring at a precipitous rate, (b) local producers preserve and adapt their traditions, and (c) *S. thurberi* supports Yoreme heritage while providing economic benefit. The resulting land-use projections along with the cultural value of pitaya products shows the importance of conserving land and promoting sustainable projects instead of clearing land for other uses. If habitat shrinking continues at the current rate, it is likely that both Yoreme livelihoods and continued cultural practices will suffer.

3.3 Introduction

The persistence of traditional cultures and modes of land use within rapidly changing, globalized societies is a central issue in understanding ecological and cultural change in the Anthropocene. Human-induced land-use changes, often referred to as the human footprint, affect biodiversity and ecosystem services (Sanderson et al., 2002; Butchart et al., 2010; Romanelli et al., 2015). These changes are noteworthy in Mexico, especially in southern Sonora and northern Sinaloa, where land development is widespread and often occurs side by side with ancestral traditions, practices, and surviving natural ecosystems (González-Abraham et al., 2015). One region where the interaction between traditional and modern systems is particularly strong is in the ancestral territory of the Yoreme people (Yetman and Van Devender, 2002; Semotiuk, Semotiuk, and Ezcurra, 2015). The Yoreme (often referred to as the Mayo) live in and around the transition zone from the Sonoran Desert into the Sinaloan thornscrubs (Moctezuma Zamarrón and López Aceves, 2007; Arizona-Sonora Desert Museum, 2014). Here, the mechanized and large scale farming operations of the Green Revolution are widespread (Nabhan, 2012) while, at the same time, there persists a strong culture of plant and ecosystem use based on traditional knowledge and management practices in the region (Yetman and Van Devender, 2002).

One peculiarity in the region is the contrast between the irrigated grain farms and the neighboring *pitaya*-dominated thornscrub. The pitaya (*Stenocereus thurberi* (Engelm.) Buxb., Cactaceae, also known as *pitaya dulce* to distinguish it from other columnar cacti as the one with especially sweet (*dulce*) fruits), or organ pipe cactus in English, is a dominant element in large remnant patches of native vegetation that sharply delineate the edges of cultivated grain fields.

This candelabriform cactus branches profusely from the base, sending its arms up above the thornscrub canopy (Molina-Freaner, Tinoco-Ojanguren, and Niklas, 1998; Búrquez, Martínez-Yrízar, et al., 1999). Along the ribs of these arms, white-funnelform flowers and, subsequently, spiny fruits form. The spines easily fall away from mature, red fruits that are of variable sizes usually between that of a golf and tennis ball (4–7 cm). The term *cereus* in its Latin name *Stenocereus* refers to the wax-taper form of the plant (Anderson, 2001). The fruits of many species of the genus *Stenocereus* have been harvested in areas from the south to the north of Mexico (Pimienta-Barrios and Nobel, 1994). The peculiar contrast of pitaya thorn-scrub alongside large-scale agriculture leads us to hypothesize the former presence of widespread ancestral stands of *S. thurberi* thornscrub on what are now large agricultural plots. The current patches of *S. thurberi* seem to be remnants of this larger matrix. It seems interesting to analyze the benefit and complementarity of both food production systems.

In this study, we calculate the rate of land-use change in the ancestral territory of the Yoreme people and examine possible social reasons as to why the change may have occurred, what uses these lands are turning into, and what potential botanical resources and uses are being lost. We hypothesize that *S. thurberi* supports Yoreme heritage and sustenance amidst anthropogenic changes to the landscape. The landscape changes affecting indigenous peoples around the world provide strong rationale for investigating hypotheses along these lines (United Nations, 2009). With these changes come changes in species available to cultures and many times these are vital for the stability of continued cultural practices (Garibaldi and Turner, 2004). This study seeks to address this all too common happening around the globe to gain a glimpse of cultural resilience, supported by local flora, amidst outside pressures.

3.4 Study Location

The Yoreme people settled along the banks of three main rivers, the Mayo, the Fuerte, and the Sinaloa ca. 1800 yBP, during the Mesoamerican Formative period (Berry and Doyon, 2001; Fig. 3.1). Their settlements took the form of scattered hamlets known as *rancherías* that depended on mixed hunter-gatherer and farming practices (Phillips, 1989). Currently, the Yoreme still inhabit the area, which is now known for agricultural production from networks of irrigation canals (Banister, 2011). Work is largely seasonal depending on harvest times in the fields and fishing seasons along the coast. Correspondingly, there are large gaps in conventional types of jobs. As a result, many people fill one of these gaps in May with the harvest of wild pitaya fruits. To the people of the *pitayal*, the birdsong of the *pipiski* or red cardinal (*Cardinalis cardinalis*; Russell and Monson, 1998) signifies the start of the pitaya harvest (Consultant interview, pers. comm., January 26, 2015). These spiny fruits, botanically berries, are plucked off the tall columns with a long rod, often fashioned from an agave (*Agave* ssp.) scape, and collected into twenty-liter buckets. The yield depends on the weather conditions and pollination from bats (*Leptonycteris curasoae*), hummingbirds (*Cynanthus latirostris* and *Calypte costae*), and insects (Sahley, 2001). The fruits' sweetness is highly dependent on rain. If there are a few heavy rains just before harvest, the fruits are less sweet than if there was no or little rain (Consultant interview, pers. comm., January 26, 2015).

The pitaya-dominated thornscrub lies in the heart of the ancestral land of the Yoreme (See the distribution map of Figure 3.2). This site offers an ideal study area because of the visual prominence in the advancement of land development and the dependence local people have on seasonal work from *S. thurberi.* Seasonal rainfall in the area ranges from 200–400 mm with the heaviest rains in late summer around the month of August. Elevation from the coast slowly increases to about 100 m at the base of the Sierra Madre Occidental mountain range near the state line and then shoots to over 2000 m once inside the states of Chihuahua and Durango. Average annual temperatures range between 22–26°C with summer highs often in the mid 40s and winter lows sometimes reaching a frost (INEGI, 2005a). With this low rainfall and high temperatures, farm crops must be heavily irrigated. The diversion of water around Sonora has been a major cause of contention historically and in recent years (Meyer, 1996; Banister, 2011; Radonic, 2015). Interestingly, yields of *S. thurberi* are independent of irrigation, and rely on seasonal rains.

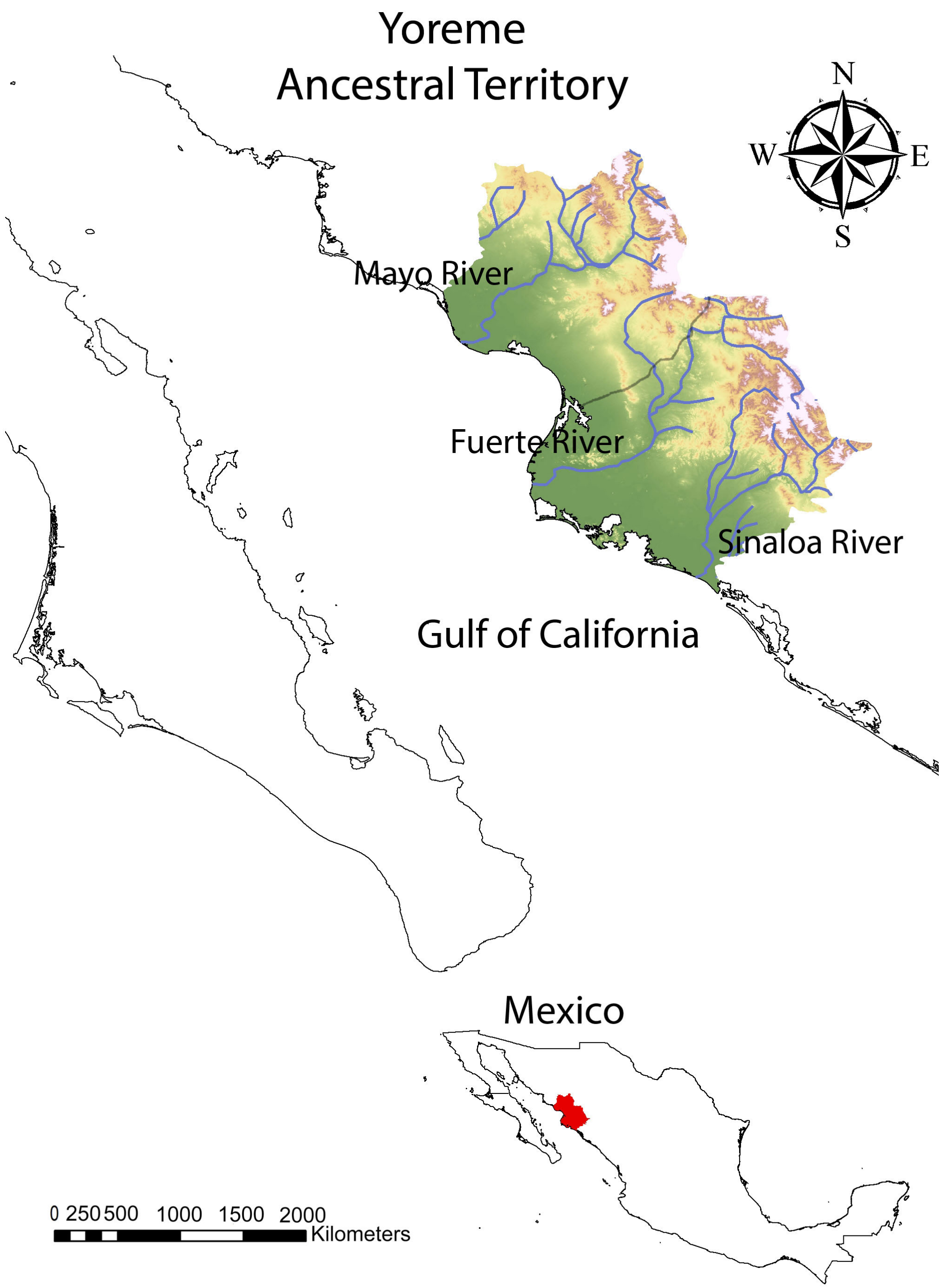


Figure 3.1: Yoreme ancestral territory estimated from current municipalities with Yoreme villages (Amarillas Valenzuela, 2010; CDI, 2010a)

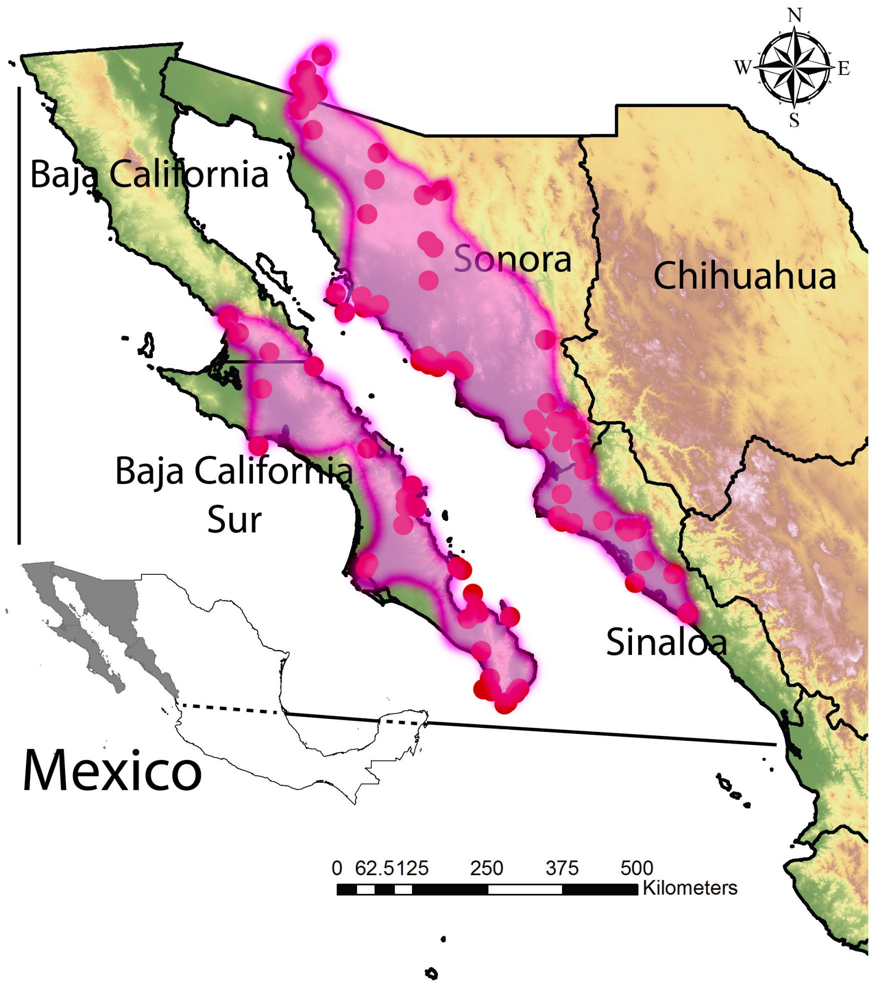


Figure 3.2: Distribution of *S. thurberi*. The distribution follows low elevations around the coast of the Gulf of California and across the Sonoran Desert up into southern Arizona. Each point is a collection record taken from the GBIF Database (GBIF, 2015)

3.5 Materials and Methods

3.5.1 Interviews

Community members were interviewed about harvest, sale, and processing of *S. thurberi* fruits. Consultants for interviews were identified via the snowball method. For this, consultants could recommend others who were knowledgeable about pitaya and could potentially participate in interviews. This data was collected on field trips to southern Sonora and northern Sinaloa between January 7–31, 2015; May 10 – August 28, 2015; and January 28 – March 10, 2016 in Juchica and Sirebampo, Sonora. Seven adult consultants with three from Juchica and four from Sirebampo (four women and three men) were interviewed about land-use and sale of pitaya. Interviews took the form of one-on-one conversations while the investigator wrote notes in a field book. All interviews were conducted in Spanish with prior-informed consent and with pre-approval from the University of California, Riverside, Institutional Review Board (HS-14-103, HS-13-036) and followed the International Society of Ethnobiology Code of Ethics (International Society of Ethnobiology, 2006).

3.5.2 Vegetation Surveys

Vegetation surveys of the pitaya-dominated thornscrub were conducted using the vegetation cover survey method of Martin et al. (1997). This method is designed to measure vegetation in and around sites selected for nesting or other uses. We sought to measure the vegetation cover of *S. thurberi* at frequently used points of harvest identified by local consultants. This method measures vegetation cover at selected sites by sampling a central plot and three peripheral plots 50 meters away from the central plot and separated by 120°from each other. The angle of the first peripheral plot was randomly chosen by dropping either a spinning arrow or pencil on the ground to randomly assign the direction of the plot. Each survey plot was 11.3 m radius around its central point, corresponding to 401.1 m^2 (approximately one tenth of an acre). All individual plants of *S. thurberi* were counted within each plot and categorized as mature (over head height and with multiple branches), intermediate (greater than one meter), or immature (less than one meter). In each of three actively harvested sites, we marked four circular survey plots as described above. In addition to counting plants in harvested areas, we also repeated the procedure at three randomly-selected sites to compare species density in sites selected by traditional harvesters compared to randomly-selected sites. Randomly-selected sites were assigned by generating a random assortment of longitude and latitude coordinate pairs. All pairs that landed inside the pitaya thicket near Sirebampo, Sonora (N 26° 38' 24.37", W 109° 14' 13.14") were included while those that landed outside, on a zone such as a road or waterway, were not surveyed. All herbarium specimens collected during vegetation surveys were collected under the appropriate collections permit (SEMARNAT, permit number FAUT-0265) and deposited in the University of Sonora Herbarium (USON24030 and USON24031).

Because plant density is a frequency count, we tested the difference between harvest sites and randomly-selected sites by means of a χ^2 test using a log-linear model with the number of plants at each plot as dependent variables and harvest type (harvested vs. randomly-selected) as predictor. The analysis was done using the R programing language for statistical computing (R Core Team, 2013).

3.5.3 Land-use Analysis

Land classification data was downloaded as digital vector files from the website of Mexico's National Institute of Statistics and Geography (*Instituto Nacional de Estadística, Geografía, e Informática*—INEGI) at www.inegi.org.mx. Data came in the form of shape files (*.shp) at a scale of 1:1 000 000 and 1:250 000 for the years of 1996 and 2011 respectively. The land classifications were categorized into natural or induced land cover where the "natural" category included all areas with native vegetation and without farming, mining, or urbanization; while the "induced" category included all areas where the native vegetation cover has been lost such as farms, mines, or urban sites. The shape files were projected into ESRI World Cylindrical Equal Area projection, intersected with Mexican municipal boundaries, and the area of each polygon was calculated to determine the area of land-use change. The resulting areas were used to calculate the percent of land-use change using the rate equation $Rate = \frac{1}{A} \times \frac{\mathrm{d}A}{\mathrm{d}t}$, which can be approximated as a finite difference equation $Rate = \ln(A_1/A_0)/(t_1 - t_0)$. Further, predictive maps of land-cover trajectories were created based on the 2011 land cover and the land conversion rates over the past 15 years. The analysis was done using ArcGIS software (ESRI, Redlands, California, U.S.A.) and Microsoft Excel (Seattle, Washington, U.S.A.) for map algebra operations. The full protocol is available as supplemental material (Appendix C).

3.6 Results

3.6.1 *Stenocereus thurberi* Uses

To determine the potential role of *S. thurberi* in being a part of Yoreme life, culture, and sustenance, we examined the current harvest practices and uses of the fruit. The most apparent use is direct sale at local markets. People harvest fruit into twenty-liter buckets, carry them to the nearest highway, and transport them by bus to larger town centers such as Navojoa and Etchojoa. We further examined local value-added marketing strategies and the current value-added products made from this fruit. We present a list of products in Table 3.1 and representative photographs in Figure 3.3. Historically, winemaking with pitaya was common with local Yoreme and other tribes such as the Comcáac (Seri), but the practice has been diminishing since the latter part of the twentieth century (Felger and Moser, 1985; Yetman and Van Devender, 2002), and it was not mentioned during our fieldwork.

3.6.2 *Stenocereus thurberi* Density

Because the pitaya harvest sites must be selected by the harvester, vegetation surveys were conducted to measure the density of *S. thurberi*. The mean density in human-selected harvest sites was 450.8 ($SE \pm 41.7$) plants per hectare and the density in randomly-selected sites (as described in the materials and methods) was 652.3 ± 75.7 plants per hectare (Fig. 3.4). The number of mature plants in harvest sites (280.4 ± 33.0) was lower than the number of mature plants in randomly-selected sites (423.8 ± 64.8), and the difference was highly significant ($\chi^2 = 14.1, d.f. 1, P < 0.0001$). The same trend was maintained in intermediate and immature plants (81.0 ± 20.0

Table 3.1: Pitaya uses for food and value-added products. Prices are given in value of 2016 Mexican pesos with the US dollar equivalent given in parenthesis and rounded to the nearest ten-cent unit. Some local vernacular of the region includes the popular *coyota*, which is a thin, round, fruit-filled pastry with a flaky crust. *Empanadas* are also a fruit-filled pastry, but with a thicker filling. Pitaya water is made by mashing fruit in a pitcher of water, and as the pulp settles the sugars and flavors dissolve to create a refreshing drink. Pitaya paste is the precursor ingredient for many items on the table including fillings and also dried fruit rolls and dehydrated pitaya. The fruit rolls are individual servings, while the dehydrated pitaya is sold by the gram in larger quantities

Product	Maximum Price (MXN)	Minimum Price (MXN)	Unit Size
Coyotas	15 (90¢)	10 (60¢)	2 pastries
Marmalade	200 ($12.00)	100 ($6.00)	$\sim$ 400 ml
Candied fruit with chile	10 (60¢)	5 (30¢)	1 piece
Pitaya water	5 (30¢)	5 (30¢)	$\sim$ 200 ml
Dried fruit rolls	30 ($1.80)	20 ($1.20)	15 $\times$ 25 cm
Dehydrated pitaya	400 ($24.00)	400 ($24.00)	100 gram
Pitaya sorbet	5	5	1 scoop
Empanadas	5	5	1 pastry
Nursery stock	20	20	1 starter plant
Milk shake	Not sold		
Pitaya with cream	Not sold		
Yogurt	Not sold		
Paste	Not sold		
Firewood	Not sold		
Roof and wall paneling	Not sold		

Figure 3.3: The usefulness of *S. thurberi* can be seen in its versatility. Photos show the species' use in value-added, marketed products. A) Nursery stock of young *S. thurberi* for sale. B, C) Coyotas made with *S. thurberi* fruit pulp. D) Brick oven fired with *S. thurberi* firewood to bake pitaya coyotas. E) Kitchen constructed with roofing and walling of *S. thurberi*

Table 3.2: Land conversion rates of municipalities in the distribution range of *S. thurberi*. These municipalities lie in and around the Yoreme ancestral territory

State	Municipality	Undeveloped Land Loss Rate (% Loss per year)
Sonora	Quiriego	1.93
Sonora	Cajeme	1.74
Sonora	Etchojoa	1.32
Sonora	Navojoa	1.31
Sinaloa	Guasave	2.61
Sinaloa	Angostura	1.73
Sinaloa	Culiacán	1.61
Sinaloa	Ahome	1.45
Sinaloa	Salvador Alvarado	1.38

and 89.3 ± 39.6 in harvest sites vs. 118.4 ± 21.9 and 110.1 ± 11.0 in randomly-selected sites), but the differences were non-significant.

3.6.3 Land-use Change

In the 15-year period studied (1996–2011), the conversion of land from wild areas to developed agriculture or urban areas considered in our study had the highest rate in the area of the pitaya-dominated thornscrub (Fig. 3.5 and 3.6). The rate of wildland loss reached over two and a half percent per year (Table 3.2 and Appendix D).

3.6.4 Land-use Change Purposes

We asked local consultants for what purposes land clearing was occurring. The responses varied over a range of uses including seeding of invasive buffel grass (*Cenchrus ciliaris* L. [= *Pennisetum ciliare* (L.) Link]), dryland agriculture, development subdivisions, aquaculture, and clearing for irrigated agriculture (Table 3.3). With the exception of irrigated agriculture and land subdivision, all other induced land uses were abandoned. These developments are driven largely by non-Yoreme investors

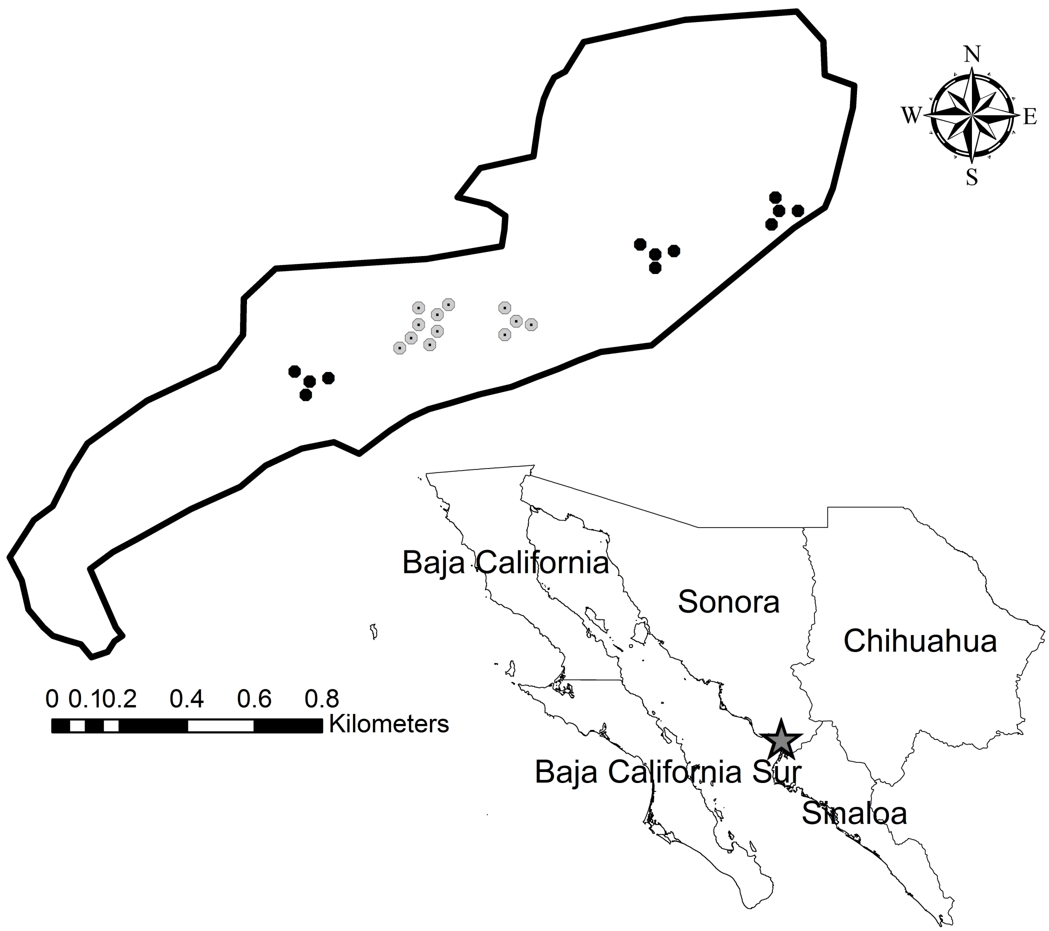


Figure 3.4: This map shows vegetation survey plots of *S. thurberi* in human-selected sites (gray) and randomly selected sites (black). Boundary shows the main expanse of *S. thurberi* north of Sirebampo, Sonora

Figure 3.5: Constrasting land uses become apparent when one observes fields side by side. Just outside Agiabampo, Sonora, (near the border with Sinaloa) grain fields and stands of *S. thurberi* meet. A) Stands of *S. thurberi* B, C) Contrasting lines between fields of *S. thurberi* and grain fields

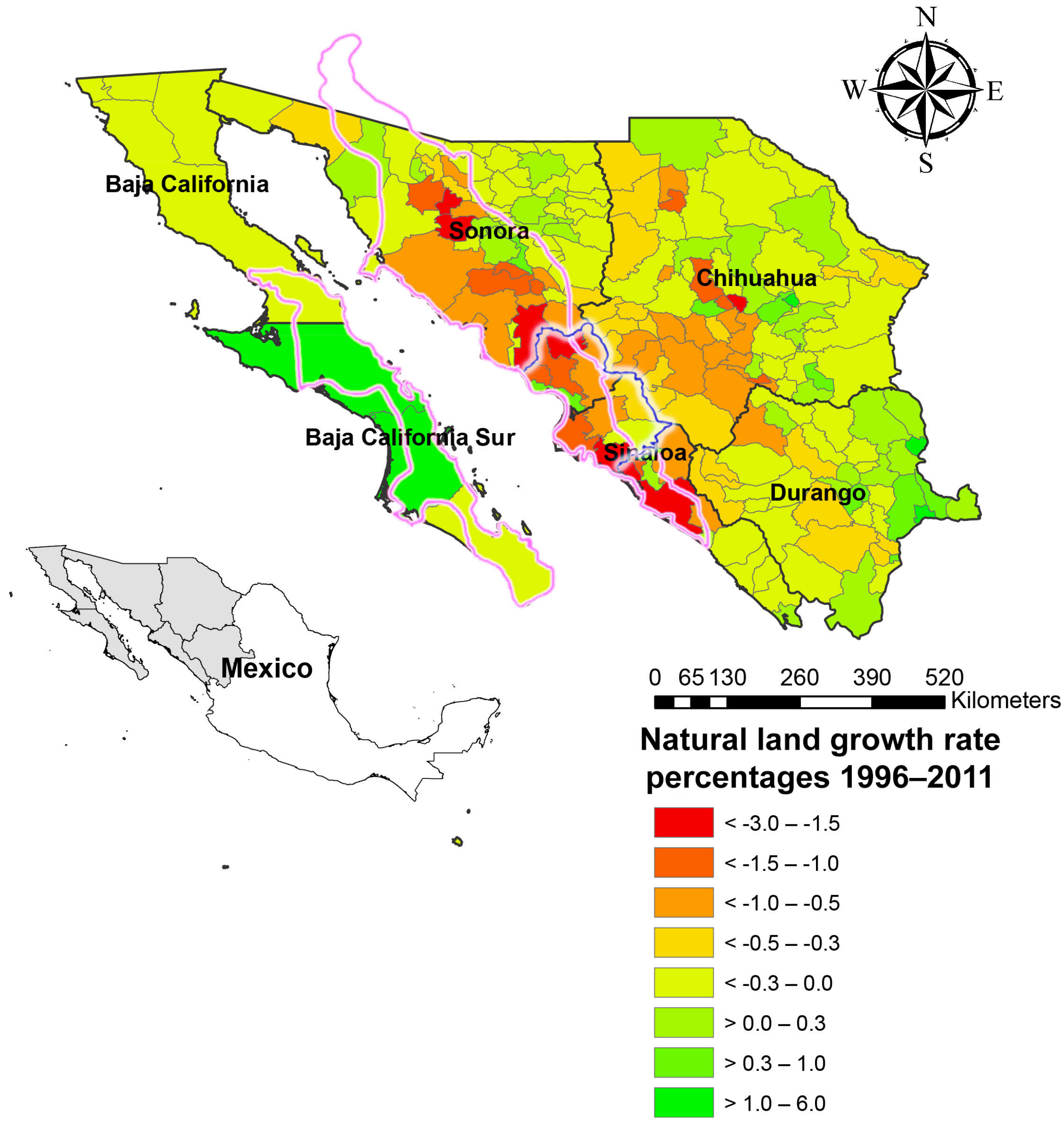


Figure 3.6: Many of the highest land conversion rates in northwestern Mexico are occurring in the ancestral land of the Yoreme and the habitat for the pitaya forest. The radiant blue outline shows the ancestral Yoreme territory and the pink outline shows the distribution of *S. thurberi* as per GBIF database records

such as regional realtors or industrial farm developers. The investments may or may not have paid during the term of their use, but it is sure that the recovery of *S. thurberi* stands, if it ever occurs, will take many decades.

Table 3.3: Land conversion purposes

Use	Status	Note
Community pasture	Abandoned	Overgrazed non-native grass
Chiltepín (*Capsicum annuum* var. *glabriusculum*) plantation	Never completed	No secondary pitaya growth
Dryland garbanzo	Abandoned	Construction of road blocked drain water
Vacation lots	Under construction	No cacti left on lots
Shrimp aquaculture	Abandoned	Chose least ecological impact area
Irrigated agriculture	Active wheat crops	Production with irrigation

3.6.5 Future Projections

In order to gain perspective of human conversion of land, we projected current land-use change rates into the years 2030 and 2050, showing the future trajectory of natural lands given the rate of land conversion over the last 15 years. These projections along with the 2011 percent cover of natural lands are displayed in Figure 3.7.

3.7 Discussion

Stenocereus thurberi supports the function of the thornscrub of the Yoreme ancestral territory as productive land. In the present study, we examined the interaction of people, *S. thurberi*, and land-use choices. This study offers three findings. (1) Land conversion of the pitaya-dominated thornscrub into other, induced and often non-renewable, land uses is occurring at a much higher rate than in other ecosystems of the region. (2) Local producers preserve and adapt traditions making value-added products from the native pitaya. (3) *S. thurberi* supports Yoreme heritage and provides economic benefits to traditional community members.

Interestingly, *S. thurberi* density in human-selected sites was lower than in randomly-selected sites, suggesting that site selection is influenced by factors other than density of the resource, such as accessibility, quality of the fruit, or cultural traditions. Although harvested sites have similar recruitment as randomly-selected sites (indicated by the non-significant differences in immature and intermediate plants) traditional harvesters seem to actively search for more open sites within the thornscrub, with less dense formations of mature pitayas, possibly because these sites allow for easier movement during harvest operations. In any case and at a larger scale, pitaya patches are dwindling rapidly in all areas. If habitat shrinking continues at the current rate,

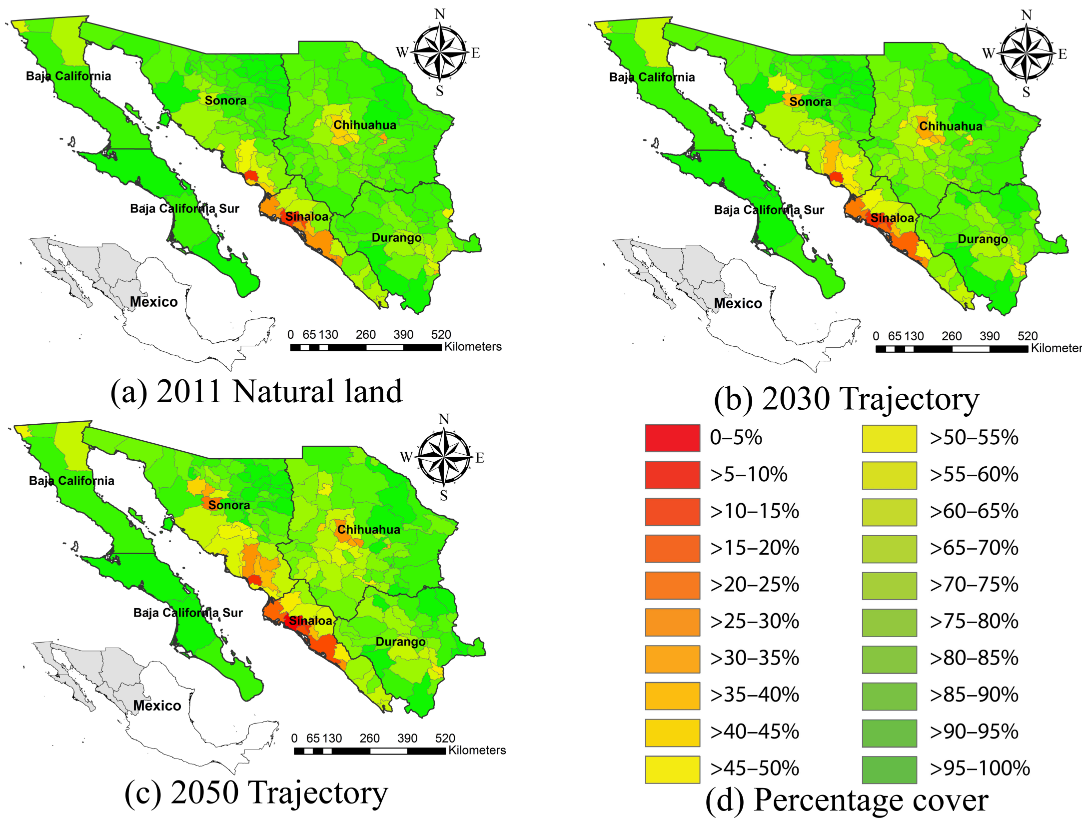


Figure 3.7: Maps display the percent cover of natural lands per municipal area. The 2011 map displays the most up-to-date data on land cover, while the 2030 and 2050 show the projection of land cover trajectories based on land conversion rates for the last 15 years

it is likely that both livelihoods and continued cultural practices will suffer. The loss of habitat signifies a loss in ecosystem services (Romanelli et al., 2015). Unfortunately, the growth of columnar cacti such as *S. thurberi* progresses at a slow rate with a long regeneration time (Drezner and Lazarus, 2008). This slow regeneration time is hindered even more by rangelands being seeded with invasive grasses such as *Cenchrus ciliaris* (Van Devender, Felger, and Búrquez, 1997; Búrquez and Martínez-Yrízar, 2000). Even if cacti are spared during creation of rangelands, they have been shown to be driven to local extirpation as was the case with the columnar etcho cactus (*Pachycereus pecten-aboriginum* (Engelm. ex S.Watson) Britton & Rose) in sites north of our study area (Morales-Romero et al., 2012). This creates a troubling scenario where local cattle producers feel the need to create "productive" rangeland in a way that hinders the productivity of local vegetation. It is a complex interaction with no clear solution (Vasquez-León and Liverman, 2004).

The main causes of land-use change can be understood in the context of Mexico's shifting land ownership policies. The most notable of these was the establishment of the *ejido* or communal-land system established by President Lázaro Cárdenas (1934–1940). This system allowed farmers to use and manage land that could never legally be bought, sold, or leased. President Carlos Salinas de Gortari (1988–1994) modified the system to allow individual ejido members to sell their land, bringing a long wave of parcels changing ownership that opens the door for new investors with ideas on some new land use. Along with these changes, such as increased fencing, come impediments of access to resources that are still under communal ownership. This seems to be increasing the economic troubles of farmers and ranchers as opposed to helping them (Yetman, 2000). With private investment and decreased overall economic ability, it is attractive for remaining ejido members to take advantage of anything that may provide a source of income. This, along with an increasing cattle market in Mexico

(Peel, Mathews Jr, and Johnson, 2012; FIRA, 2015), can be a large motivator driving land clearing for pasture, *chiltepín* plantations, or sale of land to developers and vacationers. As a result, larger investors currently accumulate parcels in the hopes of developing large tracts of land and, in this competitive environment, local producers of pitaya products take advantage of low-input and sustainable fruit production to the benefit of their family income and environment.

Unfortunately, the ideals of short-term profit often clash with the vision of long-term conservation. This, combined with the scarcity and cost of irrigation water in the area, gives a meager outlook for land clearing endeavors. Further, induced ecosystems such as non-native grasslands can prove very profitable one year and fail completely the next, or catch fire during drought, potentially leading to more native habitat loss. All the while, native thornscrub can survive and even maintain some productivity during dry years.

The productivity of *S. thurberi* takes many forms. The most predominant products in our study were value-added products from the fruit. Some studies have found that profits from harvest of wild plant products can be a highly volatile proposition (Arnold and Ruiz Pérez, 1998), but others demonstrate that this challenging industry has potential to give good profit margins (Belcher and Schreckenberg, 2007; Tugume et al., 2016). Perhaps the most assuring observation on local harvesters is not the promise of income, but that wild plant products provide a valuable safety net of food and basic necessities for economically disadvantaged families (Shackleton and Shackleton, 2004). In and around the pitayal, families can taste and sell the sweet fruits of their labor without the need for high-cost inputs such as irrigation, pesticides and herbicides, tillage (expensive for annual crops such as wheat), and bank financing (usually not available to the Yoreme). It is, without a doubt, an extremely low input crop (Mizrahi, Nerd, and Nobel, 1997) that local villagers can and do benefit from.

Local villagers have been picking pitaya from time immemorial, but this is not to say that their traditions continue unchanged. Almost a century ago, Ralph L. Beals (1932) described shifts and changes in Yoreme culture. Later research showed preservation and evolution of Yoreme traditions (Valenzuela, 1992). Our results suggest that culinary practices with pitaya fruits are adapted to current market demands. Further, these may lead to economically significant products available only if current cactus stands are preserved.

Taken together, we propose that stands of pitaya-rich thornscrub play a valuable role in Yoreme culture, heritage, and economics. Further, destruction of this valuable monetary and cultural resource shows little to gain compared to the benefit it currently, and potentially, produces for local citizens and the region as a whole.

Chapter 4

Keeping it in the Family: Phylogeny and Traditional Knowledge Guide Mechanistic Studies on the Anti-diabetic Effects of ***Ibervillea sonorae***

4.1 Keywords

Cucurbitaceae, Phylogeny, *Ibervillea sonorae*, Diabetes, Mexico, Sonora, α-glucosidase, Insulin

4.2 Abstract

Members of the squash family (Cucurbitaceae) are distributed world wide and are often employed as diabetes remedies. Here we examine anti-diabetic reports in the context of the Cucurbitaceae phylogeny as a guide to our studies of anti-diabetic

species of Mexico. The surge of diabetes in Mexico and in people of ancestry from the Americas is particularly widespread. In this same scenario, traditional and herbal medicine use by Mexicans is particularly strong. Here, the caudex of *Ibervillea sonorae* (S. Watson) Greene, Cucurbitaceae, has risen to prominence as a supplement with hypoglycemic properties. In this study, we examine the hypothesis that the phylogeny of Cucurbitaceae may reveal gaps in knowledge of how this family may and could be used as a remedy for diabetes. Given *I. sonorae*'s widespread and ancestral use, empirical and traditional knowledge and practices may guide further studies on this popular herbal medicine of Mexico. We began by sampling the literature and measuring the frequency of anti-diabetic reports in the family Cucurbitaceae. These were compared using Pearson's χ^2 test. In addition, local healers and herbal shopkeepers were interviewed regarding the treatment of diabetes with *I. sonorae*. We used colorimetric α-glucosidase activity assays, enzyme-linked immunosorbant assays (ELISA), and reverse transcription qPCR to investigate potential medicinal mechanisms. The overlay of anti-diabetic reports and cucurbit phylogeny revealed even distribution of reports throughout the family, yet uneven research emphasis with studies largely focusing on the tribe Momordiceae. Healer and shopkeeper interviews revealed a prescription similar to one for the α-glucosidase inhibitor, acarbose. Subsequent inhibition studies revealed dose dependent and competitive inhibition of α-glucosidase by aqueous *I. sonorae* extract. Further, aqueous extract stimulated insulin secretion from RIN-m5F pancreatic β cells. Taken together, these results display the potential of phylogeny in providing context and guidance for ethnopharmacological studies within a plant family. In addition, understanding the inhibition type of this popular supplement (*I. sonorae*) in α-glucosidase inhibition and stimulation of insulin secretion from β cells supports patient care by aiding physicians to avoid potential contraindications and also shows the value of continued pharmacological studies on this plant family.

4.3 Introduction

Members of the squash family (Cucurbitaceae) are distributed world-wide and often provide food and medicine (Rahman et al., 2008; Tripathy, Kumar, and Jena, 2014; EOL, 2017; GBIF.org, 2017). These are gathered from the wild or cultivated, and various plant parts are employed for use. Notwithstanding its broad use around the globe, one must not take the use of members in this family lightly. While sometimes mentioned in antiquity as related to the divine (Part I—The birth of the deities, *The Kojiki*) or a symbol of happiness and success (JMF, 2017), warnings of unfamiliar species as a path to death in a pot of stew are just as attention grabbing (2 Kings 4:38–41, *Holy Bible*). In between this balance of glorious life and sorrowful death most consumers use common members of this family as food or in moderation as a medicinal remedy.

One of the principal ailments treated with cucurbits is diabetes (Dhiman et al., 2012). Diabetes does not have one root cause, and also does not have one treatment method (Bloomgarden, 2009; American Diabetes Association et al., 2016). It is a metabolic disease where for one of many possible reasons, blood glucose levels are too high. Many studies have demonstrated that various members of the Cucurbitaceae reduce blood glucose levels in mice, rats, rabbits, and even humans, suggesting some validation of ancestral and widespread use as an anti-diabetic remedy (Román-Ramos, Flores-Saenz, and Alarcón-Aguilar, 1995; Grover et al., 2001; Huyen et al., 2010; Salahuddin and Jalalpure, 2010).

Interestingly, hypoglycemic activity can be found in both hydrophilic and hydrophobic extracts. Moreover, when separated further, activity can be seen in saponins, fatty acids, terpenoids, extracts of polar and non-polar solvents, and juices (Raman and Lau, 1996; Alarcón-Aguilar, Hernández-Galicia, et al., 2002; Alarcón-Aguilar, Calzada-Bermejo, et al., 2005; Harinantenaina et al., 2006; Hernández-Galicia, Calzada, et al., 2007; Wu et al., 2007; Han, Hui, and Wang, 2008; Kumar et al., 2014). As if that were not enough, the mode of action seems to revolve around most physiological processes involving diabetes. Whether it be glycogen synthesis, glucose uptake, insulin production, or even inhibition of hydrolytic enzymes, this family seems to do it all (Rathi, Grover, and Vats, 2002; Fonseka et al., 2006; Keller et al., 2011; Zapata-Bustos et al., 2014).

Given the breadth of use and apparent broad scale effects, we place these in the context of the Cucurbitaceae phylogeny. It may be possible that the medicinal reports focus on one branch of the phylogenetic tree or that they are evenly distributed throughout. Further, traditional use and scientific studies may or may not be biased to one or more tribes within the family. We seek to identify gaps of knowledge within this plant family to open up new avenues for hypothesis generation as to how this family interacts with humans to treat and reduce the impact of diabetes. As part of this, we focus on diabetes remedies in Mexico.

4.3.1 Traditional Herbal Medicine and Diabetes in Mexico

Herbal medicine plays a major role in Mexican healing traditions (Smith, 2003). Throughout Mexico this traditional culture of medicine is strong with a high demand from people seeking natural remedies (Euromonitor International, 2014). Herbal remedies used in these traditions are made available to the general population at local markets where herbalists prescribe treatments and dosages to customers (Towell and León, 2010).

A major disease for which patients in Mexico seek traditional treatments is diabetes. The frequency of diabetes cases is currently increasing worldwide (King, Aubert, and Herman, 1998; WHO, 2014) and this trend is surging in Mexico (Phillips and Salmerón, 1992; Meza et al., 2015), where multiple and complex factors contribute to this upswing. Mexicans and Mexican Americans with ancestry from the Americas show higher rates of diabetes than those from European descent (Florez et al., 2009; American Diabetes Association, 2014; Hu et al., 2015). Moreover, there is evidence that inheritance of "thrifty genes", which are beneficial during food scarcity, from the Americas can be a factor related to diabetes risk (Neel, 1962; Diamond, 2003). In addition to ancestry, lifestyle factors play a large role in diabetes likelihood (Martorell, 2005; Florez et al., 2009; Haddad et al., 2012). While the physiological effects of diabetes have their own negative consequences, secondary economic effects ripple out. For example, Mexicans with diabetes, especially men and the poor, show reduced chances of employment (Seuring, Goryakin, and Suhrcke, 2015). These risks and difficulties seem to spur individuals to seek herbal medicine in search of relief within their cultural framework. The draw to herbal medicine is deeply rooted in Mexico, so much so that 90% of the population uses medicinal plants (Taddei-Bringas et al., 1999). In another study, 91% of Hispanic women in the southwestern U.S. used herbal remedies in addition to conventional treatment. Many of these were for treatment of diabetes (Johnson, Strich, et al., 2006). Further studies report that these, however, are often taken without consulting their primary care physician to inquire about possible interactions (Poss, Jezewski, and Stuart, 2003).

Although herbal preparations are often complex, one species in particular is very commonly used in herbal treatments for diabetes and has recently soared in popularity (Martínez-Castañeda, Ramírez-Sotelo, and Piña-Guzmán, 2011). *Wereke*, often spelled *guareke* or *guaregüi*, is the dried powder of the caudex (enlarged perennial stem tissue) of *Ibervillea sonorae* (S. Watson) Greene (Fig. 4.1), a plant from the Cucurbitaceae that is sold throughout Mexico and the southwestern U.S. Patients with diabetes in Sonora report self-treatment (Saucedo-Tamayo et al., 2006) as do patients in the southwestern U.S. (Johnson, Strich, et al., 2006). We have personally seen this remedy sold throughout Mexico in the form of both preparations and bulk plant material. It is marketed in Sonora along the highway to semi-truck drivers and travelers; it is sold in municipal markets; packaged neatly, it is also sold in affluent alternative medicine shops. *Ibervillea sonorae* has served as a remedy for many years and still serves the native populations of the Sonoran desert region. An early, if not the first, written record of this species was composed by the Jesuit missionary named Ignaz Pfefferkorn. He reported that the guareke "tree" when dried and ground is quite effective at healing wounds without causing additional pain (Pfefferkorn, 1794). The taxon attracted the attention of taxonomists from early on. The genus was initially named *Maximowiczia* (Cogniaux, 1881), but was later changed to *Ibervillea* for reasons of taxonomic priority (Ruprecht and Maximowicz, 1857; Greene, 1895).

4.3.2 Diabetes Models

The use of *I. sonorae* for diabetes has been well documented in ethnobotanical surveys (Yetman and Van Devender, 2002) and subsequently studied in the hopes of finding a treatment for this looming public health concern in Mexico. Both aqueous and dichloromethane extracts administered by intraperitoneal injection showed hypoglycemic effects in partially diabetic rats and mice (Alarcón-Aguilar, Calzada-Bermejo, et al., 2005), but not in fully diabetic alloxane treated mice (Alarcón-Aguilar, Campos-Sepúlveda, et al., 2002). These studies suggested that the effects of *I. sonorae* are dependent on some basal insulin concentration. In another study, intraperitoneal injection of dichloromethane extracted *I. sonorae* showed an increase in serum insulin concentration in rats, although the pattern was not signif-

Figure 4.1: Photograph of *Ibervillea sonorae* (S. Watson) Greene in its habitat. Vines climb adjacent structures of neighboring plants to set fruit seemingly as high as possible

icant (Banderas-Dorantes, 2006). Further studies on the ATP-sensitive potassium channel (K_{ATP}) showed that *I. sonorae* extract blocks the K_{ATP} channel in rat aortic rings (Banderas-Dorantes et al., 2012). Together, these studies indicate that *I. sonorae* has hypoglycemic effects that may operate by blocking K_{ATP} channels through stimulating insulin production, although the stimulation of insulin secretion was not statistically significant.

In other experiments, *I. sonorae* modulated the maximal velocity (V_{max}) and Michaelis constant (K_M) of glucose transport in Bergmann glial cells (Hernández Díaz, 2011). Further studies showed stimulation of glucose uptake through a PI3K-independent mechanism in human adipocytes, but a PI3K-dependence in murine adipocytes (Zapata-Bustos et al., 2014). In contrast to studies on rats where basal insulin was needed for hypoglycemic effects, cells rendered insensitive to insulin by TNF-α treatment still showed stimulation of glucose uptake in the presence of *I. sonorae* (Zapata-Bustos et al., 2014). Validation studies showed hypoglycemic activity in streptozotocin-induced diabetic rats (Andrade-Cetto and Heinrich, 2005). Interestingly, one group found hypoglycemic activity with a monoglyceride fraction (Hernández-Galicia, 2007; Hernández-Galicia, Calzada, et al., 2007). *I. sonorae* also showed hypoglycemic effects on all parameters of Bermang's minimal model which indicates efficiency of response to glucose load (Sánchez-Velarde et al., 2015). It is yet to be shown whether *I. sonorae* shows medicinal activity along other diabetes-specific pathways. In addition to the demonstrated glucose uptake and the yet unclear insulin production, major additional pathways include α-glucosidase (EC 3.2.1.20) inhibition and glycogen storage. It has been suggested that α-glucosidase inhibition assays are a good target during a search for anti-diabetic properties from plants, possibly owing to α-glucosidase inhibitors' use in conventional medicine (Matsuura et al., 2004). Additional activity may include inhibition of glucose production from glycogen in the liver, modulation of adipogenesis, or changes in insulin sensitivity by anti-inflammatory properties, which may decrease inflammatory factors (Haddad et al., 2012). Out of many potential pathways, some strategies are to incorporate traditional knowledge of local elders (Haddad et al., 2012) and to use phylogeny (Saslis-Lagoudakis, Savolainen, et al., 2012) to guide mechanistic studies on anti-diabetic plants.

4.3.3 Hypothesis

We hypothesize that the phylogeny of Cucurbitaceae may reveal gaps in knowledge of how this family may and could be used as a remedy for diabetes. Further, we predict that species of under-reported branches will show similar modes of action as other branches. Given *I. sonorae*'s widespread and ancestral use, empirical and traditional knowledge and practices may guide further studies on this popular herbal medicine of Mexico. The merit in these studies lies in the ability of a solid phylogenetic framework to guide research. The context of medicinal properties in phylogeny is paramount for ethnobotanical comparisons and for guiding *in vitro* and *in vivo* animal studies. By comparing previous work and building upon known phylogeny, we can gain some insight into potential hypotheses and predictions on the use of species in this family used and valued around the world.

4.4 Materials and Methods

4.4.1 Diabetes Treatment Place in the Cucurbitaceae Phylogeny

We aimed to answer two questions. (1) Are all branches of the Cucurbitaceae phylogeny used for diabetes or only select segments? (2) Are research efforts evenly distributed among the phylogenetic branches? To answer these questions we began by sampling the literature and measuring the frequency of anti-diabetic reports in the family Cucurbitaceae. We queried the Web of Knowledge search engine (Clarivate Analytics, apps.webofknowledge.com) for "diabetes AND cucurbitaceae" on May 5, 2017. We set the parameters to search all available databases with an unrestricted year range. The criteria for inclusion was to include a scientific species name of a cucurbit, address or include analysis of a parameter related to diabetes (*in vitro* or *in vivo*), and be accessible for download. We assembled a database of species reports and corresponding taxonomic tribes. All plant names were updated to the most recent accepted name as per the International Plant Name Index (www.ipni.org) and The Plant List (www.theplantlist.org). We counted the number of species in each tribe and also the number of articles published with experiments using a species of each tribe. Given that the number of remedies and the number of articles reported for each tribe are frequency counts, we tested whether these two variables were proportional to the species richness in each tribe: i.e., the Cucurbitaceae phylogeny gives us the expected distribution. This concept was eloquently described in Karl Pearson's seminal article describing what we know now as the chi-squared test, where he states,

> The question we wish to determine is whether the sample may be reasonably considered to represent a random system of deviations from the theoretical frequency distribution of the general population, but *this distribution has to be inferred from the sample itself.* (Pearson, 1900, emphasis added)

We assessed our tables via a χ^2 test for goodness of fit to test whether the observed frequency distribution of anti-diabetic remedy use is proportionally higher in some tribes than in others, or if remedy use is simply proportional to the number of species in each tribe. We also did the same analysis on the frequency of articles published in each tribe. In frequency data, the errors should follow a Poisson distribution, where the mean is equal to the variance. Hence, the residuals of a χ^2 fit, known as Pearson residuals ($Pearson\ Residual = \frac{(Observed - Expected)}{\sqrt{Expected}}$), are really standardized residuals and should asymptotically follow a normal distribution, so that, if the overall χ^2 value is significant then each residual can be tested against the normal distribution (Upton, 1978). In order to keep the probability of type I error low, we used a Bonferroni correction for multiple comparisons with an overall significance threshold of $P = 0.05$.

4.4.2 Informant Interviews

During field work, two indigenous Yoreme healers and three herbal shopkeepers were interviewed in the Mayo Valley of Southern Sonora. Interviews were conducted at the healers' home or the shopkeepers' herbal shop, and informants participated on a voluntary basis with prior informed consent. All interviews were conducted in Spanish and focused on questions regarding traditional uses of *I. sonorae.* Responses were written down by the investigator. All interviews and surveys used in the present study were approved by the University of California Riverside Human Research Review Board (Protocol Number HS-14-103) and followed the International Society for Ethnobiology Code of Ethics for the facilitation of ethical conduct and equitable relationships (International Society of Ethnobiology, 2006).

4.4.3 *Ibervillea sonorae* Extract Preparation

Caudices of *Ibervillea sonorae* were collected in the Mayo Valley (N 27.125536, W 109.532605). In addition to wild-collected specimens, caudices were purchased in Southern Sonora at the Highway 15 toll-booth market (Estación Don, N 26.405980, W 109.015154) and the Ciudad Obregón municipal market (N 27.491265, W 109.933223). The appropriate collection permit was obtained from the Secretary of the Environment and Natural Resources (Semarnat, permit number FAUT-0265). These caudices were determined to be *Ibervillea sonorae* (S. Watson) Greene at the University of Sonora Herbarium where three voucher specimens were deposited (USON21412, USON21413, and USON23800). Nine caudices were then washed with water, peeled, dried at 37°C for 48 hours until brittle and milled into powder using an electric blender. Two-hundred and fifty grams of the powder was boiled in five liters of water for two hours with continuous stirring. This solution was cooled to 25°C and allowed to settle. The aqueous extract was decanted off the sediment and stored at −20°C overnight, thawed, then centrifuged at 11,000 g for 30 minutes. The supernatant was filtered in number four Watman filter paper (Watman, Maidstone, England) and then 0.45 μm nitrocellulose membrane filter (Millipore, Ireland). Filtered preparations were lyophilized.

4.4.4 α-Glucosidase Inhibition Studies

Inhibition studies followed a modified method originally described by John M. Walker (Walker, Winder, and Kellam, 1993; Watanabe et al., 1997). All preparations were done in phosphate-buffered saline solution of pH 7.4 with 2% bovine serum albumin at 25°C. Lyophilized aqueous *Ibervillea sonorae* extracts were dissolved at maximum solubility to 0.25 g/ml and half-logarithmic serial dilutions were prepared to 10^{-5}. Half-log dilutions of the positive control, acarbose (Sigma, St. Louis, U.S.A.), were also formulated. Type 1 α-glucosidase from baker's yeast (Sigma, St. Louis, U.S.A.) at a concentration of 0.5 IU/ml was prepared along with 5 mM 4-nitrophenyl α-D-glucopyranoside (Sigma, St. Louis, U.S.A.). Extracts, positive control (acarbose), and negative control (buffer) were preincubated 20 minutes before reacting with 4-nitrophenyl α-D-glucopyranoside for 15 minutes. Enzyme activity was inferred from the change in absorbance at 405 nm in a Beckman-Coulter DTX-880 multimode detector. To determine inhibition type, the experiment was repeated with differing concentrations of substrate. Absorbance readings were taken immediately upon reaction and taken continuously until well past the initial reaction rate phase. The enzyme kinetic parameters of maximal enzyme velocity (V_{max}) and the Michaelis constant (K_M) were calculated by curve fitting.

4.4.5 Cell Culture

The insulin-producing pancreatic β-cell line, RIN-m5f, was originally derived from *Rattus norvegicus* islets of Langerhans with radiation-induced insulinoma (Skelin, Rupnik, and Cencic, 2010). Rat insulinoma RIN-m5f cells (kindly provided by María del Carmen Escobar-Villanueva, Universidad Autónoma Metropolitana, México) were inoculated (1×10^4 cells/well) in 24-well plates (Corning Glass Works, New York, U.S.A.) into RPMI-1640 medium (Moore 1967; Gibco, now Thermofisher, Pittsburgh, U.S.A.) supplemented with 10% fetal bovine serum (FBS; HyClone, Logan, South Carolina, U.S.A.), 1 mM sodium pyruvate, 23.8 mM $NaCO_3$, and antibiotics (2000 IU/ml penicillin and 20 mg/ml streptomycin). Two days later, cells were re-fed with different concentrations of *Ibervillea sonorae* aqueous extract in RPMI medium. Cell viability was monitored for several days in culture by direct cell counting by hemocytometer. Counts showed that concentrations ranging from 1 μg/ml to 10 μg/ml did not affect cell counts. Cell cultures in RPMI-1640 medium were maintained at 37°C in a humidified 5% CO_2 atmosphere with changes of medium every other day.

4.4.6 Insulin Secretion Studies

Confluent RIN-m5F cells were treated with 0, 1, and 10 μg/ml of *Ibervillea sonorae* aqueous extract for 30 minutes and then the surrounding culture media were recovered and analyzed by enzyme-linked immunosorbant assay (ELISA) for detection of insulin (Vogel, 2008). The remaining cells were prepared for reverse transcription qPCR (Vogel, 2008). Insulin secretion was measured using the sandwich technique, two site enzyme immunoassay of the Mercodia Rat Insulin ELISA kit 10-1250-01 (Mercodia, Uppsala, Sweden). ELISA experimentation followed the kit protocol for standard ELISA procedures. A standard curve was produced with known insulin concentrations and fit to an exponential model in the R programming language (R Core Team, 2015). All insulin ranges were within the standard curve.

4.4.7 Reverse Transcription Quantitative PCR of Insulin mRNA

To assess whether treatment with *Ibervillea sonorae* extract stimulated expression of insulin in the insulin-secreting RIN-m5f cells, the expression levels of the two rat insulin genes Ins1 and Ins2 were measured. Total RNA was extracted from cells after two-hour exposure to *I. sonorae* extract concentrations of 0, 1, and 10 μg/ml using the TRIzol® reagent (Invitrogen, U.S.A.) according to the manufacturer's instructions. cDNA was synthesized using 1 μg of total RNA isolated from the samples, random primers (0.5 μg), M-MLV buffer (ThermoFisher, U.S.A.), dNTP'S 0.5 mM, M-MLV RT buffer (ThermoFisher, USA) 200 U/μL, and H_2O. After PCR amplification, qPCR was carried out with primers for Ins1: CAC AAA GGT GCT GTT TGA CAA, GTG ACC AGC TAC AAT CAT AGA CC, (Rn.PT.58.44697661.gs); Ins2: GCC AAG GTC TGA AGG TCA C, AGC GTG GAT TCT TCT ACA CAC (Rn.PT.58.45043780.g); and Actb: CTC ATC GTA CTC CTG CTT GC, CCT

AGC ACC ATG AAG ATC AAG A (Rn.PT.58.9220704.g) with 5'FAM/ZEN/3'IBFQ probes (PrimeTime® qPCR Assay; IDT Technologies, Iowa, U.S.A.) using the LightCycler rapid thermal cycler system. Reactions were performed in 10 μL reaction volume containing 5 μL of PrimeTime® gene expression reverse transcriptase mastermix, 1 μL PrimeTime® Assay 10×, H_2O, and 100 ng of cDNA. All protocols included a 5 minute denaturation step and then continued for 45 cycles consisting of a 95°C denaturation for 10 seconds, annealing for 30 seconds at 58°C, and an extension for 30 seconds at 72°C. The mRNA expression was assessed with the $2^{-\Delta\Delta C_T}$ method (Schmittgen and Livak, 2008). The $2^{-\Delta C_T}$ values were calculated in every sample for each gene of interest as follows: $2^{-\Delta C_T} = (C_{T\ gene\ of\ interest} - C_{T\ reference\ gene})$, with β-actin as the reference gene. Relative changes in the expression level of one specific gene ($\Delta\Delta C_T$) were calculated as ΔC_T of the test group minus ΔC_T of the control group and then presented as $2^{-\Delta\Delta C_T}$.

4.4.8 Statistical Analysis

Dose-response data were recorded as change in 405 nm light absorbance, and the inhibitory effect of the extract at each concentration was expressed as a percentage value relative to the negative control. Percent inhibition showed a well-defined sigmoidal curve when plotted against the dilution of the inhibitor on a logarithmic scale. To fit this trend, we used a logistic function of the type:

$$y = b + \frac{(100 - b)}{1 + e^{(-r(x - x_{50})}} \quad , \tag{4.1}$$

where y is the relative activity of α-glucosidase enzyme (as a percentage of the control), b is the activity at full concentration of the inhibitor (efficacy), x is the log-dilution, x_{50} is the dilution at which inhibition reaches 50% of its maximum effect (the inflection point of the curve or IC_{50}), and r is a rate parameter describing the sensitivity of the inhibition to growing concentrations of the inhibitor. The value of these parameters and their standard errors were estimated using the nonlinear least squares function of the nlstools package in the R programming language (Baty et al., 2015; R Core Team, 2015).

For the analysis of enzyme inhibition, we calculated the change in absorbance at 405 nm of α-glucosidase reacting with the colorimetric glucose analog, 4-Nitrophenyl α-D-glucopyranoside, as an indicator of enzyme activity. Our data analysis design was planned to test whether our *I. sonorae* extract inhibits by competitive, noncompetitive, or mixed inhibition. We first determined the initial velocity of the enzymatic reaction for different concentrations of substrate and inhibitor by fitting, for each combination of substrate and inhibitor, a product-versus-time power function of the type $p = kt^z$. The rate of product formation is $\frac{\mathrm{d}p}{\mathrm{d}t} = kzt^{z-1}$, which at $t = 1$ second is simply $k \times z$. Thus, for each curve we estimated the initial velocity as $V = kz$. The parameters were estimated from a simple linear regression using the log-log transform $\ln(p) = \ln(k) + z\ln(t)$. This approach provided more rigor than visually determining the initial rate by the tangent method and evaded errors of the two chord secant method (Waley, 1981; Bisswanger, 2002). For additional details see article supplement.

We then plotted, for each concentration of the inhibitor, the initial velocity values (V) against the concentration values of the substrate (S) and fitted the Michaelis-Menten equation (Henri, 1903; Michaelis and Menten, 1913; Johnson and Goody, 2011) to the data, so that

$$V = \frac{V_{max}S}{K_M + S} \quad , \tag{4.2}$$

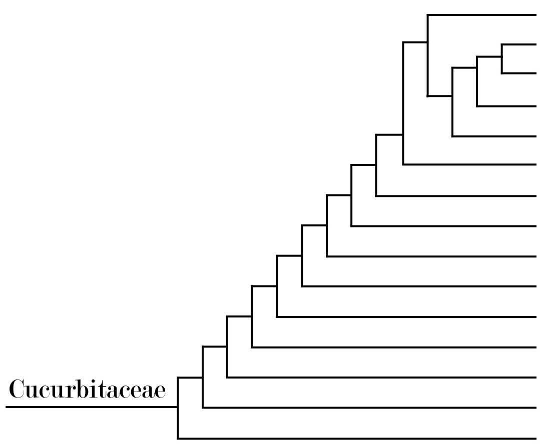
where V_{max} is the maximal velocity at full substrate availability (the asymptote) and K_M is the concentration of substrate at one-half V_{max}. We fitted the Michaelis-Menten model on the V versus S scatterplot through nonlinear regression using the nlstools package in the R programming language (Baty et al., 2015; R Core Team, 2015). Differences in V_{max} and K_M for different concentrations of inhibitor were compared to test whether the inhibitor affected primarily the overall velocity of the reaction (the V_{max} parameter, a measure of competitive inhibition) or the velocity at low concentrations (the K_M parameter, a measure of enzyme affinity and noncompetitive inhibition). ELISA data were compared to a known standard curve to determine absolute insulin concentration. The resulting values were, in turn, compared among themselves by using a pairwise t-test.

4.5 Results

4.5.1 Diabetes Treatment Place in Cucurbitaceae Phylogeny

Our query of the Web of Knowledge databases returned 1 155 publications. Based on our inclusion criteria of including a species of Cucurbitaceae used to treat diabetes and article availability, 457 were included in the database and authors may have written about one or more species per article. The resulting χ^2 tables (Table 4.1) revealed no concentration of medicinal property reports for diabetes on any specific tribe or group of tribes. The reported frequency follows the expected values based on the frequency of taxonomic species, $\chi^2 = 11.92, DF = 14, P = 0.534$. In contrast, the frequency of published articles concentrated on the tribes Momordiceae (269 articles), Benincaseae (154), Sicyoeae (42), Cucurbiteae (35), $\chi^2 = 1291.13, DF = 14, P < 0.0001$. The tribes Momordiceae and Siraitieae had significantly more articles than those predicted by the taxonomic frequency of species. While Coniandreae, Gomphogyneae, Sicyoeae, Thladiantheae, and Triceratieae had less publications than would be expected (Table 4.2).

Table 4.1: The distribution of anti-diabetic reports throughout the Cucurbitaceae

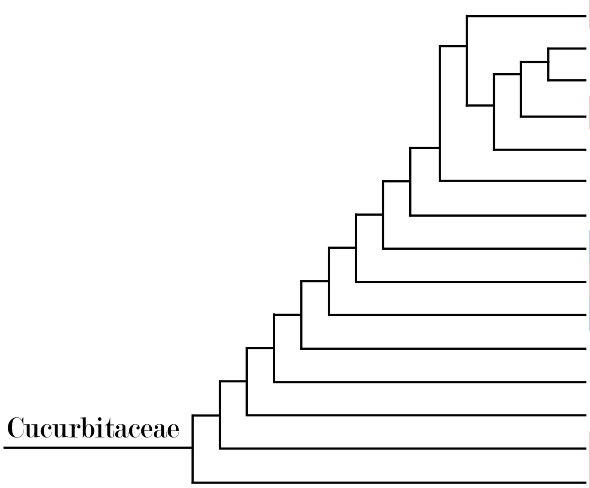
Cucurbitaceae phylogeny	Tribe	Taxonomic species	Studied species	Pearson Residual
	Sicyoeae	198	12	-0.1
	Benincaseae	210	13	-0.1
	Cucurbiteae	65	4	-0.1
	Coniandreae	61	4	0.1
	Schizopeponeae	4	0	-0.5
	Bryonieae	19	2	0.7
	Joliffieae	10	2	1.7
	Momordiceae	61	6	1.1
	Thladiantheae	18	0	-1.1
	Siraitieae	3	1	1.9
	Indofevilleeae	2	0	-0.4
	Actinostemmateae	2	0	-0.4
	Zanonieae	11	1	0.4
	Triceratieae	14	0	-0.9
	Gomphogyneae	51	1	-1.2
	Sum	729	46	
			χ^2	12.4
			DF	14
			P	0.574

4.5.2 *Ibervillea sonorae* Caudex Yield

Raw caudices yielded 16.5% dry weight of powder after desiccation ($SD\pm0.6\%$). This powder provided 14.6 grams lyophilized extract per 100 grams dried powder giving an overall yield of 2.4% lyophilized powder per unit of raw caudex mass.

Table 4.2: The frequency of academic studies focuses on specific tribes of Cucurbitaceae. These are shown as significant as $P < 0.01$ with one asterisk (*) and $P < 0.001$ with two asterisks (**). The red highlight signifies a number of studies lower than predicted and the blue highlight a number higher than predicted

Cucurbitaceae phylogeny



Tribe	Taxonomic species	Number of studies	Pearson Residual
Sicyoeae	198	42	-8.7**
Benincaseae	210	154	-0.2
Cucurbiteae	65	35	-1.9
Coniandreae	61	9	-5.4**
Schizopeponeae	4	0	-1.7
Bryonieae	19	3	-3.0
Joliffieae	10	4	-1.3
Momordiceae	61	269	33.1**
Thladiantheae	18	0	-3.7**
Siraitieae	3	10	5.2**
Indofevilleeae	2	0	-1.2
Actinostemmateae	2	0	-1.2
Zanonieae	11	1	-2.5
Triceratieae	14	0	-3.2*
Gomphogyneae	51	17	-3.4*
Sum	729	544	
		χ^2	1291
		DF	14
		$P <$	0.001

4.5.3 Local and Current Use Practices

When interviewed, three herbal shopkeepers and two healers of five total informants cited benefit to people with diabetes when taking *I. sonorae*. Interestingly, one herbal shopkeeper cited prescriptions specifying that the patient must take the dried wereke powder thirty minutes before eating. One healer prescribed use throughout the day without specifying before or after eating. The other informants did not express instructions on timing of treatment.

Table 4.3: Inhibitory concentration at 50% inhibition for aqueous *I. sonorae* extract and the positive control, acarbose, are shown along with their corresponding 95% confidence intervals. Efficacy as activity at maximal inhibition is shown as percent negative control ± standard error for five experiments. See text for statistical analysis

	I. sonorae	Acarbose
IC_{50}	3.0 mg/ml	0.76 mg/ml (1.2 mM)
[conf. int.]	[4.4–2.0]	[2.0–0.7]
Efficacy $\pm SE$	$38.6 \pm 6.1\%$	$9.1 \pm 6.8\%$

4.5.4 Effect of *Ibervillea sonorae* on α-Glucosidase Activity

Lyophilized aqueous extracts of *I. sonorae* showed inhibition of α-glucosidase (Fig. 4.2). Aqueous *I. sonorae* extract and the positive control, acarbose, show marked inhibition. The inhibitory concentrations at fifty percent (IC_{50}) values and efficacy are displayed in Table 4.3. The potency, as expressed by the IC_{50}, of extract and acarbose is difficult to accurately compare, because acarbose is a pure preparation while the extract may contain numerous plant metabolites. However, the efficacies of the two can be compared in the lower activity threshold at full concentration of inhibitor (the b parameter of the logistic equation), where *I. sonorae* inhibits activity to 38.6% while acarbose inhibits activity to 9.1%.

4.5.5 Type of Inhibition

When exposed to increasing concentrations of *I. sonorae* extract, the V_{max} of the Michaelis-Menten model for α-glucosidase showed a significantly decreasing trend ($P < 0.05$) between no extract and 50 mg/ml *I. sonorae* extract (Fig. 4.3). In contrast, we did not find a detectable trend for changes in K_M.

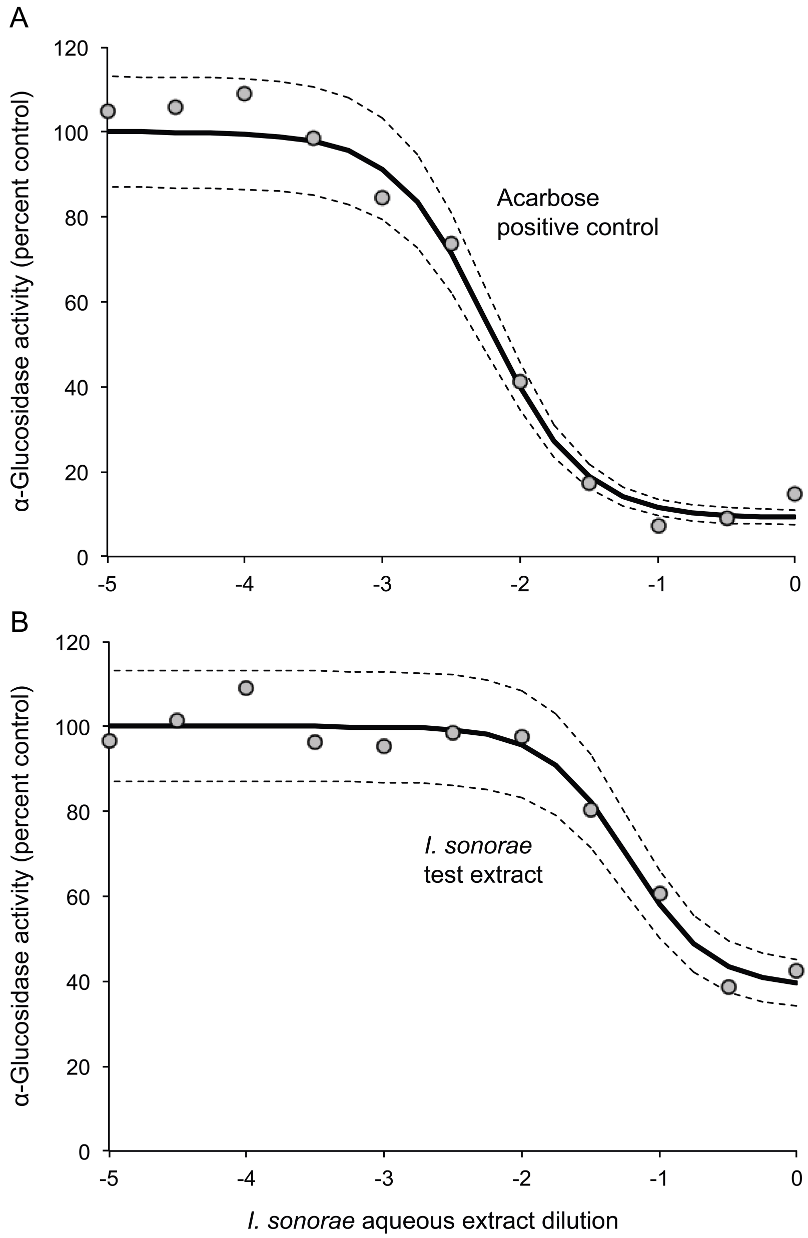


Figure 4.2: Effect of *I. sonorae* extract on α-glucosidase activity. α-Glucosidase was incubated with dilutions of extract for 20 minutes and then mixed with 2.0 mM of 4-Nitrophenyl α-D-glucopyranoside, a glucose analog substrate. Curve A shows the effect of commercial inhibitor, acarbose, a positive control. Curve B shows the effect of *I. sonorae* extract. Inhibition of α-glucosidase is shown by the decrease in percent negative control as a function of extract dilution. Maximal dilution of extract was 50 mg/ml per well, while acarbose started at 129 mg/ml or 200 mM. Dots represent average of data points, solid line represents the fitted logistic curve, and dotted lines represent the upper and lower 95% confidence interval. See text for statistical analysis

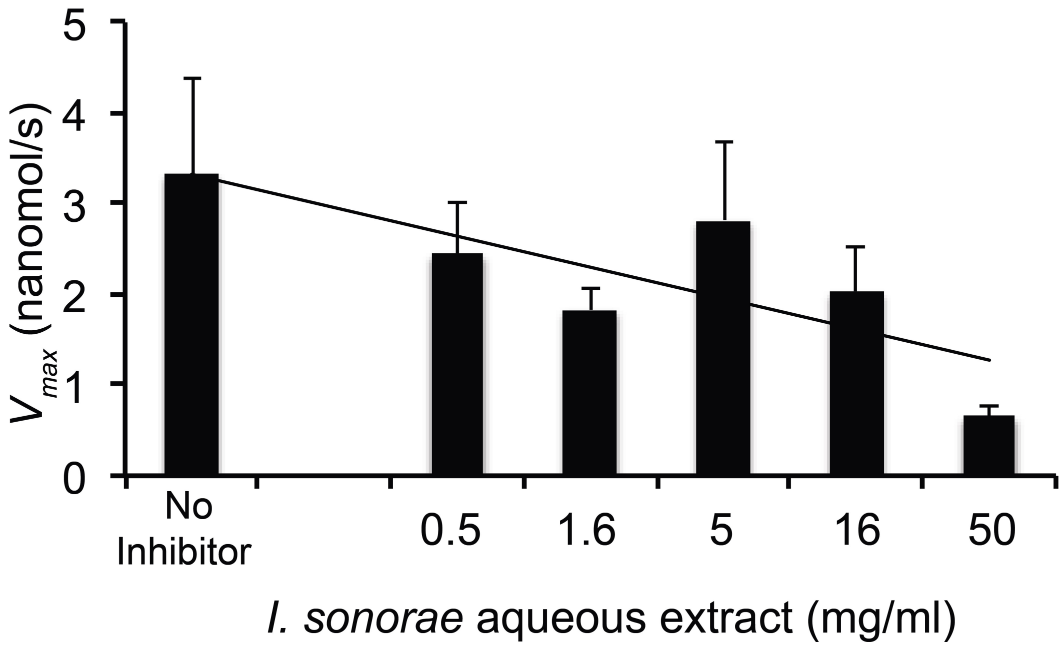


Figure 4.3: Effect of aqueous *I. sonorae* extract on V_{max}. The enzyme α-glucosidase was incubated with dilutions of extract for 20 minutes and exposed to substrate concentrations ranging from 0–5 mM. Increases in V_{max} were plotted to show inhibition as a function of inhibitor dilution. Values are means $\pm$ standard error from five experiments

4.5.6 ELISA

At a high concentration (10 μg/ml) of *I. sonorae* extract, RIN-m5f β cells secreted significantly more insulin into the surrounding culture media than the control ($P < 0.05$, pairwise t-test). Lower concentrations of extract (1 μg/ml) produced intermediate values of insulin production, but did not differ significantly from the control (Fig. 4.4).

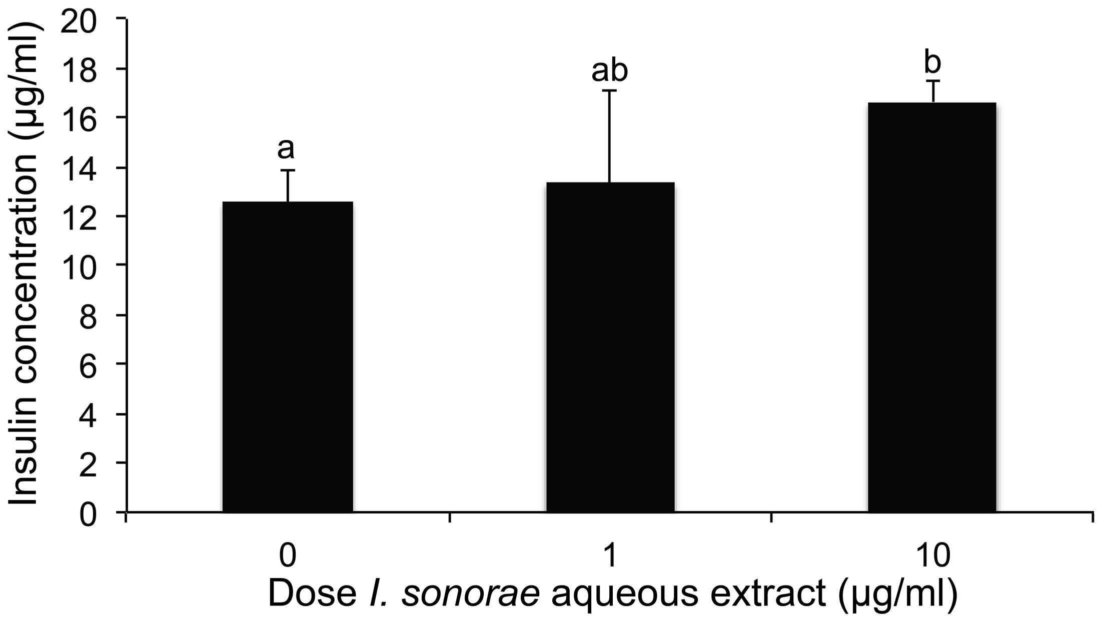


Figure 4.4: Effect of aqueous *I. sonorae* extract on insulin secretion by the β-cell line RIN-m5f. Cells were treated with complete culture media as vehicle control, this same media with 1.0 μg/ml, and 10 μg/ml extract. Values are means $\pm$ standard error from five experiments. Different letters indicate significant differences at $P < 0.05$

4.5.7 Reverse Transcription Quantitative PCR

Messenger RNA expression of the insulin genes Ins1 and Ins2 did not show a significant change in expression after treatment with *I. sonorae* extract ($P < 0.05$). The doses

Figure 4.5: Expression level of Ins1 (grey) and Ins2 (black) mRNA. RIN-m5F cells were treated with 0, 1, and 10 μg/ml *I. sonorae* extract for two hours. Total RNA was extracted from the cells and measured by reverse transcription quantitative PCR. Results are mean $2^{-\Delta\Delta C_T}$ values $\pm SE$

of 1 μg/ml, and 10 μg/ml did not show increases or decreases in insulin mRNA (Fig. 4.5) as fold change normalized to the housekeeping gene, β-actin.

4.6 Discussion

The present ethnopharmacological study offers four new findings. Firstly, an overlay of phylogeny and medicinal reports reveal homogeneous distribution of hypoglycemic reports throughout the Cucurbitaceae. Secondly, research within the family is unbalanced and swayed towards a handful of tribes, especially Momordiceae of the popular bitter melon (*Momordica charantia*). Thirdly, *Ibervillea sonorae* aqueous extract inhibits α-glucosidase via a reduction in the overall velocity of the enzymatic reaction (V_{max}) signifying competitive inhibition. Fourthly, *I. sonorae* stimulates insulin secretion in RIN-m5f β-cell culture, but this stimulation does not appear to operate through upregulation of the insulin genes (Ins1 and Ins2).

4.6.1 Cucurbits and Diabetes

The relationship between cucurbits and diabetes takes on increasing complexity when we view the two as a whole. While diabetes takes root via multiple pathways, remedies from the Cucurbitaceae come from a barage of plant parts and preparations. One may think that there must be one or a few compounds present throughout the plant. But examples such as where one species (*Ibervillea sonorae*) activates K_{ATP} channels and another (*Cucurbita ficifolia*) does not, seem intriguing (Banderas-Dorantes et al., 2012). This absence of a clear single mechanism is especially interesting since the latter increases calcium influx through a seemingly different mechanism than potassium channel activation (Miranda-Pérez et al., 2016). This, combined with the multiple pathways affected by various fractions of extracts addressed in the introduction, brings out many potential questions. Is it possible to find an active compound? Is it possible to find many active compounds? Or is any one active compound in excess toxic, and traditional remedies depend on a low dose of multiple active compounds? These questions have yet to be addressed, but a continued and thorough onslaught of animal-model validation studies on *Momordica charantia* will not provide an answer! On the other hand, mechanistic studies on crude or well-purified extracts can help explain the activity of this family.

Phylogenetic exploration of medicinal plant use reports can potentially guide studies on natural products. Some studies find clustering of active compounds or medicinal uses on phylogenetic branches (Saslis-Lagoudakis, Klitgaard, et al., 2011; Saslis-Lagoudakis, Savolainen, et al., 2012; Ernst et al., 2016). Yet sometimes this clustering is weak or not present (Rønsted et al., 2012; Yessoufou, Daru, and Muasya, 2015). Another idea is to use phylogeny to guide research and ask where studies and efforts have been directed. Any gaps provide an opportunity to ask whether historical practices or traditional knowledge have already guided us away from a group of species or is this potentially a branch that researchers have neglected. Our study showed that researchers have clustered their efforts in some tribes of the Cucurbitaceae even though all branches have shown members reported to be anti-diabetic. This research preference may be the result of researchers building on previous studies or of chance, but in any event, an objective view of investigations in the context of a phylogenetic tree provides a context for future project rationale.

Experiments on species from underrepresented tribes would help fill gaps in knowledge. These may lead to further contradictions of activity within the family or increased consistency. The medicinal properties of the Cucurbitaceae are an integral part of the family and express themselves in diverse ways for the benefit of humans affected by a multi-faceted disease such as diabetes. This presents opportunity for new discoveries in both understudied species and toxicological reports. The literature lacks thorough toxicology studies, which gives an opportunity to researchers who wish to fill this gap in knowledge and help guide possible future use and development of compounds within the Cucurbitaceae. While some studies show antiproliferative effects *in vitro* (Torres-Moreno et al., 2015) and in animal models (Hernández-Galicia, Campos-Sepúlveda, et al., 2002; El Batran, El-Gengaihi, and El Shabrawy, 2006; Atole et al., 2009; Kosanovic et al., 2009), there is more work to be done throughout the family.

Our research centers around anti-diabetic plants of Mexico. For this, we chose to investigate more closely *Ibervillea sonorae* of the tribe Coniandreae. Coniandrea is understudied within the Cucurbitaceae, yet the genus *Ibervillea* has some background literature to build upon. Published evidence indicates that *I. sonorae* decreases blood sugar in multiple validation studies, some mechanistic studies, and also phytochemical studies (Alarcón-Aguilar, Calzada-Bermejo, et al., 2005; Banderas-Dorantes et al., 2012; Zapata-Bustos et al., 2014; Torres-Moreno et al., 2015). Because these studies vary widely in routes of administration and possible mechanisms or active compounds of this species, it follows that overall hypoglycemic effects reflect the possible integration of various mechanisms. Consistent with this view, a comparison of local prescriptions of wereke match closely prescriptions for acarbose in conventional medicine. In both cases the patient must take the treatment before consuming their meal (carbohydrate source). In this way, α-glucosidase, which hydrolyzes starch into glucose in the digestive tract, becomes inhibited. Thus less glucose is absorbed into the bloodstream resulting in a net hypoglycemic effect. *I. sonorae*-treated α-glucosidase was inhibited in a dose-dependent manner. Owing to the Michaelis-Menten model of enzyme kinetics, we can characterize the mechanism of α-glucosidase inhibition by *I. sonorae* extract. The type of inhibition may be inferred from the parameters V_{max} and K_M. In this study, we found a significant decrease in V_{max} as inhibitor concentration increased, yet found no effect related to K_M. Taken together, this finding indicates that *I. sonorae* acts as a competitive inhibitor of α-glucosidase. This innate property may explain the stipulation in a local prescription to take this treatment before eating. During the write-up of our manuscript, a research group published a thesis and subsequent book chapter where the α-glucosidase inhibition potential of "*Ibirvirea Sonorae*" (sic) was mentioned (Rodríguez-Carmona, 2016; Ramírez-Ortíz et al., 2017). Presumably the intended name was *Ibervillea sonorae*, and the study stopped at estimating the EC_{50} value from a linear plot as opposed to a fitted dose-response curve. Nevertheless, this group corroborates the base activity that we found. We describe dose-dependent inhibition and delve into detailed Michaelis-Menton parameters and type of inhibition of *Ibervillea sonorae*.

Given previous observations suggesting a potential increase of blood insulin levels in Wistar rats when treated with *I. sonorae* (Banderas-Dorantes, 2006), we examined the hypothesis that *I. sonorae* stimulates insulin secretion. In our experiments, *I. sonorae* extract significantly increased insulin secretion of RIN-m5f β cells, suggesting that it effectively stimulates insulin secretion by acting on the β cells of the pancreas (Fig. 4.6). In addition, reverse transcription qPCR showed no upregulation of insulin gene expression. This adds more credence to the studies of Alarcón-Aguilar's group where they suggest that *I. sonorae* may block K_{ATP} channels as a possible mechanism for stimulating insulin secretion (Banderas-Dorantes et al., 2012). Our study shows that further investigation on stimulation of insulin secretion from β cells is warranted. Also, given that *Cucurbita ficifolia* appears to stimulate calcium influx from the ER (Miranda-Pérez et al., 2016), studies on potential calcium signalling and its source could further enhance our understanding of this mechanism.

Mechanistic studies of herbal medicine inform health care practitioners and consumers on possible contraindications. Considering the public health concern of diabetes in Mexico, combined with the vibrant use of traditional and herbal remedies, studies on mechanisms of anti-diabetic plants are pressing. Physicians must know what patients treat themselves with in the home, and beyond this, how these compounds may affect human physiology. This study provides evidence that *I. sonorae* acts through competitive inhibition very similarly to widely prescribed α-glucosidase inhibitors and also stimulates insulin secretion of β cells *in vitro*. Further studies on calcium signalling are warranted and investigators may consider broadening the scope

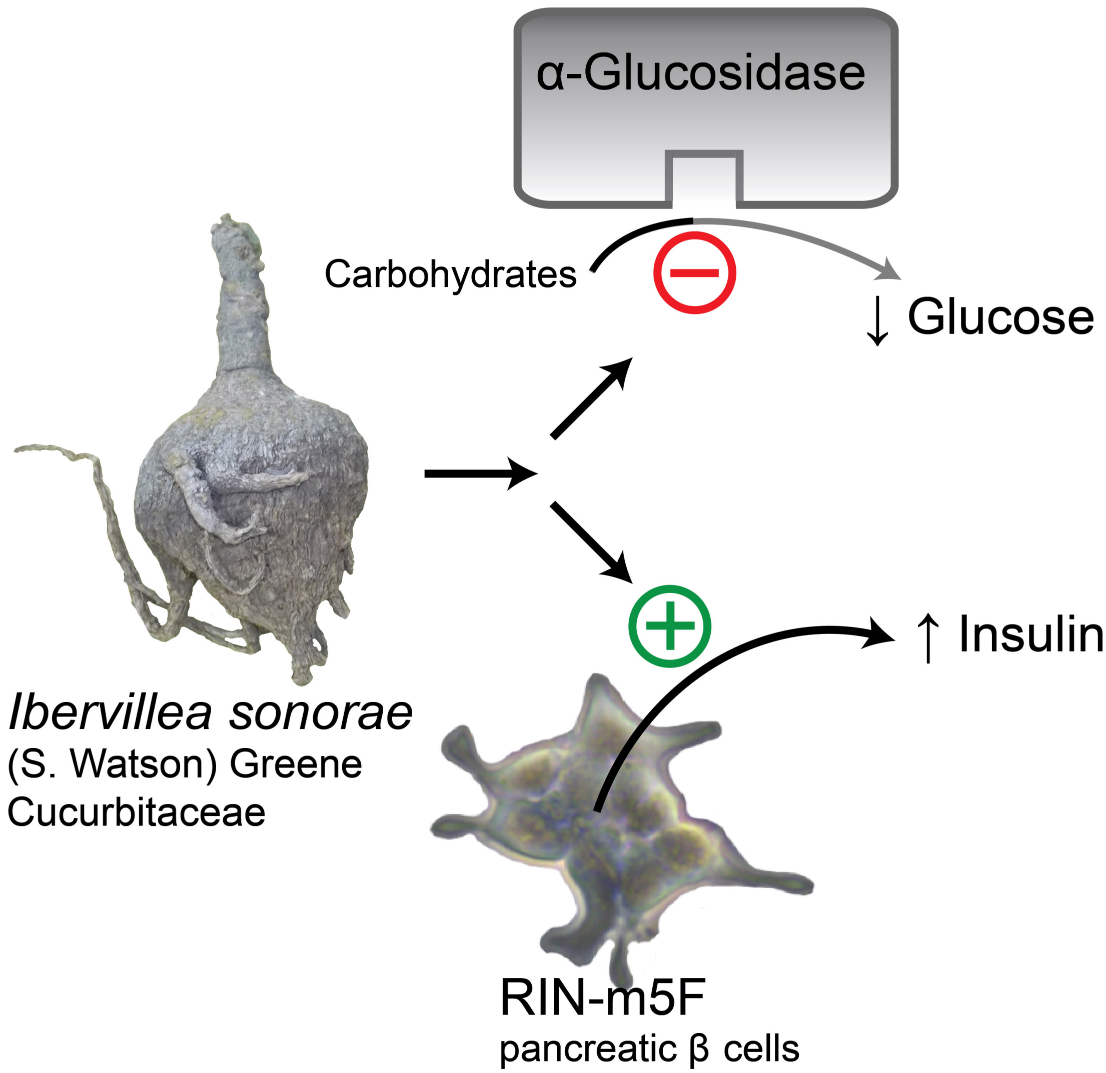


Figure 4.6: The modes of action of *I. sonorae in vitro* show potential reduction in glucose from starch hydrolization and stimulation of insulin production. Subsequent experiments revealed the type of inhibition of α-glucosidase as competitive inhibition

of their research to other genera and species that are understudied. Together, these findings provide support for quality diabetic patient care in a country with strong herbal traditions such as Mexico.

Chapter 5

Ancestral Traditions of the Future: Where is Traditional Knowledge and Practice Preservation Directed?

5.1 Abstract

The interactions between people and their natural environment over generations have given rise to traditional knowledge and practice systems. The traditional knowledge and practice of cultures around the globe draws the attention of biologists, anthropologists, and linguists, among others. Unfortunately, the general consensus is that traditional knowledge and practice prevalence is declining at an alarming rate. Because of this, scientists may call for the preservation, conservation, or documentation of such knowledge. Furthermore, researchers or nonprofit organizations may attempt to stimulate preservation and use. In this study, we ask what preservation strategies are reported in the literature, what follow-up measures (if any) teach us about their effectiveness, and what categories of traditional knowledge and conservation practices

are currently being attempted by nonprofit organizations. To answer these questions, we systematically reviewed the literature for keywords related to TKP preservation and also searched databases of organizations with missions to preserve such knowledge. We found a range of traditional knowledge and practice preservation strategies that we categorized, and we provide a state of the current literature. The literature revealed anecdotal and qualitative follow-up measures with much emphasis on intellectual property rights. Many studies in the sample had seemingly no follow up and quantitative post evaluation was eerily sparse. The most convincing argument we found came from anecdotal evidence showing the fundamental importance of experiential learning with elders on ancestral land for the purpose of passing traditions, ideas, and knowledge from one generation to the next. Interestingly, nonprofit organizations honed in on policy and community education as predominant objectives in their mission statements. In all, these results show the pressing need and importance of follow-up measures (both quantitative and qualitative) on initiatives done in the field. Overall, we recommend that both researcher and nonprofit organizations assess these trends and caveats to help them form and direct their objectives to best conserve traditional knowledge and practices. Then, we urge all to follow up with their activities to ensure success of their mission statement or research objectives.

5.2 Introduction

Every ethnobiology student eagerly studies and upholds the value of traditional knowledge and practices (TKP). The worrisome decline of this knowledge (Anderson et al., 2012) motivates them even more as they travel into the field to seek and preserve TKP. But how can these energetic students actually achieve their goal? Let us take a good hard look at TKP preservation initiatives and at trends in the nonprofit sector to gain some clues.

Traditional knowledge and practices (TKP) are the concepts held by one interacting with the landscape. This knowledge is largely passed from generation to generation as oral tradition and often leads to visible interactions with the landscape—practices. Some prominent practices include use of herbal medicine and ceremonial dances, but include many other aspects of life including, but not limited to, shelter, food, heat, drink, agriculture, song, speech, story, philosophy, law, and ethics (Conabio, n.d.). The collective nature of TKP reflects the nature community ties and interconnectedness to their local landscape.

Most agree that TKP deserves a prominent place in a healthy conservation program (Cunningham, 2001). The concepts of cultural keystone species and places show the connection of TKP to the ecosystems where these cultures thrive. These key species along with culturally significant places on the landscape provide a crucial linchpin to connect TKP with the natural environment (Garibaldi and Turner, 2004; Cuerrier, Turner, et al., 2015). Many keepers of TKP live and work, in the midst of sensitive areas, on the front lines of environmental conservation and climate change (IASG, 2014). Further, communities demonstrate the value of TKP in preserving biodiversity and genetic resources (Fenta, 2004). Unfortunately, TKP prevalence often diminishes due to development of areas of natural resources, poverty and emigration of local TKP keepers, and stigmas that cause youth to devalue their heritage (Twarog, 2004). Out of these circumstances have arisen ideas, strategies, initiatives, and organizations aimed at preserving and aiding the continued practice of TKP for future generations.

The United Nations has recognized the importance of TKP by publishing the Declaration on the Rights of Indigenous Peoples (United Nations, 2008) and forming the Inter-Agency Support Group on Indigenous Peoples' Issues. This agency has continued to support the rights and needs of indigenous peoples since the *Rio Earth Summit* in 1992 (IASG, 2014). Additionally, the Convention on Biological Diversity has created the *Traditional Knowledge Information Portal* to incorporate TKP into conservation plans (CBD, n.d.). Moreover, the World Health Organization, The World Conservation Fund, and the World Wide Fund for Nature also emphasize the need to preserve traditional knowledge and practices of, in this case, medicinal plants (WHO, 1993). This shows the recognition of TKP on the world stage. While important at a global level, TKP also makes up a core part of the culture and world view of local communities.

Traditional knowledge and practices have intrinsic value to the communities that hold it. This intrinsic value includes social, cultural, spiritual, economic, scientific, intellectual, commercial, and educational contributions (dos Santos-Duisenberg, 2010). This knowledge ebbs and flows with the needs of the community. It may become richer or poorer, and sometimes it disappears (Pacón, 2004). This allows keepers of TKP to adapt and modify their craft to meet the needs of a changing world (Ondrusova, 2004). With any adaptation, the overall practice, craft, or product exhibits the local community's world view (Ole Karbolo, 2004). As much as holders of TKP might adapt to situations around them, current systems for commercialization and intellectual property rights (IPR) consistently prove inadequate because of innate differences between IPR and TKP (United Nations, 2001).

The value of TKP extends beyond commercial products or rights. Land management of protected areas can benefit from involvement of communities who include TKP in the management process (Berkes and Turner, 2006; Gómez-Baggethun, Mingorria, et al., 2010). Exclusion of local communities from conservation schemes prevents them from experimenting and continuing to develop their TKP. While this exclusion reduces the prevalence of TKP, including groups in conservation management can help TKP thrive (Gómez-Baggethun and Reyes-García, 2013). Beyond merely land management, one must consider that plants, animals, and cultures coexist in the same ecosystem, forming cultural landscapes where biodiversity and TKP are intertwined (Reyes-García, 2007). Because of this, many suggest that TKP preservation and involvement of local communities can, and probably should, be directed at benefiting the health of the whole ecosystem including plants, animals, peoples, and cultures (Reyes-García, 2010; Vandebroek, Reyes-García, et al., 2011).

The importance of TKP may be well established, yet the interworkings of how this knowledge stays alive within groups of people is little understood (Tang, Gavin, et al., 2016). A mechanistic understanding is lacking and students risk "re-inventing the wheel" without a clear framework of TKP conservation. Because of this, we reviewed the literature to identify key factors in TKP preservation. We see this as an initial step in initiating TKP conservation strategies that can show demarkable benefit to the landscape and cultures that depend on it.

In this study, we hypothesize that trends in TKP research and preservation initiatives can guide us to generate precise initiatives that meet community and landscape needs. The merit in this study lies in the idea that we must design and build programs objectively and based on previous work. Therefore, to identify potential factors and assess their effects, we conducted a systematic review of previously published research on TKP preservation strategies. We also analyzed mission statements of established nonprofit organizations who work to support TKP around the world.

Table 5.1: Queried databases with accompanying search terms

Database	Search Term	Articles Selected	Year Range
Academic Search Complete	"traditional knowledge" preservation	17	All
UN Trade and Development publications	"traditional knowledge"	12	All
Google Scholar	"ethnobotanical garden" OR "ethnobotanical gardens"	43	All
Google Scholar	"traditional knowledge conservation" OR "traditional knowledge preservation" OR "traditional ecological knowledge conservation" OR "traditional ecological knowledge preservation"	44	All
Google Scholar	"ethnobotanical trails" OR "ethnobotanical trail"	3	All

5.3 Materials and Methods

5.3.1 Literature Review

We systematically reviewed the literature to assemble a bank of articles for analysis. To achieve this, we queried academic databases with accompanying search terms as shown in Table 5.1. The systematic review guidelines published by the Centre for Evidence-Based Conservation served as our guide during assessment of articles and extraction of information (Collaboration for Environmental Evidence, 2013). All queries took place between October 2016 and March 2017.

Our search queries produced a grand total of 3,558 results over an unrestricted year range. By focusing only on studies related to TKP preservation, this number was reduced to 119 articles. We assessed the resulting articles and selected those that describe an initiative, project, action, situation, or discernible idea or recommendation about preserving traditional or indigenous knowledge. Articles were excluded if the article itself was the only instrument presented as documenting knowledge to preserve it. This reduced our sample to 46 articles that outlined a preservation strategy and 35 with a proposed recommendation. We then analyzed these articles for the strategy type, location, assessment, and premise presented by the authors.

5.3.2 Data Analysis

We created an attribute database for TKP preservation projects based on the literature reviewed. These attributes included strategy, category, country, people, and post-assessment result. Following this, we created a map of TKP preservation endeavors based on the location data cited in the articles using the open source geographic information system QGIS (QGIS Development Team, 2017). The location data was obtained from articles as given by location data, identifying a certain group of people that generally reside in a geographic area, or by citing the country or territory.

5.3.3 Traditional Knowledge Preservation Organizations

To assess trends in current TKP preservation strategies applied by the nonprofit sector, we analyzed mission statements of organizations who strive to promote TKP. We searched the list of indigenous and nonprofit organizations published by the International Work Group for Indigenous Affairs (IWGIA, n.d.) and the Guidestar database of nonprofit organizations (Guidestar, 2017) for organizations that aim to preserve traditional knowledge and practices. The search terms "traditional knowledge," "traditional ecological knowledge," and "indigenous knowledge" were used. The mission statements of the resulting organizations were categorized according to the TKP conservation classification system of Tang and Gavin (2016). This classification system has five primary categories: indigenous capacity building, community-based TKP conservation activities, education and awareness building, policy and legislative support, and research and documentation of TKP. These classifications were developed to serve as a structure to examine trends in TKP conservation actions (Tang, Gavin, et al., 2016).

5.4 Results

5.4.1 Traditional Knowledge and Practice Preservation Strategies

Our systematic literature review aimed to find established strategies that help guide TKP research and conservation. This review resulted in 46 articles that yielded information on 50 studies of TKP preservation initiatives. The initiatives covered a diverse array of strategies on all inhabited continents. We present a summary of these strategies in Table 5.2. When assessing the data, follow-up measures, either quantitative or qualitative, were scarce. Furthermore, all but one of the follow-up assessments are opinion based. The only data-based follow-up assessment depicted a case where a local elder would call students after ethno-educational sessions for a *post-hoc* interview. These interviews took place months or years after the sessions. His qualitative assessment depicted how students had a renewed interest in learning after attending the ethno-educational sessions with elders (Mathew, 1999).

5.4.2 Location of TKP Preservation Initiatives

Around the world, attempts to conserve TKP use various methods. An analysis of location data shows that Southern Asia is a leader in examples of digital databases meant to prevent biopiracy by showing prior art for various applications of TKP. Australia sports original library and database techniques aimed at facilitating entry and access to TKP. Additionally, community partnership programs seem to be common in Sub-Saharan Africa. In all, the distribution of TKP preservation initiatives is presented in Fig. 5.1.

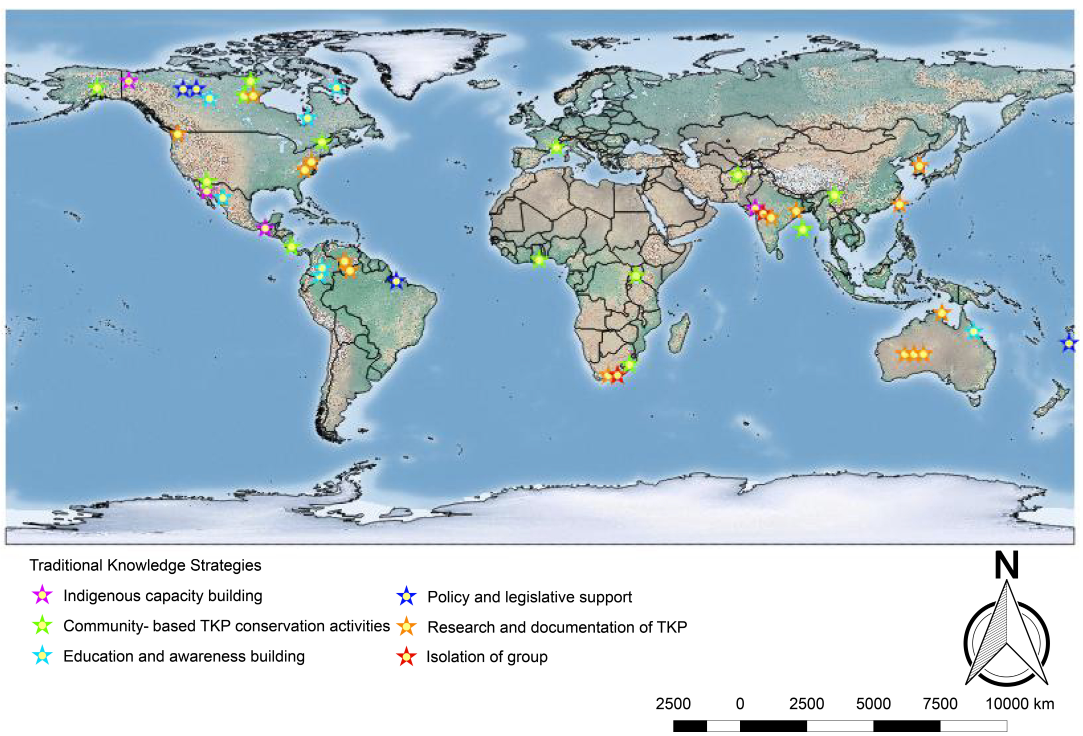


Figure 5.1: Traditional knowledge and practice preservation strategies occur around the globe. Various styles of TKP preservation serve the needs of people in these regions. Here we depict the initiatives from our literature search as a reference to the general location of these varied approaches ($N = 45$). World map data was sourced from Natural Earth (Natural Earth, 2012)

5.4.3 Post Assessments of TKP Endeavors

Although the majority of studies do not possess a post-assessment measure, some authors produced a post assessment. We analyzed these assessments and present them in Table 5.3.

5.4.4 Researcher proposed strategies

To assess the general attitude towards TKP preservation in the literature, we compiled and categorized recommendations presented by researchers in the field. These recommendations came out of their data, conclusions, perspectives, and experience working with keepers of traditional knowledge and practices. The key premise of each recommendation is summarized in Table 4.

Table 5.2: Classified TKP preservation strategies show the emphasis of publications in the field. Interestingly, the majority of *post hoc* proposals and assessments, if any, are based on opinion. The acronym for traditional ecological knowledge (TEK) is used if used in the cited work

Strategy	Category	Country	People	Post Assessment	Result	Reference
Collaboration with indigenous groups	Indigenous capacity building	Mexico	Comcáac	Opinion	Tension between knowledge systems can lead to clever new ideas given much collaboration	(Wilder et al., 2016)
Financial and administrative support	Indigenous capacity building	India	Indian cultures	None	None	(Gupta, 2000)
Museum collection	Research and documentation of TEK	USA	Native Americans	Opinion	Databases remove TKP from its wholistic context	(United Nations, 2005)
Co-management regime	Indigenous capacity building	Canada	Canadians, US citizens, and First Nations	None	None	(Brockman, Masuzumi, and Augustine, 1997)
Sample collection network	Indigenous capacity building	Mexico	Maya	Opinion	Disagreement of communities on sharing TKP related biodiversity	(Feceña, 2000)

Table 5.2 continued from previous page

Strategy	Category	Country	People	Post Assessment	Result	Reference
Medicinal plant supply for gardens	Community-based TEK conservation activities	Ghana	Local communities	None	None	(Waylen, 2006)
Hunting supply	Community-based TEK conservation activities	Nunavut	First Nations	None	None	(Brockman, Masuzumi, and Augustine, 1997)
Hunting supply	Community-based TEK conservation activities	Alaska	Native Americans	None	None	(Brockman, Masuzumi, and Augustine, 1997)
Land management	Community-based TEK conservation activities	Throughout tropics	NA	None	None	(Posey and Dutfield, 1996)
Ethnobotanical garden	Community-based TEK conservation activities	Belize	Q'eqchi'	Opinion	Community run projects are more sustainable	(Audet et al., 2013)
Ethnobotanical garden	Community-based TEK conservation activities	None	NA	None	None	(Jones and Hoversten, 2004)

Table 5.2 continued from previous page

Strategy	Category	Country	People	Post Assessment	Result	Reference
Ethnobotanical garden	Community-based TEK conservation activities	France	NA	None	None	(Brousse, 2015)
Ethnobotanical garden	Community-based TEK conservation activities	Canada	First Nations	None	None	(Dias and Janeira, 2005)
Ethnobotanical garden	Community-based TEK conservation activities	Costa Rica	Costa Rican Communities	None	None	(Waylen, 2006)
Ethnobotanical garden	Community-based TEK conservation activities	Uganda	Women and Children of Uganda	None	None	(Waylen, 2006)
Medicinal plant supply for gardens	Community-based TEK conservation activities	South Africa	HIV/AIDS patients	None	None	(Waylen, 2006)
Botanic garden	Community-based TEK conservation activities	NA	NA	None	None	(Martellos et al., 2016)

Table 5.2 continued from previous page

Strategy	Category	Country	People	Post Assessment	Result	Reference
Visual art	Community-based TEK conservation activities	Canada	Inuit	Opinion	Indigenous art helps people heal from historical trauma done to their people	(Crawford, 2014)
Basket commerce	Community-based TEK conservation activities	USA	Tohono O'odham	None	None	(ONeill, 2001)
Medicinal plant commerce	Community-based TEK conservation activities	Afghanistan	Rural Afghanis	None	None	(Ottens, Dürbeck, and Otten, 2006)
Ecotourism	Community-based TEK conservation activities	China	Tibetan Kham speakers	Opinion	TKP awareness can help people value and restore ecosystems	(Chunhui et al., 2012)
Ethno-education	Education and awareness building	Suriname & Colombia	Amazon locals	Opinion	Tribal peoples desire basic needs and ethno-education	(Murray, 2006)
Ethno-education	Education and awareness building	Canada	Eeyou-Cree	Anecdote	Renewed interest in learning when youth spend time on the land learning from elders	(Mathew, 1999)

Table 5.2 continued from previous page

Strategy	Category	Country	People	Post Assessment	Result	Reference
Multi-generational excursions	Education and awareness building	Australia	Girringun Aboriginal	None	None	(Zurba, 2010)
Interdisciplinary communication between healers	Education and awareness building	Colombia	Afro-Colombians	None	None	(López et al., 2011)
TKP-themed television	Education and awareness building	Canada	Canadians and First Nations	None	None	(Brockman, Masuzumi, and Augustine, 1997)
TKP-themed television	Education and awareness building	Canada	Canadians and First Nations	None	None	(Brockman, Masuzumi, and Augustine, 1997)
TKP-themed radio	Education and awareness building	Mexico	Tarahumara Raramuri	None	None	(Tang, Gavin, et al., 2016)

Table 5.2 continued from previous page

Strategy	Category	Country	People	Post Assessment	Result	Reference
Policy for TKP	Policy and legislative support	Pacific Islands	Pacific Islanders	None	None	(Kariyawasam, 2008)
Policy for TKP	Policy and legislative support	Canada	Residents NWT	Opinion	Unclear how to implement policy and lack of cross-cultural training	(Brockman, Masuzumi, and Augustine, 1997)
Official language status	Policy and legislative support	Canada	Residents NWT	Opinion	Number of speakers continues to decline	(Brockman, Masuzumi, and Augustine, 1997)
Policy for TKP	Policy and legislative support	Brazil	World	Opinion	Declaration of Belém catalyzes TKP rights in Brazil	(Soldati and Albuquerque, 2016)
Digital database	Research and documentation of TEK	India	Indians	Opinion	Shows prior art of TKP	(Poorna, Mymoon, and Hariharan, 2014)
Digital database	Research and documentation of TEK	South Korea	Koreans	Opinion	Shows prior art of TKP	(Poorna, Mymoon, and Hariharan, 2014)

Table 5.2 continued from previous page

Strategy	Category	Country	People	Post Assessment	Result	Reference
Digital database	Research and documentation of TEK	Taiwan	Chinese ancestry	Opinion	Shows prior art of TKP	(Poorna, Mymoon, and Hariharan, 2014)
Digital database	Research and documentation of TEK	Venezuela	Amazonian ethnic groups	Opinion	Shows prior art of TKP	(Poorna, Mymoon, and Hariharan, 2014)
Digital database	Research and documentation of TEK	South Africa	Durban area	Opinion	Increases accessibility	(Poorna, Mymoon, and Hariharan, 2014)
Digital database	Research and documentation of TEK	Australia	Anangu and other groups, western and central Australia	Opinion	Increases accessibility	(Poorna, Mymoon, and Hariharan, 2014)
Digital database	Research and documentation of TEK	USA	Tulalip	None	None	(Twarog, 2004)

Table 5.2 continued from previous page

Strategy	Category	Country	People	Post Assessment	Result	Reference
Digital database	Research and documentation of TEK	India	Indians	None	None	(Twarog, 2004)
Digital database	Research and documentation of TEK	Canada	Kaska	None	None	(United Nations, 2005)
Digital database	Research and documentation of TEK	Venezuela	NA	Opinion	Existence of database let to access limitations to protect potential IP	(Vivas Eugui and Ruiz Muller, 2001)
Digital database	Research and documentation of TEK	China	NA	None	None	(Du, Guo, and Xue, 2013)
Digital database	Research and documentation of TEK	Australia	Ethnic groups across Australia	Opinion	TKP must be accessible to community members	(Stevens, 2008)
Library collection	Research and documentation of TEK	Canada	Inuit	Opinion	TKP must be accessible to community members	(Stevens, 2008)
User contributed stories	Research and documentation of TEK	Australia	Yolngu	Opinion	TKP must be accessible to community members	(Stevens, 2008)

Table 5.2 continued from previous page

Strategy	Category	Country	People	Post Assessment	Result	Reference
Information management	Research and documentationof TEK	NA	NA	None	None	(Maina, 2012)
User contributed stories	Research and documentationof TEK	NA	NA	None	None	(Hunter, 2005)
User contributed stories	Research and documentation of TEK	Australia, Galiwinku	Yolngu	Opinion	Presence of indigenous centres can help communities	(Beale, 2003)
Isolation	NA	South Africa	NA	Mixed opinions	Isolation may help or hinder TKP	(Philander, 2012)

Table 5.3: Post assessments of TKP preservation strategies

Name	Strategy	Country	People	Assessment	Reference
Itzamma Garden and Medicinal Plant Project	Ethnobotanical Garden	Belize	Q'eqchi'	Community run gardens evade funding swings of academia and NGOs	(Audet et al., 2013)
Declaration of Belém	TKP rights	Brazil	World	Declaration of Belém and Posey's letter spurred TKP rights discussion	(Soldati and Albuquerque, 2016)
Baimaxueshan National Nature Reserve Ecological Restoration and Traditional Knowledge Preservation through Eco-cultural Tourism	TKP and ecotourism	China	Tibetan Kham speakers	Involving local elders in pastureland restoration seemed to boost the value of TKP in the minds of surrounding people	(Chunhui et al., 2012)
Cree School Board Outdoor Eduation	Ethno-education	Canada	Eeyou-Cree	After intergenerational courses held on native lands, adolescents had a renewed interest in learning.	(Mathew, 1999)
Biodiversity Index collaboration with the Comcáac	Collaboration with indigenous groups	Mexico	Comcáac	Tensions between knowledge systems can lead to clever insignts for diligent collaborators	(Wilder et al., 2016)

Table 5.3 continued from previous page

Name	Strategy	Country	People	Assessment	Reference
National Museum of the American Indian Repatriation	Artifact repatriation through database	Australia	Ethnic groups across Australia	Skeptical that TKP removed from its context still has value	(Stevens, 2008)
Tuktu and Nogak Project	TEK Caribou hunt	Canada	Inuit	Skeptical that TKP removed from its context still has value	(Stevens, 2008)
Our Story Database	User contributed stories	Australia	Yolngu	Skeptical that TKP removed from its context still has value	(Stevens, 2008)
Traditional Knowledge Digital Library	Digital Database	India	Indians	Non-codified (tacit) knowledge is difficult to store, yet imperative since it can help protect intellectual property rights	(Poorna, Mymoon, and Hariharan, 2014)
Korean Traditional Knowledge Portal	Digital Database	South Korea	Koreans	Digital databases can help prevent biopiracy	(Poorna, Mymoon, and Hariharan, 2014)
Chinese Traditional Medicine Database System	Digital Database	Taiwan	Chinese ancestry	Digital databases can help prevent biopiracy	(Poorna, Mymoon, and Hariharan, 2014)
BioZulua Project	Digital Database	Venezuela	Amazonian ethnic groups	Digital databases can help prevent biopiracy	(Poorna, Mymoon, and Hariharan, 2014)

Table 5.3 continued from previous page

Name	Strategy	Country	People	Assessment	Reference
Ulwazi programme of Durban	Digital Database	South Africa	Durban area	TKP can be disseminated via freeware and library services	(Poorna, Mymoon, and Hariharan, 2014)
Ara Irititja Project	Digital Database	Australia	Anangu and other groups, western and central Australia	TKP must be accessible to communities	(Poorna, Mymoon, and Hariharan, 2014)
Inuit Art	Visual art	Canada	Inuit	Visual arts can help people examine and heal from historical trauma	(Crawford, 2014)
Galiwin'ku Indigenous Knowledge Centre	User contributed stories	Australia, Galiwinku	Yolngu	TKP resource centres help communities find solutions to their needs	(Beale, 2003)
Smithsonian Center for Folklife and Cultural Heritage	Collection	USA	NA	Databases take TKP out of their holistic context and preserve them in a static state	(United Nations, 2005)
The Library of Congress		USA		Databases take TKP out of their holistic context and preserve them in a static state	(United Nations, 2005)

Table 5.3 continued from previous page

Name	Strategy	Country	People	Assessment	Reference
The Database of Official Insignia of Native American Tribes (DONATI)	Digital Database	USA	Native Americans of USA	Databases take TKP out of their holistic context and preserve them in a static state	(United Nations, 2005)
Biozulua Database	Digital Database	Venezuela	NA	Databases take TKP out of their holistic context and preserve them in a static state	(Vivas Eugui and Ruiz Muller, 2001)
Amazon Conservation Team	Ethno-education and TKP conservation	Suriname & Colombia	Amazon locals	Conservation strategies that take community needs into account succeed	(Murray, 2006)
Northwest Territories' Official Languages Act	Grant official language status	Canada	Residents NWT	Indigenous language speaker numbers still declined after gaining official language status; government policy alone cannot save language	(Brockman, Masuzumi, and Augustine, 1997)
Northwest Territories' Government Wide Traditional Knowledge Policy	Government wide policy for TKP	Canada	Residents NWT	How policy is often unclear and crosscultural training is often lacking	(Brockman, Masuzumi, and Augustine, 1997)

Table 5.4: Proposed recommendations found in the literature for conservation or preservation of traditional knowledge and practices

Categorized Recommendations	**Reference**
Indigenous capacity building	
Apply TKP to conservation and agriculture	(Oviedo, Gonzales, and Maffi, 2004)
Collaborate with communities to generate new ideas	(Wilder et al., 2016)
Create access to markets	(Twarog and Kapoor, 2004)
Create TKP community associations	(Ondrusova, 2004)
Empower women and children	(Oviedo, Gonzales, and Maffi, 2004)
Focus on community run projects	(Audet et al., 2013)
Preserve indigenous identity	(Twarog and Kapoor, 2004)
Promote traditional diets	(ONeill, 2001)
Provide financing	(Twarog and Kapoor, 2004)
Strengthen local capacity	(Vivas Eugui and Ruiz Muller, 2001)
Support women and elderly	(United Nations, 2005)
Community-based TEK conservation activities	
Alternative to IPR: Geographic indicator	(United Nations, 2014a)
Alternative to IPR: Pay and use system	(United Nations, 2014b)
Commercialize TKP resources	(Twarog and Kapoor, 2004)
Emphasize conservation instead of monetization of resources	(United Nations, 2001)
Include TKP in conservation programs	(Chunhui et al., 2012)
Involve communities in management and decision making	(Brockman, Masuzumi, and Augustine, 1997)
Promote community involvement	(Oviedo, Gonzales, and Maffi, 2004)
Promote indigenous language	(Oviedo, Gonzales, and Maffi, 2004)
Promote TKP for development and trade	(United Nations, 2001)
Protect biodiversity	(Twarog and Kapoor, 2004)
Sell traditional goods online	(Twarog and Kapoor, 2004)
Sell value added products	(Ottens, Dürbeck, and Otten, 2006)
Education and awareness building	
Disseminate TKP in educational activities	(Brousse, 2015)

Table 5.4 continued from previous page

Categorized Recommendations	Reference
Encourage language use	(Oviedo, Gonzales, and Maffi, 2004)
Inform TKP practitioners about IPR	(Ondrusova, 2004)
Inform TKP practitioners about IPR	(Vivas Eugui and Ruiz Muller, 2001)
Intergeneration projects connect youth with elders	(Zurba, 2010)
Produce indigenous language media	(United Nations, 2005)
Promote ethno-education	(Twarog and Kapoor, 2004; Ondrusova, 2004; Oviedo, Gonzales, and Maffi, 2004; United Nations, 2005)
Promote intergenerational ethno-education on native lands	(Mathew, 1999)
Promote TKP awareness in media	(Brockman, Masuzumi, and Augustine, 1997; United Nations, 2005; Poorna, Mymoon, and Hariharan, 2014)
Promote TKP dialogue in botanic garden setting	(Dias and Janeira, 2005)
Promote traditional and civil society communication styles	(Twarog and Kapoor, 2004)
Provide training programs	(United Nations, 2001; Vivas Eugui and Ruiz Muller, 2001; Oviedo, Gonzales, and Maffi, 2004; Waylen, 2006)
Recognize strengths of customary practices	(United Nations, 2005)
Spur communication between traditional healers and conventional physicians	(López et al., 2011)
Use online communication to connect youth from distant communities	(United Nations, 2005)
Use traditional art to examine and recover from historical trauma	(Crawford, 2014)
Policy and legislative support	
Acknowledge ancestral rights	(Cabrera Medaglia, 2004)
Acknowledge IPR alone does not protect knowledge	(Vivas Eugui and Ruiz Muller, 2001)
Acknowledge that TKP may be collective	(Cabrera Medaglia, 2004)
Acknowledge TKP as valuable even if it is in the public domain	(Cabrera Medaglia, 2004)

Table 5.4 continued from previous page

Categorized Recommendations	Reference
Alternative to IPR: Sui generis systems	(United Nations, 2001; Vivas Eugui and Ruiz Muller, 2001; Kaushik, 2004; Oviedo, Gonzales, and Maffi, 2004)
Be aware of distinctions between rights to genetic resources and rights to the associated TKP	(Cabrera Medaglia, 2004)
Be consistent in TKP protection	(Roberts, 2004)
Communities need legal representation	(Vivas Eugui and Ruiz Muller, 2001)
Conserve lands	(Oviedo, Gonzales, and Maffi, 2004)
Conserve resources	(Oviedo, Gonzales, and Maffi, 2004)
Create local registers of TKP	(Cabrera Medaglia, 2004)
Define TKP protection	(Vivas Eugui and Ruiz Muller, 2001)
Develop identification system for TKP	(Ondrusova, 2004)
Develop legal framework to deal IPR issues and TKP	(Twarog and Kapoor, 2004)
Develop legal framework to deal IPR issues and TKP	(United Nations, 2001)
Have contact centres to respond to communities' needs	(Beale, 2003)
Must not assume IPR systems will work for a community	(Vivas Eugui and Ruiz Muller, 2001)
Promote plant variety protection programs	(Greengrass, 2004)
Protect rights of prior art	(Poorna, Mymoon, and Hariharan, 2014)
Realize it is hard to get large groups of people to agree and agreement may change in the future	(Ceceña, 2000)
Realize that government policy alone cannot save a language	(Brockman, Masuzumi, and Augustine, 1997)
Recognize communities as central actor in conservation	(Vivas Eugui and Ruiz Muller, 2001)
Recognize existing IPR laws are not sufficient	(Kariyawasam, 2008)
Recognize the obligation of the state to protect cultural identity	(United Nations, 2005)
Recognize land rights	(United Nations, 2005)

Table 5.4 continued from previous page

Categorized Recommendations	Reference
Review difficulties in legal framework	(United Nations, 2001)
Share benefits earned from TKP	(Twarog and Kapoor, 2004)
Tackle the problem of planning and enforceability	(Vivas Eugui and Ruiz Muller, 2001)
Use existing alternatives to patents: trademarks, trade secrets, appelations of origin	(Vivas Eugui and Ruiz Muller, 2001)
Research and documentation of TEK	
Digital libraries may help prevent biopiracy	(Du, Guo, and Xue, 2013)
Disseminate research findings to local communities	(Waylen, 2006)
Documentation may help prevent biopiracy	(Poorna, Mymoon, and Hariharan, 2014)
Enable metadata forms that keepers of TKP can edit	(Hunter, 2005)
Evaluate instruments used to protect TKP	(Vivas Eugui and Ruiz Muller, 2001)
Promote community-based TKP documentation	(Oviedo, Gonzales, and Maffi, 2004; United Nations, 2005)
Publish conclusions of TKP work groups	(United Nations, 2001)
Reassess library categorization to include community members	(Stevens, 2008)
Reassess library categorization to include community members	(Maina, 2012)
Use botanic gardens to preserve TKP	(Jones and Hoversten, 2004; Martellos et al., 2016)

5.4.5 Nonprofit and academic sector trajectories

The nonprofit sector focuses time, energy, and funds on preserving TKP. This energy flows in multiple directions as per the organizations mission. Policy receives the most emphasis with 40% (Fig. 5.2). Interestingly, documentation and research including digital databases seem to lag behind as the least common objective of organizations with only 5% of organizations focusing on documentation and research. When viewing the focus of strategies presented in academic articles the largest portion of emphasis is placed on research and documentation followed by community-based conservation activities. Interestingly policy support, which is the largest focus of nonprofit organizations, is one of the lowest in academic circles (Fig. 5.3).

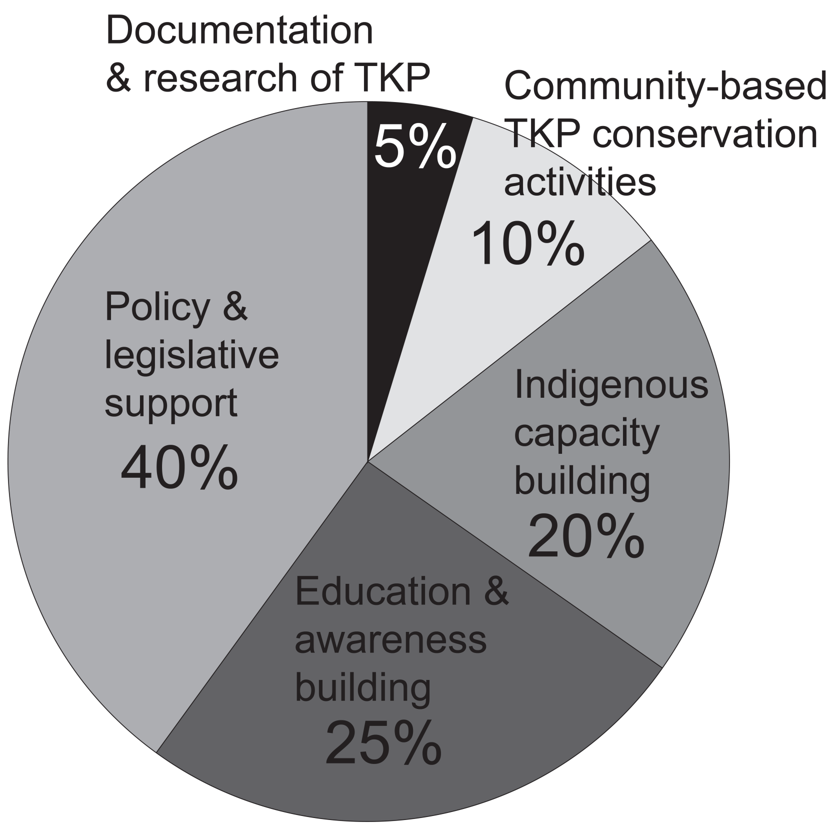


Figure 5.2: Organizations that aim to preserve and support TKP in some fashion. Their mission statement categorization show differences in emphasis and strategies as outlined by Tang, Gavin, et al., and then compared as a percentage of total initiatives ($N = 83$)

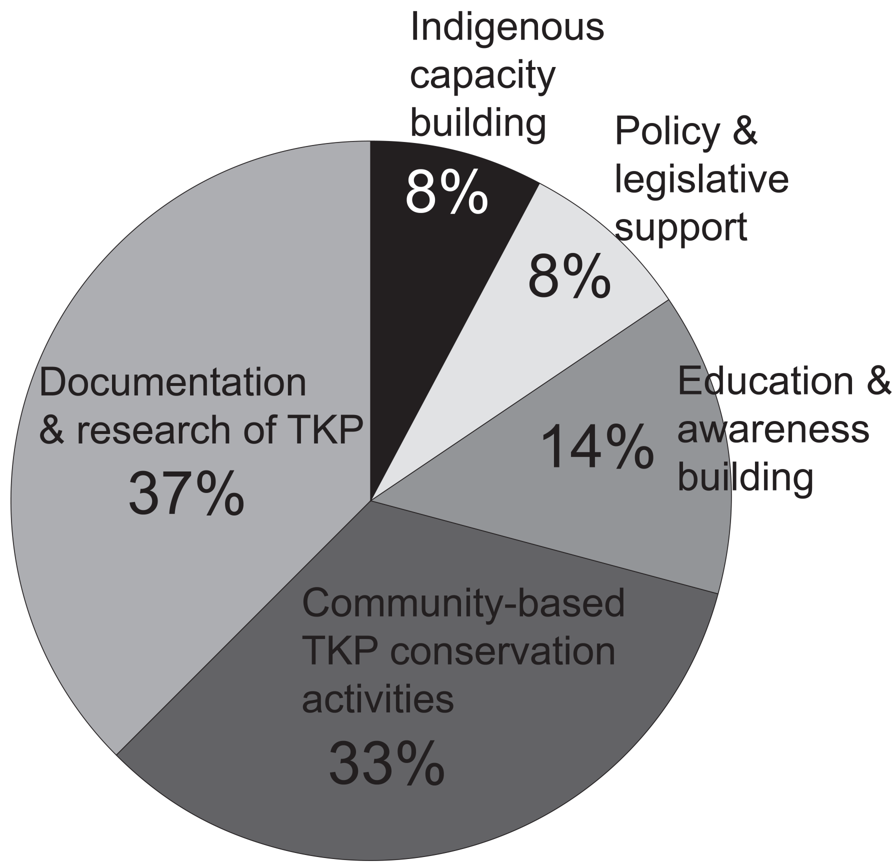


Figure 5.3: Academic studies that identify TKP preservation initiatives were categorized as per the categories of Tang, Gavin, et al., and then compared as a percentage of total initiatives ($N = 51$)

5.5 Discussion

In this investigation, we analyzed traditional knowledge and practice preservation strategies for the purpose of guiding future fieldwork by ethnobiologists. Our analysis of current strategies, follow-up assessments, recommendations, and directions of the nonprofit sector show gaps in the field that provide opportunities for ambitious students and researchers. This study offers five observations. First, there is a tremendous need for both quantitative and qualitative post-assessment measurements. Second, location data reveal the emphasis of TKP initiatives in some geographic regions. Third, of the extremely sparse follow-up data, anecdotal evidence pointing to inter-generational time on native lands gave the most applicable advice. Fourth, recommendations largely express difficulties merging traditional and conventional systems. Fifth, the nonprofit sector predominately focuses on policy and legislation, and focuses least on documentation and research of TKP.

5.5.1 Traditional knowledge and practice preservation strategies around the world

This current assembly of TKP preservation strategies reveals the state of the literature on TKP conservation. Authors discuss and refer to preservation initiatives, yet rarely give an assessment of past programs. When assessments are discussed, there is little to no quantitative or qualitative data to support any conjectures. Given the importance of traditional knowledge and practice systems in ethnobiology (Salick et al., 2003) and the availability of tools to quantify changes in TKP over time (Vandebroek and Balick, 2012; Reyes-García, Guèze, et al., 2013), our analysis shows the need and real possibility for studies in applied conservation of TKP.

Ethnobiologists can draw on methods from museum evaluations. Museums routinely do *post-hoc* assessments in the form of visitor evaluations. These methods are simple and would quite easily fit into a research plan. These evaluations include participant involvement in planning and then evaluation of attitude changes, learning, intent to return, and intent to recommend a given program (Bickman and Hamner, 1998; Rowe and Frewer, 2000; Harrison and Shaw, 2004). With slight modification, ethnobiologists can use these existing concepts to evaluate the impact and efficacy of their TKP research and projects.

The qualitative data that exists supports the idea that intergenerational ethnoeducation where elders and youth can learn on their native land is needed, desired, and productive for TKP preservation. Indeed, Cuerrier, Downing, Johnstone, et al., 2012 (2012) have shown the importance of inter-generational workshops to maintain TKP. Although related to climate change, Downing and Cuerrier, 2011 (2011) have illustrated the link between elders and youth for preserving cultural practices, leading possibly to community wellness and adaptation to global warming which visibly affects their northern climate. To determine the role of categories of TKP preservation in geographic areas, we mapped the strategies. We see some trends where databases and library curation predominates in Australia. Further, digital databases appear to be popular in Southeast Asia. Interestingly, the Americas show quite an even mixture of strategy categories. In all, an easily accessible list of TKP initiatives around the world would benefit research, community involvement, and interaction with volunteers.

5.5.2 Post-assessment data

Post assessment opinions highlight areas of hope and concern for TKP conservation initiatives. When taken together, a progression of ideas becomes clear. To begin, TKP preservation projects must be based on community needs (Royte, 2005). These projects should be community run (Audet et al., 2013) because when local elders are consulted, the population of the greater area may get a morale boost (Chunhui et al., 2012). Subsequently, potential programs facilitating inter-generational learning on the land can stimulate youth learning (Mathew, 1999). Later, when interacting with outside organizations, different knowledge systems may pose apparent barriers to project completion, but the struggle of learning and working with multiple knowledge systems and philosophies can actually give rise to novel and beneficial ideas (Wilder et al., 2016). In addition, modes of TKP, like art, can help community members process and start healing from past trauma of their community (Crawford, 2014). The aspects that have been praised, and seem to have good results, mainly share the concept of addressing needs on a personal level between a parent and child, or leaders discussing options for their community. Conversely, some aspects provoked negative comments in the literature. External types of approaches garnered criticism. For example, documenting TKP in a static state takes it out of its holistic context (Vivas Eugui and Ruiz Muller, 2001; United Nations, 2005). Given that TKP is not static (Pacón, 2004), but changing, a static state of pure documentation does not pose much benefit. Further, good policy changes with intentions of protecting or promoting TKP are often frustratingly difficult on a practical level. It often remains unclear how to implement the policy and moreover, cross-cultural training is many times lacking (Brockman, Masuzumi, and Augustine, 1997). Even if training and implementation instructions do come about, there is no guarantee that a new policy will change an outcome. Giving language as an example, the number of indigenous language speakers in the Canadian Northwest Territories is still declining even though all local languages have been given official status (Brockman, Masuzumi, and Augustine, 1997). While policies are very important for reasons such as societal inclusion, it appears that the continuation of TKP depends on personal interaction as opposed to an external system. Other ideas include that TKP resource centers and information services and dissemination of TKP via technology benefits local communities in a positive way (Beale, 2003). Additionally, some purport that digital databases may help prevent biopiracy (Vivas Eugui and Ruiz Muller, 2001; Poorna, Mymoon, and Hariharan, 2014). In all, the systems and frameworks to enable TKP use in communities, homes, and through interpersonal relations are valuable for just that, allowing TKP to be accessible to benefit personal needs.

5.5.3 Recommendations from the literature

Authors often recommended an ideal and clear picture of TKP conservation. The tricky part comes when the path to this imagery of vibrant TKP is blurry. Recommendations on Table 5.4 varied in their degree of specificity and clarity. In the category of "Indigenous capacity building," recommendations focused on notions of empowerment, infrastructure creation, and collaboration.

The recommendations from the "Community-based TKP conservation activities" centered on commercializing products related to TKP and integrating TKP into IPR (Twarog and Kapoor, 2004). The underlying idea would be that connecting traditional practices to the market economy will boost the monetary value and incentivize continued use of a given practice. Interestingly, there was also a calling for emphasis on conservation instead of monetization of resources (United Nations, 2001; Ottens, Dürbeck, and Otten, 2006). Along these lines, the objectives of community members often align with an emphasis on conservation (Cuerrier, Downing, Patterson, et al., 2012). These two notions, resource commercialization and conservation, seem to clash in the minds of some and seem to be harmonious in the minds of others. This shows the lack of complete understanding of how commercialization of local resources may or may not affect traditional knowledge and practice prevalence and conservation of the greater ecosystem. Whatever plan is used, Cash et al., 2003 (2003) admonishes planners to methodically plan, implement, and evaluate initiatives in the context of hands-on field experience. Further, if resources will be commercialized, Berkes and Davidson-Hunt, 2007 (Berkes and Davidson-Hunt, 2007) suggests management take a community-based focus with the management being done by people close to the resource as opposed to external overseeing agencies.

The recommendations from the "Education and awareness building" section focus on promoting the cultural value of TKP, disseminating it via schools and through new technologies, creating dialogue between societies, creating awareness of IPR amongst community members, and using indigenous art forms to address historical trauma. One of the most progressive suggestions was to use online communication technologies to connect seemingly distant, yet culturally complementary communities (United Nations, 2005). In this way, youth from a small community can collaborate with youth from another, possibly isolated, community. Increasing access to internet-capable mobile phones and the popularity of social media may foster communication for these communities (Owiny, Mehta, and Maretzki, 2014). While connectivity has been hampered in the past, access is quickly increasing around the world (IWS, 2017a). With these collaborations, they can form bonds, take pride in their culture, and develop their local TKP.

The recommendations from the "Policy and legislative support" section highlight the main problem that TKP and conventional IPR systems do not match. Many authors make a call to acknowledge the value of TKP and to create a new system as designated by the Latin term *sui generis*. Yet, what this *sui generis* system could, or should, be is lacking. Others feel that instead of trying to invent a completely new system, both external groups and local communities should focus on existing alternatives to patents (Vivas Eugui and Ruiz Muller, 2001). These alternatives may work for a given community in their current form, which include trademarks, trade secrets, and appelations of origin. Even if one of these would work just fine, other authors bring up the difficulty of getting large groups of people to agree, and if an agreement is reached, there is no guarantee that the agreement won't change in the future (Ceceña, 2000; Moerman, 2008). Delving into legal rights often requires communities to form one of various forms of corporations and file documents through this legal entity. For these formalities of IPR protection, researchers remind us that communities need high quality legal counsel (Vivas Eugui and Ruiz Muller, 2001). Yet even so, the legal ideologies are foreign and often contradictory to local systems, traditions, and beliefs.

The ideas suggested in the "Research and documentation of TKP" section stem from the thought process that documenting TKP can protect it from biopiracy. The going idea is that if a use for a resource is documented, then this documentation shows prior art, and therefore that a use cannot be patented by an external party. Having stated that, it does not prevent a person or company from patenting a process pertaining to some preparation or procedure related to that use. Since this knowledge is part of the community, some suggest that community-based documentation initiatives pose the best option (Oviedo, Gonzales, and Maffi, 2004). If this community-based model includes multiple generations it could help bolster inter-generational interaction. Community-based projects can take various forms. No matter which form it may take, this documentation is best when managed and used by community members. (Stevens, 2008; Maina, 2012).

Another option involves nurturing living collections such as botanic gardens. These can help document, disseminate, and promote TKP to the local community and beyond (Jones and Hoversten, 2004; Martellos et al., 2016). Botanic gardens serve as a useful tool for TKP preservation. They can expose TKP to the public, and they can include the public in various forms of conservation through citizen science programs (Martellos et al., 2016). Given the estimated 250 million visitors to botanic gardens each year (Ward, Parker, and Shackleton, 2010), they serve as a ready and useful TKP educational tool. Along these lines, Morgan et al. (2009) found positive changes in youth who participated in garden education programs. These included increased environmental awareness, social and personal growth, and positive life experience and cultural appreciation. More than education, gardens can even be incorporated into therapeutic services for disabled, orphaned, or at risk youth with criminal histories (Kuzevanov and Sizykh, 2006). If garden administrators include indigenous youth and elders in teaching and educational facilitation the lessons hold a reality and spark from the real life experience of these teachers.

5.5.4 Nonprofit and academic trajectory

The nonprofit sector showed a large proportion of mission statements focusing on "Policy and legislative support." This support focused mainly on representation for indigenous peoples or small community needs. "Education and awareness building" and "Indigenous capacity building" showed 25 and 20 percent respectively. While "Community-based TKP conservation activities" and "Documentation and research of TKP" had small shares at 10 and 5 percent respectively. This data shows the popularity of supporting indigenous rights and policy support along with notions of capacity building. Interestingly, inter-generational educational and community-based initiatives received enthusiastic praise in various research articles, and digital databasing and archiving received much discussion in the literature, but the nonprofit sector seemed to lean away from these towards policy and legal representation. In fact, policy support only received 8% of the discussion emphasis in academic publications, but documentation and research received the most (37%). This is not surprising that researchers would literally focus on research, but it also illustrates a disconnect between academics and nonprofit actions. It is common for research activities and to be disjointed from application. For example, biomedical research often does not reach the clinic and agricultural research often never enters the farm field in practice. Having stated that, it would serve researchers, nonprofit managers, and community members to be aware of this disconnect and build a plan that all parties view as beneficial to a mutual cause.

Links between academia and the nonprofit sector present an enticing opportunity for entreprenuerial ethnobiologists. A natural step from field research to applied ideas comes in the form of social entrepreneurship. Given the seemingly lopsided trajectory of nonprofit organizations and the hands-on experience of ethnobiologists, it is only fitting that application of concepts start being applied. Sadly, just as much of science remains abstract without translating into an applied form, many insights from students and seasoned researchers remain in abstracts and articles instead of helping grow TKP programs around the world.

5.5.5 Conclusion

The stances and strategies for the promotion and health of vibrant TKP do not fit into one sole approach (United Nations, 2005). Beyond the current state of TKP preservation, many questions remain. What will the condition of TKP systems be in the future? What effect will the current TKP conservation methods have? How can researchers identify and measure key aspects of TKP conservation? Researchers must address these questions with some means of data collection. When one attends conferences on an ethno-science like ethnobiology or ethnobotany, it is common to hear researchers speak of benevolent activities they or their students have done in the field to support TKP at their research site. Given this common chatter, it is surprising that few if any measurements are done in order to include follow-up from this work in publication of the project. This shows the great need for quantitative and qualitative measures to be included as a part of TKP conservation initiatives. We encourage ethnobiologists to consider working with social entrepreneurship groups to start programs that meet the needs of local communities, families, and individuals who hold and keep TKP. We view this analysis as helpful to startup organizations who seek to form their mission statement and to establish organizations who wish to assess their activities to ensure the success of their objectives to conserve traditional knowledge and practices.

5.6 Supplemental material

5.6.1 Highlights from the Literature

Throughout our search certain topics kept appearing. We present their key concepts below.

Communication

Recommendations for communication focus on two main channels. These channels comprise communication between elders and youth, and communication between keepers of TKP and conventional industry. For example, the Kugluktuk Angoniatit Association in the Bathhurst Inlet region of Nunavut created a project to stimulate TKP communication between youth and elders. This project consisted of interviews with a goal to document and report TKP of the region by the local youth (Thorpe et al., 2001). These types of projects provide a means to document knowledge of elders while fostering youth–elder interaction. Another form of communication suggested is communication between TKP practitioners and conventional industry. For example, some researchers call traditional healers and conventional physicians to communicate about remedies and patient treatments with the goal of providing treatment options adaptable to the patients' needs with the added safety from a joint understanding between healers and physicians (López et al., 2011). Mutual understanding of two world views allows participants from each philosophy to contribute their expertise. Often called "two-eyed seeing," this approach acknowledges the value of both TKP and science and encourages working and learning together (Bartlett, Marshall, and Marshall, 2012). Often TKP is seen as wholistic focussing on the interconnectedness of nature while science focusses on identifying component parts of a whole (Bartlett, Marshall, and Marshall, n.d.). With the two-eyed seeing approach, science does not dismantle TKP into component parts to extract useful knowledge, but TKP is used to assess the scientific questions asked, why they might be asked, and how they are asked (Martin, 2012). It is a system where both philosophies are able to refine and sharpen each other. This allows for the generation of ideas and review of current paradigms to further conservation goals.

To achieve conservation goals, some authors recommend collaboration between indigenous groups and outside organizations (Popova, 2014). This collaboration can initially present a challenge to work with groups who have different knowledge systems and philosophies, but this challenge ultimately gives fruit to clever new ideas and insights. Possible benefits of collaboration may be seen, for instance, in a combination of ecotourism with experiences of local elders. The going idea is that these elders may show what species were historically present on a landscape and help attach value to the ecosystem (Chunhui et al., 2012).

Ethnobotanical gardens

Ethnobotanical gardens present one of the most visually appealing strategies to preserve traditional knowledge and practices. While gardens can serve to document and preserve traditional knowledge and practices related to plants, humans, and animals

(Balick and Cox, 1996), they can serve a much more active role. Ethnobotanical gardens served as living pharmacies for European medical students during the early modern era (Heywood, 1987). More currently, the Q'eqchi' Mayan-Itzamma Garden in Belize provides medicinal plants to local traditional healers (Audet et al., 2013). Along with gardens come risks and challenges of plant establishment (Audet, 2009), and elements of design and planning. Fortunately, model garden plans exist and entrepreneurial garden planners can learn from these gardens (Jones and Hoversten, 2004). One core tenant is to create community run gardens. This avoids shifts in funding and guides the project towards sustainability (Audet et al., 2013). Also, one main goal of garden administrators should be to help familiarize young people with traditional plants (Martin, 1995).

Educational institutions

Educational institutions present a front line for TKP transmission. Some institutions incorporate ethno-education. Two examples include the Banfora Centre of Traditional Pharmacopoeia in Burkina Faso and Tumulkin Learning Centre in Belize. These schools combine conventional learning with traditional practices and experiences based on TKP (Dakuyo, 2004; Tumulkin Learning Centre, n.d.). With the growing scrutiny of schooling systems detracting from indigenous culture or even harming students in indigenous communities (TRC, 2015), these examples show an attempt to promote TKP via school systems. In this way, youth may fulfill their schooling in a competitive world, yet still retain and grow their cultural heritage.

Schools that include traditional practices also present an opportunity to connect students with elders of the community. The mixture of indigenous and modern education can help preserve traditions, such as native languages, and promote inter-generational connections (Arenas, Reyes, and Wyman, 2017). Programs in schools can teach about the decline in languages, which are the verbal expression of cultures, around the world (Harmon and Loh, 2010). This combined with the connection between biological and cultural diversity can help stimulate appreciation and motivation to protect delicate areas (Maffi, 2005). Of potential learning contexts, a case of a mutual learning environment between pupil and elder has given positive anecdotal results for student learning. An Eeyou-Cree elder, Robbie Mathew, reports that he takes youth on field trips to their ancestral land to practice traditions and customs of their people. Then he follows up with them months and years later to find that they have a renewed interest in learning (Mathew, 1999). This shows the importance of integrating TKP with learning tools to create a wholistic educational experience that nurtures cultural appreciation.

Policy and legislation

Legislation for the protection of TKP has been fraught with the circumstance that people consider much of TKP to be in the public domain, even though it still pertains to one or more communities. Because of this, some call for the acknowledgement that the collective nature of TKP deserves merit within a legal framework (Cabrera Medaglia, 2004). Current laws and legal schemes break down under the the intricacies of TKP which shows the need to create new laws to protect it (Kariyawasam, 2008).

Intellectual Property Rights

The idea of property stems from a concept of inclusion and exclusion (Ansong, 2014). If a person has access to something, and a set of people are excluded from access, this is considered a type of ownership. Examples of this are water rights where numerous people may have access to groundwater, yet others are excluded. However there are also forms of inclusion where nobody is excluded. This could be considered as access to air or sunlight. But some things that may be considered available to all are, in fact, not. Access to artistic or literary expression is not available to every person in the world. Some people are included and some are excluded. This concept of inclusion and exclusion gets tricky when large sets of people possess knowledge such as TKP. Since there is not one sole proprietor, some may consider TKP to be open for everyone, but this does not recognize the effort and struggle of the many community members who developed such knowledge.

Current IPR regulations allow a person or corporation to register proprietary knowledge of some form. But large groups of people do not fit this mold very easily. The main critique brought up time after time is that one may not know exactly to which person, group, or groups of people the IP belongs to (Yupari et al., 2004; Moerman, 2008). Further, current regulations on IPR do not provide protection mechanisms for knowledge that is held for long periods of time (Cameiro da Cunha, 2004). This leads to a great conundrum in that the going ideology is to promote TKP, while conventional patent regulations limit dissemination. Instead of positive, in that TKP grows, they are negative in that they restrict the number of people who can use a given concept (Roberts, 2004). This is an ongoing struggle with no clear solution. For this, along with the twenty-year expiry date of patents, some strongly suggest that local peoples take advantage of existing alternative mechanisms to protect IP such as trademarks, trade secrets, and appelations of origin (Vivas Eugui and Ruiz Muller, 2001). Yet a seamless meshing of knowledge systems remains elusive.

In some cases, problems arise when communities try to mesh knowledge systems. If the whole community does not agree on sharing TKP, but some members feel that it will benefit them financially, they might collaborate with outside speculators (Ceceña, 2000). Even if everyone in a community agrees to an elaborate contract, no guarantee exists that a nearby community does not possess the same or similar TKP, or that this TKP has prior art shown by a more distant group (Moerman, 2008). There does not seem be a guaranteed way to recognize the TKP of community members using current IPR strategies. This structure is geared towards entrepreneurial individuals and corporate entities that operate in the consumer economy.

Local communities do not share the same needs nor desires as a corporate enterprise. As seen in a quote from Mark Plotkin with the Amazon Conservation Team: "Tribes come to us. They want to protect their forest, culture, system of healing. They want clean water, job opportunities, ethno-education" (Royte, 2005). Local community members have a desire for the general well-being of their community.

5.6.2 Geographic Indicators

Geographic indicators provide a chance for local communities to protect marketable products. These provide regulations on the location in which a product may be produced. This can help local producers on tight profit margins, but can also lead to degradation of biodiversity as is the case with *Agave tequilana* F.A.C.Weber where this marketing protection pushed production of only one species (United Nations, 2014a).

Benefits

While TKP from some groups can help conservation of genetic resources (Fenta, 2004), conservation of genetic resources can also benefit indigenous groups. The re-introduction of traditional corn varieties demonstrated this when a seed bank inventory was able to replace that which a Brazilian tribe had thought was lost (Guedes and Amstalden Sampaio, 2004).

Libraries and digital databases

The tacit nature of TKP does not lend itself well to the information management schemes of libraries (Rahman, 2004; Maina, 2012). Because of this, some suggest that librarians must challenge the status quo and incorporate new strategies in their classification systems. Examples of this include the Brian Deer Classification System, curation services for TKP at the Galiqin'ku Indigenous Knowledge Centre in Australia, and editable metadata by keepers of TKP (Beale, 2003; Hunter, 2005; Maina, 2012). These systems can increase accessibility to and contribution of libraries and digital databases by keepers of TKP.

Digital databases play a key role in documenting, protecting, and disseminating TKP. Each scenario of databasing has its own intricacies and approach. Some databases place information in the public domain, while others restrict access and treat TKP as a trade secret (Vivas Eugui and Ruiz Muller, 2001; Poorna, Mymoon, and Hariharan, 2014). Some databases are community owned and controlled for local needs on a small scale, while others are on a national scale and aimed at preventing international biopiracy (Hunter, 2005). With all of these scenarios, the core problem is the difficulty in knowing if the original TKP holders gave permission for the release of information that has already been divulged to the public domain (Twarog, 2004). Out of this conundrum comes the popular idea that digitally documenting TKP is a way to show prior art and thus protect the future use, or misuse, of such TKP (Du, Guo, and Xue, 2013). The exact path or legal cost of warding off some misuse remains unclear.

5.6.3 Isolation

A contentious opinion is one that isolation promotes TKP. Given the tensions of apartheid in South Africa and the occurrence of segregation of groups of people, this example is highly debated (Philander, Makunga, and Platten, 2011; Philander, 2012). One must take into account that TKP is malleable and resilient in the face of change (Ondrusova, 2004; Pacón, 2004) when entering into this debate.

Chapter 6

Wary Welcome Turned to Warm Welcome

6.0.1 Traditional Knowledge and Practice Remodeling

Throughout my research with the Yoreme of southern Sonora, Mexico I have seen modifications of traditional knowledge form and expression. These modifications stem from ecological, economic, social, and familial circumstances. I chose to study these shifts in TKP and the interworkings of how these changes may occur. These changes in TKP are often described with a statement that traditional knowledge changes or evolves with environmental or socioeconomic conditions (Reyes-García, Aceituno-Mata, et al., 2014). In order to study these phenomena, I call the changing and adaptive expression of TKP "traditional knowledge and practice remodeling." Based on my previous mechanistic work with models of vascular remodeling, I coined this term to help describe the ideas and observations of TKP adaptation and change as one general concept—TKP remodeling. With this, we can conceptualize TKP change and investigate shifts, potential stimuli of these shifts, and conditioning factors that enable these changes to happen. Then, we may develop hypotheses of how this remodeling occurs, possibly predict how it may change in certain localities, and propose social programs to protect TKP and its associated biodiversity.

Traditional knowledge and practice remodeling shapes TKP as it supports individuals, families, and groups of people. While the idea that TKP is static and unchanging for millenia is vanishing fast from academic circles (Berkes and Folke, 2002; Reenberg et al., 2008; Gómez-Baggethun and Reyes-García, 2013; Reyes-García, Aceituno-Mata, et al., 2014), the mechanism of change and, even more, a clear pathway of TKP growth is yet unclear. Because of this, I investigated production and sale of medicinal herbs, artisan cactus fruit production, modes and mechanisms of local medicinal plant action, and TKP preservation initiatives. Through my research I have found that:

1. To keep up with world-wide shopping trends, traditional herbalist move their storefronts online.

2. People adapt TKP and artisan products to family and market needs. This often occurs amidst rapid encroachment of development to natural lands and sources of wild-gathered supplies.

3. Ethnomedicine research must include aspects such as natural history, phylogeny, public health, and molecular biology. This can guide studies on potential mechanisms of widely used herbal remedies towards goals of clinical studies, use in society, product creation, or toxicology.

4. While policy, technology, and commerce are good and needed as TKP support, the crucial factor of TKP health seems to be time in nature with elders—

implying family and community support programs are a promising direction for social entrepreneurs.

6.0.2 Market Adaptability

Given public news stories of corporate failures where retailers fail to adapt to digital shopping habits (Newman, 2010; Blatt, 2014; Vocoli, 2014), it is refreshing to see local herbalists adapt to these digital trends. Interestingly, a fellow researcher has told me that she saw similar trends in her work at herbal markets in Ghana. Observations such as these might be more common than we see reported in the literature. Recently, there has been a swing away from browsing at brick-and-mortar stores to browsing online. The internet is now not the secondary source of information, but the primary where people will refrain from purchasing before they have the chance to compare similar products online (Hartjen, 2014; RetailWire, 2014). Considering current shopping trends, I predict that online promotion and sales of herbal medicine will become the norm.

One peculiarity considering digital trends in seemingly remote areas and communities are some presumed truths, which are actually misconceptions. These misconceptions include ideas that people, or countries, with less overall income have less connectivity to cell phones, phone networks, or the internet. In addition, one may assume that a phone may have less functionality if it is not a model sold in an affluent country. In my experience, the complete opposite is true. In 2011, when I was in El Petén, Guatemala, I realized that my button-style cell phone was just that, only a cell phone. Whereas my new-found friends who earned a Guatemalan minimum wage had phones that doubled or tripled as other tools. Many phones had incorporated flashlights, and the cellular network gave access for easy money transfers and music purchases. As touch screen phones became more common, my research contacts across Guatemala, Belize, and Mexico would communicate with me on WhatsApp and Facebook Messenger while students and professors continued sending regular SMS messages or calling using a minute-based rate plan. The fast advancement of mobile networks can occur by simply building cell phone towers. In contrast, the transition of phone service in other regions took a slow progression from party lines, to private land lines, to car phones, to cell phones. This progression still occurs as I remember a fellow farmer in Saskatchewan, Canada telling me in 2008 how just a few years ago he got 911 service hooked up to his landline. These steps are being jumped by cell-phone towers in many communities. In all, indigenous people around the world are either currently connected or going to shortly be connected to the internet. How this will affect the availability, marketing, and especially the use and preparation of medicinal plants is yet to be seen. I have seen that with this transition, prepared and ready to use herbal preparations predominate as opposed to raw material for home preparation. A following question is how will TKP pass from the herbalist to the end user? It may be that people will search online for information and reduce consultations with herbalists, or it may be that online channels will facilitate wider coverage and enable more one-on-one consultations with local practitioners. This is just the beginning of large changes I expect we will see in the future.

6.0.3 Landscape Changes

Outside of the market, and in the field, TKP is caught in the middle of development pressure and natural landscapes. The shrinking of natural areas not only removes supplies such as pitaya—the fruit of *S. thurberi*, but it removes homes and family-heritage places from the landscape. During one plant collection trip I drove my 1996 black Chevy pickup truck down a road facing a rolling sea of green thornscrub. As my colleagues and I looked over this expanse of seemingly pure botany, Pricila broke the silence and said, "*Hay gente. Parece que no, pero hay gente.* (There are people there. It does not seem like it, but they are there.)" This seeming expanse of land and resources was in fact someone's house, yard, ranch, park, and their children's playground. People, plants, and cultures are affected by land-use change. Unfortunately, the food production, nutrition, and livelihoods of people and their families are seldom taken into account when land is developed for some other use. The wealth of long-standing native vegetation, if utilized in its own right, can produce much income and social benefit. Even though water is too scarce to plant an orchard of *Citrus* spp., and too scant to plant two grain crops a year, productive stands of pitaya fruit, medicinal herbs, cultural objects (deer dance *tenobarim*), and meat (hunting game) succumb to the bulldozer. But for any change in this direction of development to be successful, people's attitudes must support the people, plants, and culture of the region. For large social change, I believe the Yoreme must overcome a general anti-indigenous attitude in the region.

This stigma towards indigenous people must disappear. The natural wealth of the Sonoran landscape cannot be cherished unless the idea of 'uneducated Indians' and subsequent association with their food and medicine vanishes. During my field observations I heard many negative comments about indigenous people and their level of education. Inaccurate educational studies do not help make positive attitudes prosper either (Fernández Nistal and Mercado Ibarra, 2014). These negative tones in society hinder people from taking pride in their natural environment and the people it supports. For this, the whole paradigm must shift from an attitude of indigenous culture being second best to being the cream of the crop. Local producers will never gain favor in a regional market given prejudicial undertones. Therefore, I recommend that social entrepreneurs focus on fortifying networks of local producers and youth who can expand sales and markets online. The connectivity and talent exists in the valley. Now entrepreneurship incubators and networks must be formed to help motivated young people to launch successful ventures in their environment. Will the value and investment of natural pitaya stands ever compete with development of houses and annual crops? I hope so, because it would take multiple human generations to replace cactus stands and associated wildlife that could disappear, and then, would people remember the sweet fruit of the pitaya enough to replant it? This scenario is troubling and seems difficult at best.

In the Mayo Valley, as many areas of Mexico, rural people practice various forms of land management. While discussing development of land for agriculture or other uses, it is important to remember the long history of Mexican traditional agriculture. In fact, from the earliest known migrations of peoples into Mesoamerica, archaeological evidence shows domestication of heritage crops such as corn (*Zea* L.), beans (*Phaseolus* L.), and squash (*Cucurbita* L.) (Zizumbo-Villarreal and Colunga-GarcíaMarín, 2010). Humans shaped and managed natural landscapes. While a human-shaped natural landscape may seem difficult to conceive of given the popular notion that prestine wilderness is devoid of human inhabitants, reality around Mexico shows otherwise (Gómez-Pompa and Kaus, 1992). Even long-term growth *Stenocereus stellatus* (Pfeiff.) Riccob., a pitaya from central Mexico, has been shown to be human managed, cultivated, and artificially selected (Casas et al., 1997). This heritage holds strong in southern Sonora and northern Sinaloa. Here the Yoreme manage natural lands and also cultivate conventional crops and local species in home gardens. While the scale, practices, and philosophy of these management and cultivation practices may differ from larger developments, they do share one aspect—feeding people. With this commonality, I hope that both people in villages or cities, with a home garden or large tract of agriculture, or even an onlooker of the thornscrub vegetation can have an appreciation for the plants and landscape that sustains them. While most people think of conservation in terms of resources, I realized an appreciation on a personal level when I saw a sign posted by the Tehuelibampo Museum that states, "Nature is insulted and only offers treasures and flowers in response" (Fig. 6.1).

Figure 6.1: Inspirational sign at the boat crossing to the Tehuelibampo Museum written in Spanish stating, "Nature is insulted and only offers treasures and flowers in response. Respect this place."

During my research and analysis, I noticed one municipality that actually increased in natural land cover between 1996 and 2011. This municipality is Huatabampo, and during field work there I found the comments of local consultants interesting. They mentioned that some people from SEMARNAT (*Secretaría de Medio*

Ambiente y Recursos Naturales, Secretary of the Environment and Natural Resources) would come tell them to take care of the wild lands. Local residents mentioned that while they themselves would tell people not to chop brush just for fun, they had no real authority over any large changes. Yet they also stated that they would seed chiltepín chile peppers in between the thornscrub vegetation and also range goats there. These observations bring up interesting ideas of agriculture on natural landscapes. Firstly, if landscapes such as the stands of *Stenocereus thurberi* are preserved, could even more production occur from inter-cropping systems? Secondly, what dietary benefit in the form of food security could come from promoting such management? Thirdly, would paid land conservation programs work well in the area and are the individuals from SEMARNAT part of a program like this? (It is not customary to discuss finances and I would not expect someone to inform me if they or the community, as a whole, was getting paid to conserve some nearby land.) Finally, and most importantly, what concepts can be learned from this municipality to use as a model for other municipalities that have diminishing cover of slow-growth natural landscapes? Given the long history of multi-cropping in traditional Mexican agriculture, the promising scenario of Huatabampo's increase in natural land, and the entrepreneurial spirit of local landholders; land conservation mixed with stimulous of traditional multi-cropping systems may prove a good method to conserve habitats, provide an income, and continue the legacy of Mexican traditional agriculture. In addition to conservation, herbalists would benefit from teaming up with local land managers. Currently herbalists who sell in markets rely on wildcrafters. These wildcrafters collect plants in natural landscapes and take them to markets to sell wholesale. Yet, often a herbalist would tell me that sometimes they do not have a consistent supply. Forming networks between herbalists and land managers who manage large species such as *Stenocereus* *thurberi* and also smaller undergrowth such as medicinal herbs and culinary chiles could provide a sustainable model for both business and ecological health.

Within this system, the adaptation of pitaya producers to sell value-added products under severe habitat destruction is intriguing. It gives hope to small producers. But more than this, it shows that there may be a possibility to conglomerate multiple players via entrepreneurship incubators. With this, producers may be able to connect with digital marketers, distributors, and potential buyers. This would be different than cooperatives where multiple producers band together. In a conversation with a well-respected community leader in Tehuelibampo, I was told that cooperatives often fail because they are made up of strangers working together. Further, they often compete one with another. He also noted that he thought family units can succeed. This spurred the idea with me that possibly the problem lies with the fact that each member was producing the same thing. What if the groups took tools from models of entrepreneurship that worked? Then we would have producers of pitaya connected with marketers, legal advisors, and other key elements of success. With various strong ventures, the onslaught of developing "vacant" land filled with wonderful *Stenocereus thurberi* might just slow down.

6.0.4 Plants' Effects on Humans

While people shape the landscape of and markets for plants they use and depend on, these plants also affect the human body. To investigate these effects, I reviewed medicinal Cucurbitaceae species in light of their phylogeny and focused on *Ibervillea sonorae* for biochemical studies. During this review a mountain of validation studies on *Momordica charantia* began to accumulate. Many have slight modifications, but the general idea is the same. One administers a dose of an extract, measures parameters such as blood glucose and insulin levels, they may do some extra studies on the liver, and then report that the traditional remedy has hypoglycemic properties. While validation studies are important to advance science, how many more mice, rats, and rabbits need to fall to the researchers guillotine before we establish that there is hypoglycemic potential? The answer is none. A better, guided research question would be, "What shall we do with this potential?"

The research field in herbal medicine needs updating. Too many studies do not have a clear long term goal. I understand this since I, myself, am a graduate student who needs to publish. Each student and many professors want to find an effect of an ethnomedicine. People often ask me if a remedy "works." I think that ethnomedicine studies should contain aspects of botany and natural history, phylogeny, *in vitro* or *in vivo* studies, and interpretation towards their goal. This goal could be the long road towards clinical trials, it could be to gain social understanding on use of a herb within a society, to produce a natural supplement, or to do toxicological work. In any event, the goal should be clear. The long list of studies that do mainly the same thing do not progress science as much as a study towards a clear goal well placed in the context of the literature.

By examining phylogeny combined with medicinal reports, we can see gaps in knowledge and identify potential hypoglycemic species or potential mechanisms of action within species of a phylogenetic branch. One of these understudied branches is the Coniandreae tribe. Within this tribe, *Ibervillea sonorae* is a popular remedy in Mexico and the American Southwest. We found that it competitively inhibits α-glucosidase and stimulates insulin secretion *in vitro*. The significance of this lies in the need to know how plants may affect humans. One of the most used reference books on herbal medicine consumption is *Physicians Desk Reference for Herbal Medicine* (Gruenwald et al., 2007). This volume compiles clinical and *in vitro* studies of potential activity, contraindications, and side effects. These sections help guide physicians on potential interactions between conventional medicine and herbal medicine that may act on the same or different pathways in the body. In the same way, our study can shed some light on possible interactions between *I. sonorae* and conventional treatment. For example, if one takes acarbose alongside *I. sonorae* which also inhibits α-glucosidase, it is possible that they could experience extra gas and bloating—the side effects of too much α-glucosidase inhibitors. In addition, medications that stimulate insulin secretion such as sulfonylureas may cause extra strain on β cells of the pancreas. In all, one great benefit to studies on widely-used plant-based medicines is an understanding that can guide the safe use of natural medicines within the populations that rely on it. This guidance touches more lives than a search for an active constituent that even, if found and given current drug trial success rates, most probably will not ever reach the clinic (Independent Institute, 2016; Thomas et al., 2016).

6.0.5 Traditional Knowledge and Practice Preservation Around the World

My original idea for the review on TKP preservation was to find and assemble trends, experiences, qualitative data, quantitative data, and post assessments of TKP conservation initiatives around the world into a model of TKP conservation. With this goal in mind, I enthusiastically planned to build a proposed model of tactics for making a lasting impact in the use and even growth of TKP. With this idealistic model, researchers, volunteers, and indigenous people could have a guide for idea generation and guidance from previous experiences of projects that worked and projects that did not. This lofty goal proved more difficult than I had hoped. Interestingly, the lack of follow-up studies revealed a huge opportunity to incorporate existing tools from museum evaluations to ethnobiology studies (Foster, 2008; Walhimer, 2012). Filling this current gap in knowledge would make a large contribution to our understanding of TKP maintenance. These evaluations could also be used by nonprofit organizations to guide their initiatives.

From reading through studies and anecdotes, the common thread seems to be that TKP starts in the home and with elders on the natural landscape. This experiential learning seems to be the most crucial part of TKP learning and conservation. Reasonably, one must consider that variables such as land-use policy, educational systems, cultural centers, libraries, and other supportive items enable and brace up TKP. But if all these are in place without intergenerational learning, TKP stops its flow from one generation to another.

6.0.6 Meanderings Continue

As I reflect on my research experience in the Mayo Valley with the Yoreme people, I am filled with both awe and questions. I am amazed how similar we actually are. Nature knows no boundaries and seems to accept everyone into its botanical home. Unfortunately, greater society is not as welcoming. I heard the prejudicial logic of common expressions around cities like Ciudad Obregón and Navojoa. If one strings together the comments they look something like this list below with my observations following each sample comment:

"*Es que ellos no tienen educación*—They are uneducated (regarding indigenous people's manner of speaking)" Observation: The schools in the communities are lacking funding and teachers who arrive consistently at school and teach. I actually had people begging me to teach their children to read.

"*Son muy flojos*—They are very lazy" Observation: I was awoken each morning at 4:30, 5:00 and 5:30 by big yellow school buses picking up people to go work in greenhouses and fields. These workers work all day for $100 MXN ($7.50 USD equivalent at the time). Regarding the cost of living, it is important to keep in mind that while affluent Mexicans drive to Tucson and Phoenix in the United States to buy cheaper clothes, tools, and home supplies, the access to consumable products in largely indigenous communities is severely reduced. I was shocked to see worn out jeans for sale at a price of $400 MXN ($30 USD) when I was wearing new ones from Kmart that I bought for $24 and passed up the pair for $17 while I was there. So the idea that the cost of living is low might be true for hiring manual labor, but if you are the manual laborer, the cost of living is quite high!

"*No trabajan*—They do not work" Observation: It is difficult to get a job when one is relegated to a specific social group.

"*Es que gastan todo su dinero*—It is that they spend all their money" Observation: Money has one purpose—to be spent. And it appears that home budgeting, if it differs at all from non-indigenous residents, is independent of large scale land-use change, education, and work opportunities.

"*No va a ser un parto indio*—We are not going to have an Indian birth" Observation: Stigmas against traditional medical knowledge come from medical workers; in this case it was an obstetrician.

In all, circular and prejudicial arguments hamper inclusion into society. Because these connection between indigenous communities and non-indigenous society are so fragile, I am concerned about *de novo* initiatives of TKP-related activities. These may include ideas on herbal medicine marketing, treatment with herbs, artisan pitaya products, or TKP conservation projects. Given that the foundation of entrepreneurial projects and social ventures is a well-connected network (UC Davis Food and Health

Entrepreneurship Academy, personal communication during coursework, February 1–5, 2010), I worry that these frail connections between the Yoreme and greater society may hinder potentially successful TKP-related initiatives. Because of this challenge, I recommend the formation of social entrepreneurship incubators where local indigenous producers are connected with (1) other producers, (2) legal support and education on local permits, (3) pedagogy support, (4) marketers, (5) tool suppliers, (6) web designers, and (7) local government offices. These participants can be local youth who are interested in one sector of this division of labor or other companies in nearby towns and cities. With a strong network, I predict that social entrepreneurship and conventional commerce will increase for local indigenous people just as it helps entrepreneurs in general. One caveat could be that the philosophy of life is different and varied across indigenous peoples and especially when compared to urban society. It is my hope that a focus on social entrepreneurship can retain much of these cultural ideas and even help them grow.

My time with my friends and colleagues—the Yoreme of southern Sonora has helped me learn about plants, traditional knowledge and practices, and world views. As I reflect back, I see that the social constructs that divided us in the beginning broke down very quickly in the field. My Yoreme colleagues and I are not so different. We might come from different societies, but we have always shared the same botanical home.

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Appendix A

Word Usage and Meanings

Throughout this text I used terms in the most respectable and acceptable manner of the day. Often word usage and meaning changes over time. A good example of this is the word *primitive*. While it used to be used in academic circles, it now has a very negative connotation. Interestingly, in recreational survival groups, this very same word used in the sense of "primitive camp" or "primitive skills" holds a positive meaning. This example shows that word meanings can change over time and also have different connotations to different groups of people. With all that being said, I chose the most respectful phrases at the time of writing.

I chose to use the name *Yoreme* instead of *Mayo* simply because the Yoreme tribe calls themselves Yoreme.

I chose to use the word *tribe* and *indigenous* because the Yoreme use these same terms (in Spanish) when conducting any type of organized event or meeting.

I chose to use the word *informant* or *consultant* because this is the current way to speak about a person who participated in a study without giving identifying information on that individual. This is considered ethical. Along these same lines I changed the names of individuals referred to in the text to protect their privacy. During my studies, the term consultant became more common in the field of ethnobotany.

I chose to use the word *expedition* or the phrase *field trip* in the sense of going to a study site. While some people may attach a sense of colonialism to *expedition*, other may attach the sense of an elementary school outing to *field trip*. In all, I mean them to simply signify that I went to collect ethnobotanical data.

Appendix B

Vendor Surveys in English and Spanish

B.0.1 Vendor Survey

Who are your customers? What do they do for a living?

What ages are they? 10–20, 20–30, 30–40, 50–60, 60–70, 70+

What gender are they? _____% Male _____% Female

What language do they speak? _____% Spanish _____% Yaqui _____% Mayo

Who are your suppliers?

- Local gatherers/distributors
- Out of area gatherers/distributors
- Local distributors
- Out of area distributors
- Other _______

What is your target demographic for customers?

What is not in stock, but sometimes is here?

How do you know the uses of each plant?

- Internet
- Parent
- Elder
- Customers
- Friends
- School
- Books
- Family, passed down from generation to generation
- Stories
- Other ________

What plants are local and what plants are brought in from outside areas?

When are plants delivered here?

Does inventory change throughout the year?

- In what seasons does inventory change?

When are sales highest?

- What time of day?
- What season?

When are sales lowest?

- What time of day?
- What season?

Why do customers come buy herbs?

- Treat someone sick
- Prevent sickness
- Restock herb supply
- To resell
- Other ________

When do customers buy medicines?

- Certain time of the year
- When an ailment demands it

Where do you advertise?

How do you advertise?

Do you use social media in advertising?

- How so? Email, Facebook, Twitter, etc.

Do you use social media to talk with customers?

Where do the plants come from?

How do you find supply?

Do you have a story of a plant or some plants you could share?

*We originally planned to ask the vendors about each species in their inventory. This was not possible due to vendors feeling the need to protect their business by not divulging their inventory. Until it is clear to the informant that no conflict of interest exists, these questions are more difficult to ask.

B.0.2 Encuesta para el Vendedor

¿Quiénes son sus clientes? ¿En qué trabajan?

¿Qué edad tienen sus clientes? 10–20, 20–30, 30–40, 50–60, 60–70, 70+

¿Cuál es el género de sus clientes? _____% Masculino _____% Femenino

¿Qué lengua hablan sus clientes? _____% Español _____% Yaqui _____% Mayo

¿Quiénes son sus provedores?

- Colectores locales/distribuidores
- Colectores fuera del área/distribuidores
- Distribuidores locales
- Distribuidores fuera del área
- Otros ________

¿A qué sector de la población o tipo de clientes dirige sus productos?

¿Hay algo que no se encuentra almacenado aquí en este momento, pero que a veces lo ofrece como producto?

¿Cómo conoce el uso de cada planta?

- Internet
- Padres

- Gente mayor
- Clientes
- Amigos
- Escuela
- Libros
- Familia, transmitido de generación en generación
- Relatos
- Otros________

¿Cuáles plantas son locales y cuáles son traídas de otras áreas?

¿Cuándo son entregadas las plantas aquí?

¿El inventario cambia a lo largo del año?

- ¿En qué estaciones del año cambia el inventario?

¿Cuándo son las ventas más altas?

- ¿Qué hora del día?
- ¿En qué estación del año?

¿Cuándo son las ventas más bajas?

- ¿Qué hora del día?
- ¿En qué estación del año?

¿Por qué compran hierbas sus clientes?

- Tratar a alguien enfermo
- Prevenir enfermedades
- Reabastecer la oferta de hierbas
- Para revender
- Otro________

¿Cuándo compran medicinas los clientes?

- En cierta temporada del año
- Cuando tienen algún problema de salud

¿En dónde se anuncia?

¿Cómo se anuncia?

¿Utiliza medios electrónicos o redes sociales para anunciarse?

- ¿Cuáles redes sociales usa? Correo electrónico, Facebook, Twitter, etc.

¿Utiliza medios electrónicos o redes sociales para comunicarse con sus clientes?

¿De dónde vienen las plantas?

¿Cómo encuentra oferta de plantas?

¿Tiene alguna relato de alguna planta o alguna de sus plantas qué quisiera compartir?

*Originalmente íbamos a preguntar a los vendedores sobre cada especie de planta en su inventario. Esto no fuera posible porque los vendedores sentían la necesidad proteger su negocio y no dar su inventario. Hasta los vendedores quedan seguro que no haya conflicto de interés, estas preguntas son difíciles preguntar.

Appendix C

Mexico Land-use Rate of Change Protocol

Start: Create an Arcmap file named 20**_**_ **_Mex_Soil_Use_Rate

1) Add data: Mexico administrative boundaries Source: Diva GIS

Project: ESRI World Cylindrical Equal Area # Equal area projection is the crucial piece. This allows accurate comparison of land-use area. Other projections preserve shape while distorting area. A non-equal area projection would introduce much error.

2) Add data: "usoSueloVegetacion" (Data from 1996 field verification)

Source: INEGI (http://www.inegi.org.mx/geo/contenidos/recnat/usosuelo/Default.aspx)

Project: From ITRF 1992 to WGS84 and then from WGS84 to ESRI World Cylindrical Equal Area

3) Add data: "CAPA_UNION_SV" (Data from 2011 Landsat and field verification)

Source: INEGI (http://www.inegi.org.mx/geo/contenidos/recnat/usosuelo/Default.aspx)

Project: From ITRF 1992 to WGS84 and then from WGS84 to ESRI World Cylindrical Equal Area

4) Export Attribute table: Open attribute table → Table Options → Export (All records) → Create CSV files of the 1996 and 2011 land use polygons

5) Assign binned soil categories: The steps below allow us to categorize the soil uses for the 1996 and 2011 years. INEGI used more classification names in the 2011 year. For our purposes, we ask if it is Induced (developed by humans), NA (Not applicable body of water or land devoid of vegetation), or Natural (Land not developed for farms or cities). We know there is no true "wild land", therefore we set our inclusion and exclusion criteria to be land not considered agricultural by INEGI, and not city or some other modern use.

In the CSV file, place the following calculation to bin the land use into Induced, NA, or Natural. For info on this Excel calculation using, ISNUMBER and SEARCH see http://www.annielytics.com/blog/excel-tips/find-text-within-text-excel/.

```
= IF(D2="","", IF(ISNUMBER(SEARCH("*agricola*",D2)),"Induced",
    IF(ISNUMBER(SEARCH("*Natural*",D2)),"Natural",
    IF(ISNUMBER(SEARCH("*Inducido*",D2)),"Induced",
    IF(ISNUMBER(SEARCH("*Cultivado*",D2)),"Induced",
    IF(ISNUMBER(SEARCH("*ACU*",D2)),"NA",
    IF(ISNUMBER(SEARCH("*agricultura*",D2)),"Induced",
    IF(ISNUMBER(SEARCH("*bosque*",D2)),"Natural",
    IF(ISNUMBER(SEARCH("*asentamientos*",D2)),"Induced",
    IF(ISNUMBER(SEARCH("*Chaparral*",D2)),"Natural",
    IF(ISNUMBER(SEARCH("*Agua*",D2)),"NA",
    IF(ISNUMBER(SEARCH("*desprovisto*",D2)),"NA",
```

```
IF(ISNUMBER(SEARCH("*Manglar*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*Matorral*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*Mezquital*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*Palmar*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*extranjero*",D2)),"NA",
IF(ISNUMBER(SEARCH("*popal*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*Pradera*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*Sabana*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*sabanoide*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*Selva*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*aparente*",D2)),"NA",
IF(ISNUMBER(SEARCH("*Tular*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*oyamel*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*arenosos*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*dunas*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*agricola*",D2)),"Induced",
IF(ISNUMBER(SEARCH("*sin vegetacion*",D2)),"NA",
IF(ISNUMBER(SEARCH("*Urbana*",D2)),"Induced",
IF(ISNUMBER(SEARCH("*xer*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*Hal*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*galer*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*pet*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*hidr*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*Riego*",D2)),"Induced",
IF(ISNUMBER(SEARCH("*gips*",D2)),"Natural",
IF(ISNUMBER(SEARCH("*Huiza*",D2)),"Natural",
```

IF(ISNUMBER(SEARCH("*otros*",D2)),"Natural","Unkown"
)))))))))))))))))))))))))))))))))))))))

6) Join: Join this CSV to the shape file for Land Use 1996 and Land Use 2011 Right-click on your layer → Join

Make sure to use a column with a unique identifier that does not change to base the join. You could use the Object ID or FID (if your fields have not moved in your Excel file or attribute table).

7) Export shape files on one land use type: Select the attribute table by criteria Open attribute table → Table Options → Select by attributes (Make sure to clear selection between subsequent steps)

Select the Induced land in the 1996 layer Right click the layer → Export data (Export it as shape file) Export as 1996_Induced

Select the NA land in the 1996 layer Right click the layer → Export data (Export it as shape file) Export as 1996_NA

Select the Natural land in the 1996 layer Right click the layer → Export data (Export it as shape file) Export as 1996_Natural

Select the Induced land in the 2011 layer Right click the layer → Export data (Export it as shape file) Export as 2011_Induced

Select the NA land in the 2011 layer Right click the layer → Export data (Export it as shape file) Export as 2011_NA

Select the Natural land in the 2011 layer Right click the layer → Export data (Export it as shape file) Export as 2011_Natural

8) Intersect: Intersect the layers with the land changes to the layers with municipalities Toolbox → Analysis Tools → Overlay → Intersect # This will give us the land area changing within one municipality. This could be done with the state or national shape files. It could also be done with a grid of 100-hectare squares around Mexico.

Intersect the Municipality map and all variables individually. This will give data with the municipality attribute included.

1996_Induced → Intersect Municipality → 1996_Induced_Intersect

1996_NA → Intersect Municipality → 1996_NA_Intersect

1996_Natural → Intersect Municipality → 1996_Natural_Intersect

2011_Induced → Intersect Municipality → 2011_Induced_Intersect

2011_NA → Intersect Municipality → 2011_NA_Intersect

2011_Natural → Intersect Municipality → 2011_Natural_Intersect

9) Area Calculation Soil: In each attribute table add a field named Hects_Int.

Calculate Geometry: Area in hectares

each attribute table add a field named Km2_Int.

Calculate Geometry: Area in Kilometers Squared

In each attribute table add a field named Mi2_Int.

Calculate Geometry: Area in Miles Squared

Make sure you were on an equal area cylindrical coordinate system. # Click *Yes* when it asks you to calculate with numbers too large. This is why we have miles squared. So we can catch the area even if ArcMap will not calculate large or small polygons with only one unit.

10) Sumifs(): Open the attribute table for each layer Table Options → Export (All records) → Import into Excel Use the sumifs() function to sum the total Induced, NA, and Natural polygon areas separately. Then save this as a column with the municipality and the total land area in each category. Alternatively, you could sort cells by municipality then use a simpler equation: =IF(AQ2<>AQ3,"***","") This puts a triple asterisk at the end of each list of municipalities. Then use the equation: =IF(BL1<>"***", BM1+BJ2,BJ2) to sum the areas of municipalities continuously with the total at each ***. Finally, copy values and sort for the ***. These are your summed areas per municipality.

Use the =IF(ISERROR... function to get rid of empty fields. We only want numeric fields for ArcMap.

Save this as a *.csv and join it to the municipal boundaries layer.

11) Note that not all municipalities have a polygon in them for each category. To assign each polygon to its appropriate municipality, export a list of municipalities from the Mex_boundaries shape file, list these in Excel, then use the INDEX-MATCH function to match the proper value to each municipal label.

12) With our areas for two years, we can calculate rates of land transformation. We could do algebraic functions dividing by the municipal area or we could do log functions to get rates based on starting area. We can also make maps with percent-land cover for municipalities or states in Mexico.

13) Check your data that there are no empty fields. Copy values to a different sheet so you only have numeric fields.

14) Right-click on the Municipal boundaries layer (projected as equal area) → Join your CSV of choice based on the municipal IDs (ID_2).

15) We now have the area of Induced, NA, and Natural vegetation polygons connected to municipal boundaries for Mexico for 1996 and 2011.

Notes: ArcMap only accepts numeric fields well. Use IF(ISERROR) to change empty cells into an impossible value that you can exclude from your map.

To compare maps with the same color ramp, import symbology from the map with the lowest minimum threshold. This will give colors that are representative across images. Properties $\rightarrow$ Symbology $\rightarrow$ Import

Appendix D

Land-Conversion Rates and Total Natural Land Area

During our analysis of land-conversion rates, we found a peculiar case of natural land increasing in the municipality of Huatabampo. When looking at rates that differ from nearby rates one needs to assess the proportion of natural land cover. Because if the proportion is quite small, the rate may be due to small fluctuations that get magnified due to small numbers. But in the case of Huatabampo, the proportion of natural land cover is at 42%. This signifies that land clearing has slowed and even reversed on average throughout the municipality. Our study has described an alarming trend throught the area, yet also a municipality with momentum against this trend. It would be very interesting to examine community and local government actions that may contribute to this net increase in natural landscape. Hopefully the same policies could be implemented in other nearby municipalities and lead to greater appreciation and use of the thronscrub vegetation and species such as *Stenocereus thurberi*.

Here, I provide a table (Table D.1) of land-conversion rates along side total natural-land cover to assist these comparisons. Furthermore, if one uses this method and finds a location with high conversion rates of natural land that also have a high percent of total cover, it may serve as a model for conservation programs in other nearby areas.

Table D.1: Land-conversion rates across Mexican municipalities. The rates are calculated from INEGI census data from 1996 and 2011. The proportion of natural land per municipal area is given for the year of 2011. See text for calculation details. The designation NA signifies insufficient data to calculate a rate

State	Municipality	Land-conversion rate	Proportion of natural landscape
Aguascalientes	Pabellón de Arteaga	-0.011	0.267
Aguascalientes	Aguascalientes	-0.005	0.320
Aguascalientes	Calvillo	-0.001	0.576
Aguascalientes	Asientos	-0.001	0.362
Aguascalientes	San José de Gracia	0.000	0.798
Aguascalientes	Rincón de Romos	0.001	0.436
Aguascalientes	Jesús María	0.002	0.509
Aguascalientes	Cosío	0.007	0.343
Aguascalientes	Tepezalá	0.029	0.384
Baja California	Mexicali	-0.001	0.657
Baja California	Tecate	-0.001	0.884
Baja California	Tijuana	-0.001	0.570
Baja California	Mulegé	-0.001	0.946
Baja California	Ensenada	0.000	0.940
Baja California Sur	La Paz	-0.001	0.951
Baja California Sur	Mulegé	0.040	0.963
Baja California Sur	Comondú	0.059	0.918
Campeche	Campeche	-0.013	0.728
Campeche	Hecelchakán	-0.013	0.744
Campeche	Tenabo	-0.011	0.771
Campeche	Hopelchén	-0.005	0.877
Campeche	Champotón	-0.001	0.905
Campeche	Calkiní	0.006	0.800
Campeche	Palizada	0.008	0.723
Campeche	Carmen	0.035	0.633
Chiapas	La Grandeza	-0.168	0.080
Chiapas	Nicolás Ruíz	-0.072	0.236
Chiapas	Huixtán	-0.060	0.147
Chiapas	Suchiate	-0.049	0.095
Chiapas	San Lucas	-0.046	0.296
Chiapas	Bejucal de Ocampo	-0.046	0.501
Chiapas	Tila	-0.038	0.422
Chiapas	Sabanilla	-0.037	0.507

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Chiapas	Amatán	-0.037	0.493
Chiapas	Tapilula	-0.036	0.212
Chiapas	Chanal	-0.034	0.457
Chiapas	Huitiupán	-0.033	0.607
Chiapas	Osumacinta	-0.030	0.496
Chiapas	Amatenango del Valle	-0.029	0.564
Chiapas	Simojovel	-0.026	0.526
Chiapas	Amatenango de la Frontera	-0.025	0.597
Chiapas	Tapachula	-0.024	0.110
Chiapas	San Fernando	-0.024	0.563
Chiapas	Ixhuatán	-0.024	0.407
Chiapas	Las Rosas	-0.024	0.468
Chiapas	Jitotol	-0.023	0.707
Chiapas	San Cristóbal de las Casas	-0.023	0.553
Chiapas	Mazapa de Madero	-0.023	0.713
Chiapas	Pueblo Nuevo Solistahuacán	-0.022	0.710
Chiapas	Zinacantán	-0.021	0.644
Chiapas	El Bosque	-0.020	0.737
Chiapas	Teopisca	-0.019	0.616
Chiapas	Larráinzar	-0.019	0.694
Chiapas	Pantelhó	-0.018	0.427
Chiapas	Tumbalá	-0.018	0.585
Chiapas	Comitán de Domínguez	-0.018	0.552
Chiapas	Totolapa	-0.017	0.386
Chiapas	Cacahoatán	-0.017	0.264
Chiapas	Oxchuc	-0.016	0.674
Chiapas	Salto de Agua	-0.015	0.370
Chiapas	Siltepec	-0.010	0.693
Chiapas	Chilón	-0.009	0.799
Chiapas	Sitalá	-0.007	0.594
Chiapas	Bella Vista	-0.005	0.210
Chiapas	Mazatán	-0.005	0.434
Chiapas	La Trinitaria	-0.005	0.434
Chiapas	Palenque	-0.004	0.357
Chiapas	Villa Corzo	-0.004	0.556
Chiapas	La Libertad	-0.004	0.261
Chiapas	Chalchihuitán	-0.004	0.776

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Chiapas	Rayón	-0.004	0.756
Chiapas	Copainalá	-0.004	0.664
Chiapas	Ocosingo	-0.004	0.737
Chiapas	Ixtapa	-0.003	0.590
Chiapas	Acapetahua	-0.003	0.216
Chiapas	Chenalhó	-0.002	0.334
Chiapas	Berriozábal	-0.001	0.507
Chiapas	Chamula	-0.001	0.545
Chiapas	Yajalón	0.000	0.764
Chiapas	La Concordia	0.000	0.498
Chiapas	Altamirano	0.002	0.797
Chiapas	Villaflores	0.003	0.543
Chiapas	Cintalapa	0.003	0.696
Chiapas	Motozintla	0.004	0.560
Chiapas	El Porvenir	0.005	0.632
Chiapas	Jiquipilas	0.006	0.435
Chiapas	Tzimol	0.006	0.394
Chiapas	Angel Albino Corzo	0.007	0.711
Chiapas	Catazajá	0.009	0.176
Chiapas	Chicoasén	0.011	0.963
Chiapas	Las Margaritas	0.012	0.675
Chiapas	Bochil	0.013	0.679
Chiapas	Huehuetán	0.013	0.090
Chiapas	Juárez	0.014	0.125
Chiapas	Ocozocoautla de Espinosa	0.016	0.587
Chiapas	Ocotepec	0.016	0.788
Chiapas	Solosuchiapa	0.017	0.366
Chiapas	La Independencia	0.019	0.623
Chiapas	Chicomuselo	0.022	0.438
Chiapas	Pantepec	0.023	0.683
Chiapas	Villa Comaltitlán	0.023	0.242
Chiapas	Coapilla	0.025	0.852
Chiapas	Venustiano Carranza	0.029	0.186
Chiapas	Suchiapa	0.029	0.475
Chiapas	Chapultenango	0.035	0.594
Chiapas	Soyaló	0.037	0.542
Chiapas	Acala	0.039	0.375

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Chiapas	Acacoyagua	0.045	0.730
Chiapas	Huixtla	0.045	0.209
Chiapas	Tapalapa	0.051	0.863
Chiapas	Mapastepec	0.055	0.467
Chiapas	Arriaga	0.056	0.447
Chiapas	Socoltenango	0.065	0.210
Chiapas	Tonalá	0.067	0.415
Chiapas	Pijijiapan	0.067	0.440
Chiapas	Chiapa de Corzo	0.074	0.308
Chiapas	Pichucalco	0.078	0.107
Chiapas	Escuintla	0.078	0.581
Chiapas	Frontera Comalapa	0.090	0.242
Chiapas	Tenejapa	0.121	0.263
Chiapas	Tuxtla Gutiérrez	0.134	0.404
Chiapas	Ixtapangajoya	0.136	0.180
Chiapas	Tecpatán	0.153	0.216
Chiapas	Chiapilla	NA	0.079
Chiapas	Francisco León	NA	0.407
Chiapas	Frontera Hidalgo	NA	NA
Chiapas	Ixtacomitán	NA	0.298
Chiapas	Metapa	NA	NA
Chiapas	Mitontic	NA	0.698
Chiapas	Ostuacán	NA	0.231
Chiapas	Reforma	NA	0.013
Chiapas	Sunuapa	NA	0.260
Chiapas	Tuxtla Chico	NA	NA
Chiapas	Tuzantán	NA	NA
Chihuahua	General Trias	-0.016	0.475
Chihuahua	San Francisco del Oro	-0.011	0.803
Chihuahua	Galeana	-0.011	0.804
Chihuahua	Cuauhtémoc	-0.011	0.410
Chihuahua	Gran Morelos	-0.010	0.448
Chihuahua	Urique	-0.010	0.860
Chihuahua	El Tule	-0.009	0.744
Chihuahua	Matachic	-0.008	0.574
Chihuahua	Carichic	-0.008	0.797
Chihuahua	Nuevo Casas Grandes	-0.008	0.865

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Chihuahua	Bocoyna	-0.008	0.815
Chihuahua	Nonoava	-0.007	0.872
Chihuahua	Dr. Belisario Domínguez	-0.006	0.763
Chihuahua	Guazapares	-0.006	0.824
Chihuahua	Rosario	-0.006	0.818
Chihuahua	Santa Bárbara	-0.006	0.862
Chihuahua	Guachochic	-0.005	0.846
Chihuahua	Satevó	-0.005	0.825
Chihuahua	Balleza	-0.005	0.894
Chihuahua	Batopilas	-0.004	0.925
Chihuahua	Manuel Benavides	-0.004	0.928
Chihuahua	Moris	-0.004	0.940
Chihuahua	Chínipas	-0.004	0.903
Chihuahua	Uruachic	-0.004	0.861
Chihuahua	Madera	-0.004	0.841
Chihuahua	Maguarichic	-0.004	0.931
Chihuahua	Casas Grandes	-0.004	0.880
Chihuahua	Guadalupe y Calvo	-0.003	0.909
Chihuahua	Janos	-0.003	0.876
Chihuahua	San Francisco de Borja	-0.003	0.918
Chihuahua	Ocampo	-0.003	0.937
Chihuahua	Morelos	-0.003	0.943
Chihuahua	Valle de Zaragoza	-0.003	0.866
Chihuahua	Matamoros	-0.003	0.815
Chihuahua	Juárez	-0.003	0.825
Chihuahua	Hidalgo del Parral	-0.003	0.941
Chihuahua	La Cruz	-0.002	0.852
Chihuahua	Buenaventura	-0.002	0.907
Chihuahua	Temósachic	-0.002	0.872
Chihuahua	Ojinaga	-0.001	0.937
Chihuahua	Bachíniva	-0.001	0.645
Chihuahua	Camargo	-0.001	0.944
Chihuahua	Ahumada	-0.001	0.922
Chihuahua	Allende	-0.001	0.870
Chihuahua	Jiménez	-0.001	0.920
Chihuahua	Aquiles Serdán	-0.001	0.762
Chihuahua	Ignacio Zaragoza	-0.001	0.800

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Chihuahua	Julimes	-0.001	0.932
Chihuahua	Riva Palacio	0.000	0.589
Chihuahua	Guadalupe	0.000	0.964
Chihuahua	Guerrero	0.000	0.701
Chihuahua	Praxedis G. Guerrero	0.000	0.776
Chihuahua	Aldama	0.000	0.954
Chihuahua	Delicias	0.000	0.351
Chihuahua	Chihuahua	0.000	0.866
Chihuahua	Coyame del Sotol	0.000	0.986
Chihuahua	San Francisco de Conchos	0.000	0.922
Chihuahua	Ascensión	0.001	0.932
Chihuahua	Namiquipa	0.001	0.613
Chihuahua	Saucillo	0.001	0.817
Chihuahua	Coronado	0.001	0.938
Chihuahua	Huejotitán	0.002	0.834
Chihuahua	López	0.003	0.851
Chihuahua	Rosales	0.004	0.894
Chihuahua	Cusihuiriachic	0.004	0.446
Chihuahua	Meoqui	0.020	0.326
Coahuila	Castaños	-0.007	0.846
Coahuila	Candela	-0.006	0.861
Coahuila	Monclova	-0.005	0.765
Coahuila	Nava	-0.004	0.511
Coahuila	Hidalgo	-0.003	0.756
Coahuila	Múzquiz	-0.002	0.934
Coahuila	Saltillo	-0.001	0.794
Coahuila	Jiménez	-0.001	0.899
Coahuila	Ramos Arizpe	-0.001	0.919
Coahuila	Sierra Mojada	-0.001	0.971
Coahuila	Francisco I. Madero	-0.001	0.849
Coahuila	Sacramento	-0.001	0.836
Coahuila	Escobedo	-0.001	0.930
Coahuila	Cuatrociénegas	-0.001	0.966
Coahuila	Zaragoza	-0.001	0.953
Coahuila	Acuña	-0.001	0.970
Coahuila	Villa Unión	-0.001	0.870
Coahuila	Parras	0.000	0.930

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State	Municipality	Land-conversion rate	Proportion of natural landscape
Coahuila	Ocampo	0.000	0.984
Coahuila	San Buenaventura	0.000	0.976
Coahuila	Lamadrid	0.000	0.949
Coahuila	San Pedro	0.001	0.883
Coahuila	Frontera	0.001	0.552
Coahuila	General Cepeda	0.001	0.844
Coahuila	Nadadores	0.001	0.927
Coahuila	Guerrero	0.001	0.829
Coahuila	Abasolo	0.001	0.867
Coahuila	Viesca	0.002	0.877
Coahuila	Juárez	0.002	0.806
Coahuila	Torreón	0.002	0.667
Coahuila	Progreso	0.002	0.836
Coahuila	Arteaga	0.002	0.762
Coahuila	Morelos	0.004	0.573
Coahuila	Sabinas	0.007	0.904
Coahuila	Nueva Rosita	0.007	0.881
Coahuila	Allende	0.010	0.591
Coahuila	Piedras Negras	0.011	0.798
Coahuila	Matamoros	0.013	0.213
Colima	Colima	-0.017	0.445
Colima	Ixtlahuacán	-0.011	0.664
Colima	Tecomán	-0.011	0.390
Colima	Comala	-0.009	0.476
Colima	Minatitlán	-0.007	0.841
Colima	Cuauhtémoc	-0.001	0.252
Colima	Villa de Alvarez	0.000	0.416
Colima	Coquimatlán	0.003	0.679
Colima	Armería	0.013	0.529
Colima	Manzanillo	0.041	0.629
Distrito Federal	Cuauhtémoc	0.000	0.013
Distrito Federal	Gustavo A. Madero	0.000	0.115
Distrito Federal	Magdalena Contreras	0.009	0.588
Distrito Federal	Milpa Alta	0.010	0.389
Distrito Federal	Cuajimalpa de Morelos	0.010	0.620
Distrito Federal	Tlalpan	0.010	0.512
Distrito Federal	Xochimilco	0.013	0.180

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Distrito Federal	Alvaro Obregón	0.043	0.275
Distrito Federal	Venustiano Carranza	0.109	0.023
Distrito Federal	Tláhuac	0.176	0.001
Distrito Federal	Azcapotzalco	NA	NA
Distrito Federal	Benito Juárez	NA	NA
Distrito Federal	Coyoacán	NA	0.051
Distrito Federal	Iztacalco	NA	NA
Distrito Federal	Iztapalapa	NA	0.040
Distrito Federal	Miguel Hidalgo	NA	NA
Durango	Guanaceví	-0.006	0.897
Durango	Canelas	-0.005	0.930
Durango	Poanas	-0.005	0.552
Durango	Tamazula	-0.004	0.898
Durango	El Oro	-0.004	0.832
Durango	Topia	-0.004	0.915
Durango	Durango	-0.004	0.808
Durango	Nombre de Dios	-0.003	0.662
Durango	Canatlán	-0.003	0.718
Durango	Tepehuanes	-0.003	0.928
Durango	Indé	-0.002	0.769
Durango	Pánuco de Coronado	-0.002	0.664
Durango	Santiago Papasquiaro	-0.002	0.887
Durango	Súchil	-0.002	0.878
Durango	San Dimas	-0.002	0.973
Durango	Otáez	-0.002	0.977
Durango	Peñón Blanco	-0.002	0.826
Durango	Pueblo Nuevo	-0.001	0.961
Durango	San Luis de Cordero	-0.001	0.891
Durango	Ocampo	-0.001	0.869
Durango	San Pedro del Gallo	-0.001	0.914
Durango	Hidalgo	-0.001	0.937
Durango	Guadalupe Victoria	0.000	0.646
Durango	Nazas	0.000	0.906
Durango	Rodeo	0.000	0.842
Durango	Lerdo	0.001	0.872
Durango	San Bernardo	0.001	0.948
Durango	Coneto de Comonfort	0.001	0.691

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State	Municipality	Land-conversion rate	Proportion of natural landscape
Durango	San Juan de Guadalupe	0.001	0.924
Durango	Mezquital	0.001	0.966
Durango	Mapimí	0.002	0.936
Durango	Tlahualilo	0.003	0.912
Durango	San Juan del Río	0.004	0.722
Durango	General Simón Bolívar	0.004	0.890
Durango	Vicente Guerrero	0.004	0.383
Durango	Cuencamé	0.007	0.734
Durango	Gómez Palacio	0.012	0.548
Durango	Santa Clara	0.014	0.693
Guanajuato	Comonfort	-0.033	0.255
Guanajuato	Cortazar	-0.031	0.205
Guanajuato	Celaya	-0.028	0.144
Guanajuato	Valle de Santiago	-0.023	0.160
Guanajuato	Salamanca	-0.016	0.264
Guanajuato	Irapuato	-0.015	0.127
Guanajuato	Tarimoro	-0.015	0.372
Guanajuato	Apaseo el Alto	-0.013	0.118
Guanajuato	San Felipe	-0.013	0.592
Guanajuato	León	-0.012	0.360
Guanajuato	Manuel Doblado	-0.009	0.315
Guanajuato	San José Iturbide	-0.007	0.420
Guanajuato	Ocampo	-0.005	0.576
Guanajuato	Dolores Hidalgo	-0.005	0.445
Guanajuato	Guanajuato	-0.005	0.605
Guanajuato	Apaseo el Grande	-0.003	0.142
Guanajuato	Jaral del Progreso	-0.003	0.211
Guanajuato	Romita	-0.002	0.043
Guanajuato	Purísima del Rincón	-0.002	0.384
Guanajuato	Abasolo	-0.002	0.162
Guanajuato	San Diego de la Unión	-0.001	0.579
Guanajuato	Santa Catarina	-0.001	0.921
Guanajuato	San Luis de la Paz	-0.001	0.601
Guanajuato	Yuriria	0.005	0.325
Guanajuato	Allende	0.005	0.450
Guanajuato	Xichú	0.006	0.931
Guanajuato	Victoria	0.006	0.814

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State	Municipality	Land-conversion rate	Proportion of natural landscape
Guanajuato	Pénjamo	0.006	0.223
Guanajuato	Silao	0.007	0.092
Guanajuato	Doctor Mora	0.010	0.314
Guanajuato	Salvatierra	0.019	0.226
Guanajuato	Tierra Blanca	0.021	0.774
Guanajuato	San Francisco del Rincón	0.024	0.085
Guanajuato	Atarjea	0.026	0.937
Guanajuato	Santa Cruz de Juventino Rosas	0.028	0.227
Guanajuato	Cuerámaro	0.028	0.248
Guanajuato	Coroneo	0.031	0.184
Guanajuato	Acámbaro	0.031	0.262
Guanajuato	Uriangato	0.032	0.262
Guanajuato	Moroleón	0.034	0.401
Guanajuato	Jerécuaro	0.037	0.172
Guanajuato	Huanímaro	0.040	0.082
Guanajuato	Pueblo Nuevo	NA	0.105
Guanajuato	Santiago Maravatío	NA	0.399
Guanajuato	Tarandacuao	NA	0.138
Guanajuato	Villagrán	NA	NA
Guerrero	Copala	-0.049	0.356
Guerrero	Florencio Villarreal	-0.040	0.406
Guerrero	Alpoyeca	-0.038	0.268
Guerrero	Benito Juárez	-0.031	0.225
Guerrero	Azoyú	-0.024	0.516
Guerrero	Tlalixtaquilla de Maldonado	-0.021	0.551
Guerrero	Huamuxtitlán	-0.020	0.549
Guerrero	San Marcos	-0.017	0.415
Guerrero	Acapulco de Juárez	-0.016	0.597
Guerrero	Tepecoacuilco de Trujano	-0.016	0.561
Guerrero	Atenango del Río	-0.016	0.740
Guerrero	Cuautepec	-0.013	0.714
Guerrero	Juan R. Escudero	-0.012	0.720
Guerrero	Tecoanapa	-0.012	0.429
Guerrero	Huitzuco de los Figueroa	-0.011	0.735
Guerrero	Ometepec	-0.011	0.817
Guerrero	Técpan de Galeana	-0.011	0.625

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Guerrero	Igualapa	-0.010	0.833
Guerrero	Mochitlán	-0.010	0.712
Guerrero	Pedro Ascencio Alquisiras	-0.009	0.543
Guerrero	Zapotitlán Tablas	-0.009	0.807
Guerrero	Ayutla de los Libres	-0.009	0.734
Guerrero	Buenavista de Cuéllar	-0.008	0.835
Guerrero	Petatlán	-0.008	0.563
Guerrero	Iguala de la Independencia	-0.007	0.405
Guerrero	Quechultenango	-0.007	0.688
Guerrero	Apaxtla	-0.006	0.637
Guerrero	Zitlala	-0.006	0.662
Guerrero	Cuetzala del Progreso	-0.005	0.648
Guerrero	Pungarabato	-0.005	0.242
Guerrero	Tlacoapa	-0.005	0.797
Guerrero	Eduardo Neri	-0.005	0.768
Guerrero	San Luis Acatlán	-0.004	0.869
Guerrero	Cuajinicuilapa	-0.004	0.255
Guerrero	Xalpatláhuac	-0.003	0.658
Guerrero	Coyuca de Benítez	-0.002	0.694
Guerrero	Atlixtac	-0.002	0.608
Guerrero	Metlatónoc	-0.002	0.835
Guerrero	Chilapa de Alvarez	-0.001	0.477
Guerrero	Atlamajalcingo del Monte	-0.001	0.602
Guerrero	Alcozauca de Guerrero	-0.001	0.578
Guerrero	Cualác	0.000	0.748
Guerrero	General Heliodoro Castillo	0.000	0.855
Guerrero	Chilpancingo de los Bravo	0.001	0.832
Guerrero	San Miguel Totolapan	0.001	0.808
Guerrero	Tetipac	0.001	0.784
Guerrero	Cocula	0.001	0.613
Guerrero	Tlapa de Comonfort	0.001	0.726
Guerrero	Leonardo Bravo	0.001	0.916
Guerrero	Taxco de Alarcón	0.003	0.665
Guerrero	Malinaltepec	0.004	0.789
Guerrero	Tixtla de Guerrero	0.004	0.690
Guerrero	Ixcateopan de Cuauhtémoc	0.005	0.720
Guerrero	Atoyac de Alvarez	0.006	0.767

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State	Municipality	Land-conversion rate	Proportion of natural landscape
Guerrero	Tlacoachistlahuaca	0.008	0.891
Guerrero	Cutzamala de Pinzón	0.008	0.527
Guerrero	Arcelia	0.009	0.649
Guerrero	Mártir de Cuilapan	0.009	0.793
Guerrero	Ajuchitlán del Progreso	0.010	0.697
Guerrero	Olinalá	0.010	0.817
Guerrero	Ahuacuotzingo	0.010	0.821
Guerrero	Xochihuehuetlán	0.011	0.776
Guerrero	Teloloapan	0.012	0.552
Guerrero	Copalillo	0.013	0.773
Guerrero	Erongarícuaro	0.014	0.798
Guerrero	Coyuca de Catalán	0.016	0.648
Guerrero	José Azueta	0.017	0.659
Guerrero	La Union	0.018	0.759
Guerrero	Xochistlahuaca	0.019	0.993
Guerrero	Tlapehuala	0.024	0.303
Guerrero	Zirándaro	0.026	0.690
Guerrero	Pilcaya	0.030	0.579
Guerrero	Copanatoyac	0.040	0.551
Guerrero	Tlalchapa	0.060	0.424
Guerrero	General Canuto A. Neri	0.091	0.569
Hidalgo	Tlaxcoapan	-0.100	0.074
Hidalgo	Francisco I. Madero	-0.059	0.108
Hidalgo	Tepeji del Río de Ocampo	-0.043	0.168
Hidalgo	Acaxochitlán	-0.041	0.306
Hidalgo	Tepeapulco	-0.036	0.234
Hidalgo	Tula de Allende	-0.036	0.140
Hidalgo	Agua Blanca de Iturbide	-0.035	0.478
Hidalgo	Santiago de Anaya	-0.033	0.468
Hidalgo	Pachuca de Soto	-0.031	0.308
Hidalgo	Tepetitlán	-0.030	0.411
Hidalgo	Apan	-0.029	0.113
Hidalgo	El Arenal	-0.029	0.442
Hidalgo	Chapantongo	-0.029	0.172
Hidalgo	Zempoala	-0.026	0.222
Hidalgo	Nicolás Flores	-0.025	0.628
Hidalgo	Mineral del Chico	-0.025	0.449

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State	Municipality	Land-conversion rate	Proportion of natural landscape
Hidalgo	Xochiatipan	-0.025	0.315
Hidalgo	Cardonal	-0.025	0.601
Hidalgo	Zapotlán de Juárez	-0.022	0.124
Hidalgo	Tulancingo de Bravo	-0.022	0.258
Hidalgo	Ixmiquilpan	-0.021	0.366
Hidalgo	Omitlán de Juárez	-0.020	0.532
Hidalgo	Chilcuautla	-0.019	0.409
Hidalgo	Nopala de Villagrán	-0.019	0.122
Hidalgo	San Salvador	-0.018	0.148
Hidalgo	Tezontepec de Aldama	-0.017	0.132
Hidalgo	Atitalaquia	-0.017	0.736
Hidalgo	Alfajayucan	-0.017	0.331
Hidalgo	Actopan	-0.016	0.636
Hidalgo	Tetepango	-0.016	0.151
Hidalgo	Tasquillo	-0.015	0.600
Hidalgo	Eloxochitlán	-0.015	0.733
Hidalgo	Tecozautla	-0.015	0.491
Hidalgo	Lolotla	-0.014	0.650
Hidalgo	San Agustín Tlaxiaca	-0.014	0.144
Hidalgo	Tlahuiltepa	-0.014	0.794
Hidalgo	Metepec	-0.012	0.326
Hidalgo	La Misión	-0.012	0.593
Hidalgo	Metztitlán	-0.011	0.650
Hidalgo	Tlanalapa	-0.011	0.399
Hidalgo	Ajacuba	-0.011	0.329
Hidalgo	Singuilucan	-0.010	0.381
Hidalgo	Epazoyucan	-0.010	0.250
Hidalgo	Tenango de Doria	-0.009	0.528
Hidalgo	Mixquiahuala de Juárez	-0.009	0.292
Hidalgo	Almoloya	-0.009	0.339
Hidalgo	Atotonilco de Tula	-0.008	0.387
Hidalgo	Tianguistengo	-0.008	0.470
Hidalgo	Tlanchinol	-0.008	0.449
Hidalgo	Jacala de Ledezma	-0.008	0.803
Hidalgo	Cuautepec de Hinojosa	-0.008	0.273
Hidalgo	Tlahuelilpan	-0.007	0.116
Hidalgo	Tepehuacán de Guerrero	-0.007	0.600

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Hidalgo	Huichapan	-0.006	0.417
Hidalgo	Pacula	-0.005	0.822
Hidalgo	Pisaflores	-0.005	0.802
Hidalgo	Mineral del Monte	-0.004	0.620
Hidalgo	Juárez Hidalgo	-0.004	0.671
Hidalgo	Progreso de Obregón	-0.003	0.576
Hidalgo	San Agustín Metzquititlán	-0.003	0.550
Hidalgo	Zimapán	-0.003	0.762
Hidalgo	Molango de Escamilla	0.000	0.598
Hidalgo	Huasca de Ocampo	0.004	0.356
Hidalgo	Zacualtipán de Angeles	0.005	0.628
Hidalgo	Atotonilco el Grande	0.007	0.388
Hidalgo	Xochicoatlán	0.008	0.604
Hidalgo	Yahualica	0.010	0.397
Hidalgo	Chapulhuacán	0.026	0.825
Hidalgo	Emiliano Zapata	0.028	0.175
Hidalgo	Villa de Tezontepec	0.030	0.131
Hidalgo	San Bartolo Tutotepec	0.032	0.434
Hidalgo	Huautla	0.038	0.452
Hidalgo	Calnali	0.043	0.338
Hidalgo	Acatlán	0.043	0.087
Hidalgo	Huejutla de Reyes	0.067	0.220
Hidalgo	Mineral de la Reforma	0.075	0.247
Hidalgo	Atlapexco	0.082	0.466
Hidalgo	Huazalingo	0.101	0.252
Hidalgo	Santiago Tulantepec de Lugo Guerrero	0.122	0.091
Hidalgo	San Felipe Orizatlán	0.148	0.228
Hidalgo	Tizayuca	0.363	0.015
Hidalgo	Huehuetla	0.458	0.227
Hidalgo	Jaltocán	NA	0.156
Hidalgo	Tolcayuca	NA	0.009
Jalisco	Acatic	-0.116	0.032
Jalisco	Tonalá	-0.071	0.020
Jalisco	La Barca	-0.057	0.005
Jalisco	San Juan de los Lagos	-0.048	0.347
Jalisco	San Diego de Alejandría	-0.047	0.409

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Jalisco	San Julián	-0.042	0.472
Jalisco	Degollado	-0.037	0.163
Jalisco	El Arenal	-0.033	0.244
Jalisco	Jamay	-0.031	0.027
Jalisco	Tala	-0.029	0.268
Jalisco	Tepatitlán de Morelos	-0.029	0.271
Jalisco	San Miguel el Alto	-0.029	0.569
Jalisco	Jalostotitlán	-0.027	0.467
Jalisco	Atoyac	-0.026	0.443
Jalisco	Jilotlán de los Dolores	-0.026	0.593
Jalisco	Arandas	-0.025	0.264
Jalisco	Cocula	-0.025	0.337
Jalisco	Juchitlán	-0.025	0.530
Jalisco	San Martín Hidalgo	-0.024	0.300
Jalisco	Atotonilco El Alto	-0.024	0.163
Jalisco	Ocotlán	-0.024	0.187
Jalisco	Unión de San Antonio	-0.023	0.531
Jalisco	Tonila	-0.023	0.282
Jalisco	Tonaya	-0.023	0.427
Jalisco	Amacueca	-0.021	0.422
Jalisco	Ejutla	-0.021	0.669
Jalisco	Zacoalco de Torres	-0.020	0.468
Jalisco	Atengo	-0.020	0.494
Jalisco	La Manzanilla de la Paz	-0.019	0.430
Jalisco	Zapotiltic	-0.019	0.261
Jalisco	Hostotipaquillo	-0.019	0.595
Jalisco	Quitupan	-0.017	0.748
Jalisco	Ahualulco de Mercado	-0.016	0.456
Jalisco	Ixtlahuacán del Río	-0.016	0.477
Jalisco	Villa Corona	-0.015	0.333
Jalisco	Tamazula de Gordiano	-0.014	0.734
Jalisco	Tlajomulco de Zúñiga	-0.014	0.334
Jalisco	Tenamaxtlán	-0.013	0.372
Jalisco	El Limón	-0.013	0.527
Jalisco	El Salto	-0.010	0.073
Jalisco	Villa Hidalgo	-0.010	0.491
Jalisco	Tizapán el Alto	-0.010	0.318

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Jalisco	Ojuelos de Jalisco	-0.010	0.703
Jalisco	Manuel M. Dieguez	-0.009	0.869
Jalisco	Jocotepec	-0.009	0.470
Jalisco	Lago de Chapala	-0.009	0.100
Jalisco	Teocaltiche	-0.009	0.418
Jalisco	Zapotlanejo	-0.009	0.353
Jalisco	Mazamitla	-0.009	0.762
Jalisco	Tecalitlán	-0.009	0.842
Jalisco	Tuxpan	-0.009	0.453
Jalisco	Chiquilistlán	-0.008	0.684
Jalisco	Encarnación de Díaz	-0.008	0.473
Jalisco	Casimiro Castillo	-0.008	0.542
Jalisco	Ciudad Venustiano Carranza	-0.008	0.568
Jalisco	Sayula	-0.008	0.535
Jalisco	Huejuquilla el Alto	-0.007	0.655
Jalisco	Tapalpa	-0.007	0.612
Jalisco	Gómez Farías	-0.007	0.564
Jalisco	Concepción de Buenos Aires	-0.007	0.656
Jalisco	La Huerta	-0.006	0.684
Jalisco	Teocuitatlán de Corona	-0.006	0.513
Jalisco	Tolimán	-0.006	0.689
Jalisco	Valle de Juárez	-0.006	0.862
Jalisco	Teuchitlán	-0.006	0.170
Jalisco	Pihuamo	-0.006	0.758
Jalisco	Zapotitlán de Vadillo	-0.006	0.654
Jalisco	Zapopan	-0.005	0.444
Jalisco	Tuxcacuesco	-0.005	0.633
Jalisco	Tlaquepaque	-0.005	0.132
Jalisco	Ayutla	-0.004	0.641
Jalisco	Techaluta de Montenegro	-0.004	0.562
Jalisco	Huejúcar	-0.004	0.675
Jalisco	Lagos de Moreno	-0.004	0.626
Jalisco	Cuautla	-0.003	0.726
Jalisco	Tecolotlán	-0.003	0.609
Jalisco	San Sebastián del Oeste	-0.003	0.910
Jalisco	Villa Guerrero	-0.003	0.773
Jalisco	Atemajac de Brizuela	-0.003	0.772

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Jalisco	Tomatlán	-0.002	0.656
Jalisco	San Cristóbal de la Barranca	-0.002	0.669
Jalisco	Autlán de Navarro	-0.002	0.605
Jalisco	Ameca	-0.001	0.435
Jalisco	Ixtlahuacán de los Membrillos	-0.001	0.413
Jalisco	Cabo Corrientes	-0.001	0.924
Jalisco	San Marcos	-0.001	0.519
Jalisco	Puerto Vallarta	-0.001	0.698
Jalisco	Tequila	0.000	0.668
Jalisco	Mixtlán	0.000	0.777
Jalisco	Mascota	0.000	0.852
Jalisco	Cuautitlán de García Barragán	0.000	0.780
Jalisco	Amatitán	0.000	0.270
Jalisco	Antonio Escobedo	0.001	0.266
Jalisco	Yahualica de González Gallo	0.001	0.336
Jalisco	Mezquitic	0.001	0.917
Jalisco	Magdalena	0.001	0.540
Jalisco	Atenguillo	0.001	0.742
Jalisco	Unión de Tula	0.001	0.407
Jalisco	Santa María de los Angeles	0.002	0.863
Jalisco	Guachinango	0.002	0.781
Jalisco	Tuxcueca	0.002	0.502
Jalisco	Ciudad Guzman	0.003	0.316
Jalisco	Chimaltitán	0.004	0.787
Jalisco	Villa Purificación	0.005	0.664
Jalisco	Cuquito	0.007	0.286
Jalisco	Tototlán	0.007	0.222
Jalisco	Talpa de Allende	0.007	0.888
Jalisco	Totatiche	0.009	0.622
Jalisco	Colotlán	0.009	0.616
Jalisco	Poncitlán	0.010	0.242
Jalisco	Etzatlán	0.011	0.665
Jalisco	Bolaños	0.013	0.869
Jalisco	Zapotlán del Rey	0.014	0.295
Jalisco	Ayotlán	0.015	0.326
Jalisco	Mexticacán	0.019	0.636

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Jalisco	San Martín de Bolaños	0.020	0.856
Jalisco	Valle de Guadalupe	0.029	0.528
Jalisco	Jesús María	0.031	0.392
Jalisco	El Grullo	0.033	0.272
Jalisco	Cañadas de Obregón	0.062	0.532
Jalisco	Acatlán de Juárez	0.064	0.225
Jalisco	Chapala	0.065	0.094
Jalisco	Cihuatlán	0.065	0.661
Jalisco	Juanacatlán	0.200	0.104
Jalisco	Guadalajara	NA	0.000
México	Capulhuac	-0.244	0.003
México	Mexicaltzingo	-0.121	0.051
México	Juchitepec	-0.088	0.010
México	San Mateo Atenco	-0.082	0.056
México	Chapultepec	-0.080	0.173
México	Metepec	-0.075	0.030
México	Cocotitlán	-0.058	0.182
México	Otzolotepec	-0.050	0.155
México	Xonacatlán	-0.046	0.255
México	Jiquipilco	-0.045	0.261
México	Temoaya	-0.044	0.087
México	San Antonio La Isla	-0.042	0.259
México	Axapusco	-0.040	0.059
México	Almoloya del Río	-0.035	0.363
México	Ayapango	-0.033	0.445
México	Tepetlixpa	-0.033	0.227
México	Temascalapa	-0.030	0.111
México	Otumba	-0.027	0.312
México	Ozumba	-0.026	0.670
México	Lerma	-0.025	0.285
México	Morelos	-0.022	0.436
México	Ecatzingo	-0.018	0.677
México	Villa Victoria	-0.017	0.130
México	Temamatla	-0.017	0.243
México	Texcalyacac	-0.015	0.203
México	Chalco	-0.013	0.557
México	Chicoloapan	-0.012	0.115

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
México	Cuautitlán	-0.012	0.107
México	Malinalco	-0.011	0.630
México	Acambay	-0.010	0.306
México	Ocoyoacac	-0.009	0.535
México	Jalatlaco	-0.008	0.702
México	Aculco	-0.008	0.105
México	Amanalco	-0.008	0.620
México	Santo Tomás	-0.008	0.664
México	Almoloya de Alquisiras	-0.008	0.630
México	Jocotitlán	-0.007	0.143
México	Isidro Fabela	-0.006	0.482
México	Texcoco	-0.006	0.629
México	Tenancingo	-0.005	0.709
México	Ecatepec de Morelos	-0.005	0.316
México	Timilpan	-0.003	0.194
México	Amecameca	-0.002	0.916
México	Chapa de Mota	-0.002	0.337
México	Texcaltitlán	-0.001	0.711
México	Zinacatepec	-0.001	0.512
México	Tepetlaoxtoc	-0.001	0.370
México	Atlautla	-0.001	0.742
México	Huixquilucan	-0.001	0.482
México	Calimaya	0.000	0.322
México	Ocuilan	0.000	0.651
México	Tianguistenco	0.001	0.606
México	Ixtapaluca	0.004	0.629
México	Atizapán	0.004	0.913
México	Sultepec	0.004	0.677
México	San Simón de Guerrero	0.004	0.562
México	Temascaltepec	0.005	0.598
México	Otzoloapan	0.006	0.606
México	Tlalmanalco	0.006	0.838
México	Hueypoxtla	0.008	0.210
México	Donato Guerra	0.008	0.537
México	Tonatico	0.008	0.559
México	Zumpahuacan	0.009	0.639
México	Temascalcingo	0.009	0.255

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
México	Valle de Bravo	0.009	0.641
México	Jilotepec	0.009	0.111
México	Amatepec	0.010	0.551
México	Tlalnepantla	0.010	0.021
México	Tlatlaya	0.012	0.640
México	San Felipe del Progreso	0.013	0.181
México	Ixtlahuaca	0.013	0.026
México	Villa del Carbón	0.013	0.423
México	Zacualpan	0.013	0.595
México	Coyotepec	0.014	0.063
México	Almoloya de Juárez	0.014	0.055
México	Joquicingo	0.016	0.349
México	Atlacomulco	0.020	0.080
México	Nicolás Romero	0.021	0.368
México	Villa Guerrero	0.024	0.420
México	Tenango del Valle	0.024	0.343
México	Tepotzotlán	0.024	0.026
México	Tejupilco	0.024	0.554
México	Zumpango	0.025	0.155
México	Coatepec Harinas	0.025	0.373
México	Toluca	0.025	0.084
México	Jilotzingo	0.026	0.436
México	Villa de Allende	0.028	0.269
México	Apaxco	0.028	0.072
México	Ixtapan del Oro	0.030	0.605
México	Tequixquiac	0.032	0.062
México	Naucalpan de Juárez	0.033	0.174
México	Nopaltepec	0.035	0.074
México	Ixtapan de la Sal	0.043	0.407
México	Rayón	0.043	0.328
México	El Oro	0.054	0.217
México	Huehuetoca	0.060	0.267
México	Nezahualcóyotl	0.085	0.021
México	Tezoyuca	0.090	0.104
México	Zacazonapan	0.104	0.460
México	Atenco	0.123	0.068
México	Tultitlán	0.132	0.162

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
México	San Martín de las Pirámides	0.182	0.142
México	Acolman	NA	0.038
México	Atizapán de Zaragoza	NA	0.023
México	Chiautla	NA	NA
México	Chiconcuac	NA	NA
México	Chimalhuacán	NA	NA
México	Coacalco de Berriozábal	NA	0.057
México	Cuautitlán Izcalli	NA	0.000
México	Jaltenco	NA	0.088
México	La Paz	NA	NA
México	Melchor Ocampo	NA	0.011
México	Nextlalpan	NA	0.072
México	Papalotla	NA	NA
México	Polotitlán	NA	0.009
México	Soyaniquilpan de Juárez	NA	0.035
México	Tecámac	NA	NA
México	Tenango del Aire	NA	0.000
México	Teoloyucán	NA	NA
México	Teotihuacán	NA	0.011
México	Tultepec	NA	0.118
Michoacán	Huandacareo	-0.033	0.442
Michoacán	La Piedad	-0.031	0.278
Michoacán	José Sixto Verduzco	-0.030	0.157
Michoacán	Múgica	-0.028	0.172
Michoacán	Jiménez	-0.027	0.168
Michoacán	Contepec	-0.025	0.138
Michoacán	Yurécuaro	-0.025	0.297
Michoacán	Nuevo Urecho	-0.023	0.498
Michoacán	Venustiano Carranza	-0.021	0.150
Michoacán	Angangueo	-0.021	0.629
Michoacán	Nuevo Paranguricutiro	-0.020	0.589
Michoacán	Zináparo	-0.020	0.214
Michoacán	Ziracuaretiro	-0.017	0.524
Michoacán	Marcos Castellanos	-0.016	0.341
Michoacán	Peribán	-0.016	0.302
Michoacán	Tepalcatepec	-0.015	0.435
Michoacán	Chavinda	-0.014	0.356

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Michoacán	Jiquilpan	-0.014	0.455
Michoacán	Cotija	-0.013	0.689
Michoacán	Tingambato	-0.013	0.530
Michoacán	Tocumbo	-0.013	0.643
Michoacán	Juárez	-0.013	0.454
Michoacán	Angamacutiro	-0.012	0.261
Michoacán	Parácuaro	-0.012	0.292
Michoacán	Pajacuarán	-0.011	0.242
Michoacán	Ario	-0.010	0.474
Michoacán	Salvador Escalante	-0.010	0.274
Michoacán	Vista Hermosa	-0.010	0.059
Michoacán	Paracho	-0.009	0.408
Michoacán	Coahuayana	-0.009	0.397
Michoacán	Tacámbaro	-0.008	0.409
Michoacán	Churintzio	-0.008	0.418
Michoacán	Buenavista	-0.008	0.434
Michoacán	Jacona	-0.008	0.452
Michoacán	Gabriel Zamora	-0.007	0.394
Michoacán	Charapan	-0.007	0.421
Michoacán	Apatzingán	-0.006	0.644
Michoacán	Taretan	-0.006	0.457
Michoacán	Aguililla	-0.006	0.743
Michoacán	Panindícuaro	-0.006	0.426
Michoacán	Uruapan	-0.005	0.577
Michoacán	Pátzcuaro	-0.003	0.486
Michoacán	Cherán	-0.003	0.602
Michoacán	Tinguindín	-0.002	0.405
Michoacán	Tanhuato	-0.002	0.401
Michoacán	Tlazazalca	-0.002	0.532
Michoacán	Ixtlán	-0.001	0.315
Michoacán	Puruándiro	-0.001	0.369
Michoacán	Tangamandapio	-0.001	0.374
Michoacán	Zirándaro	0.000	0.508
Michoacán	Nahuatzen	0.000	0.519
Michoacán	Ocampo	0.000	0.508
Michoacán	Madero	0.000	0.898
Michoacán	Chilchota	0.001	0.586

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Michoacán	Hidalgo	0.001	0.723
Michoacán	Purépero	0.001	0.466
Michoacán	Senguio	0.001	0.449
Michoacán	Villamar	0.001	0.348
Michoacán	Los Reyes	0.002	0.450
Michoacán	Charo	0.002	0.585
Michoacán	Coalcomán de Vázquez Pallares	0.003	0.880
Michoacán	Aporo	0.003	0.602
Michoacán	Tzitzio	0.004	0.923
Michoacán	Arteaga	0.004	0.896
Michoacán	Tumbiscatío	0.004	0.899
Michoacán	Zitácuaro	0.004	0.515
Michoacán	Tlalpujahua	0.005	0.362
Michoacán	Zamora	0.006	0.303
Michoacán	Queréndaro	0.007	0.619
Michoacán	Zacapu	0.007	0.511
Michoacán	La Huacana	0.007	0.676
Michoacán	Zinapécuaro	0.008	0.438
Michoacán	Aquila	0.010	0.822
Michoacán	Chinicuila	0.010	0.667
Michoacán	Ecuandureo	0.010	0.464
Michoacán	Sahuayo	0.010	0.527
Michoacán	Penjamillo	0.010	0.303
Michoacán	Coeneo	0.012	0.320
Michoacán	Tangancícuaro	0.012	0.393
Michoacán	Tuxpan	0.012	0.568
Michoacán	Epitacio Huerta	0.013	0.106
Michoacán	Morelia	0.014	0.425
Michoacán	Erongarícuaro	0.014	0.398
Michoacán	Morelos	0.014	0.446
Michoacán	Tiquicheo de Nicolás Romero	0.015	0.777
Michoacán	Acuitzio	0.016	0.444
Michoacán	Quiroga	0.018	0.523
Michoacán	Maravatío	0.019	0.260
Michoacán	San Lucas	0.021	0.510
Michoacán	Cojumatlán de Régules	0.023	0.382

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Michoacán	Churumuco	0.024	0.668
Michoacán	Indoparapeo	0.027	0.510
Michoacán	Tuzantla	0.027	0.732
Michoacán	Irimbo	0.028	0.207
Michoacán	Huetamo	0.029	0.598
Michoacán	Carácuaro	0.035	0.656
Michoacán	Nocupétaro	0.037	0.734
Michoacán	Susupuato	0.044	0.667
Michoacán	Turicato	0.047	0.644
Michoacán	Lagunillas	0.047	0.441
Michoacán	Chucándiro	0.051	0.590
Michoacán	Numarán	0.054	0.101
Michoacán	Tzintzuntzan	0.054	0.304
Michoacán	Huaniqueo	0.058	0.341
Michoacán	Jungapeo	0.064	0.588
Michoacán	Huiramba	0.082	0.191
Michoacán	Lázaro Cárdenas	0.091	0.657
Michoacán	Cuitzeo	0.305	0.287
Michoacán	Álvaro Obregón	NA	0.130
Michoacán	Briseñas	NA	NA
Michoacán	Copándaro	NA	0.531
Michoacán	Santa Ana Maya	NA	0.219
Michoacán	Tarímbaro	NA	0.235
Morelos	Temoac	-0.062	0.102
Morelos	Jonacatepec	-0.053	0.233
Morelos	Temixco	-0.045	0.066
Morelos	Cuernavaca	-0.025	0.150
Morelos	Axochiapan	-0.019	0.368
Morelos	Jiutepec	-0.019	0.361
Morelos	Jojutla	-0.017	0.430
Morelos	Xochitepec	-0.014	0.449
Morelos	Zacatepec de Hidalgo	-0.013	0.737
Morelos	Tlaquiltenango	-0.012	0.700
Morelos	Yecapixtla	-0.008	0.067
Morelos	Tlaltizapán	-0.006	0.568
Morelos	Coatlán del Río	-0.003	0.406
Morelos	Jantetelco	-0.001	0.654

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Morelos	Huitzilac	-0.001	0.635
Morelos	Yautepec	0.000	0.154
Morelos	Puente de Ixtla	0.003	0.388
Morelos	Ayala	0.003	0.265
Morelos	Tepoztlán	0.006	0.581
Morelos	Tetecala	0.006	0.270
Morelos	Ocuituco	0.010	0.590
Morelos	Tlalnepantla	0.013	0.170
Morelos	Tepalcingo	0.016	0.332
Morelos	Zacualpan	0.017	0.165
Morelos	Emiliano Zapata	0.022	0.593
Morelos	Tetela del Volcán	0.024	0.659
Morelos	Tlayacapan	0.025	0.199
Morelos	Miacatlán	0.028	0.273
Morelos	Totolapan	0.030	0.122
Morelos	Amacuzac	0.038	0.160
Morelos	Mazatepec	0.050	0.312
Morelos	Atlatlahucan	0.214	0.170
Morelos	Cuautla	NA	0.015
Nayarit	Tuxpan	-0.021	0.266
Nayarit	Tecuala	-0.016	0.383
Nayarit	Santiago Ixcuintla	-0.009	0.444
Nayarit	Compostela	-0.006	0.688
Nayarit	Ahuacatlán	-0.004	0.713
Nayarit	Jala	-0.004	0.683
Nayarit	Rosamorada	-0.004	0.533
Nayarit	NA	-0.001	0.926
Nayarit	Huajicori	0.000	0.927
Nayarit	Acaponeta	0.001	0.638
Nayarit	Tepic	0.001	0.559
Nayarit	El Nayar	0.002	0.923
Nayarit	Amatlán de Cañas	0.002	0.719
Nayarit	San Pedro Lagunillas	0.004	0.495
Nayarit	Santa María del Oro	0.005	0.553
Nayarit	Xalisco	0.006	0.623
Nayarit	La Yesca	0.008	0.746
Nayarit	Ruíz	0.008	0.690

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Nayarit	Ixtlán del Río	0.015	0.657
Nayarit	San Blas	0.052	0.452
Nuevo León	Doctor Coss	-0.078	0.176
Nuevo León	Allende	-0.035	0.341
Nuevo León	General Bravo	-0.034	0.391
Nuevo León	China	-0.034	0.447
Nuevo León	General Terán	-0.031	0.404
Nuevo León	Cadereyta Jiménez	-0.027	0.282
Nuevo León	Marín	-0.022	0.350
Nuevo León	Linares	-0.020	0.479
Nuevo León	Montemorelos	-0.019	0.447
Nuevo León	Los Ramones	-0.018	0.438
Nuevo León	Los Aldamas	-0.018	0.486
Nuevo León	Monterrey	-0.015	0.310
Nuevo León	Juárez	-0.014	0.395
Nuevo León	Doctor González	-0.012	0.682
Nuevo León	Sabinas Hidalgo	-0.012	0.535
Nuevo León	Melchor Ocampo	-0.011	0.736
Nuevo León	Villaldama	-0.010	0.758
Nuevo León	Parás	-0.009	0.536
Nuevo León	Doctor Arroyo	-0.008	0.805
Nuevo León	General Treviño	-0.008	0.456
Nuevo León	San Pedro Garza García	-0.008	0.504
Nuevo León	Salinas Victoria	-0.007	0.707
Nuevo León	General Zuazua	-0.006	0.470
Nuevo León	Mina	-0.005	0.900
Nuevo León	Galeana	-0.005	0.795
Nuevo León	Santiago	-0.004	0.859
Nuevo León	Lampazos de Naranjo	-0.003	0.739
Nuevo León	Mier y Noriega	-0.003	0.834
Nuevo León	Bustamante	-0.003	0.870
Nuevo León	Ciénega de Flores	-0.003	0.540
Nuevo León	Los Herreras	-0.003	0.661
Nuevo León	Abasolo	-0.002	0.847
Nuevo León	Vallecillo	-0.002	0.631
Nuevo León	General Zaragoza	-0.002	0.956
Nuevo León	Hidalgo	-0.002	0.938

Table D.1 continued from previous page

State	Municipality	Land-conversion rate	Proportion of natural landscape
Nuevo León	Higueras	-0.002	0.913
Nuevo León	Aramberri	-0.002	0.896
Nuevo León	Anáhuac	-0.001	0.613
Nuevo León	Iturbide	-0.001	0.974
Nuevo León	Agualeguas	0.000	0.583
Nuevo León	García	0.000	0.930
Nuevo León	Rayones	0.000	0.958
Nuevo León	Pesquería	0.002	0.278
Nuevo León	Santa Catarina	0.003	0.939
Nuevo León	Guadalupe	0.003	0.177
Nuevo León	Cerralvo	0.006	0.747
Nuevo León	General Escobedo	0.007	0.664
Nuevo León	Carmen	0.009	0.774
Nuevo León	Apodaca	0.088	0.406
Nuevo León	San Nicolás de los Garza	0.236	0.063
Oaxaca	Dist. Jamiltepec	-0.026	0.536
Oaxaca	Dist. Teotitlan	-0.014	0.621
Oaxaca	Dist. Huajuapam	-0.009	0.564
Oaxaca	Dist. Ocotlan	-0.007	0.160
Oaxaca	Dist. Tuxtepec	-0.007	0.349
Oaxaca	Dist. Miahuatlan	-0.005	0.583
Oaxaca	Choapam	-0.005	0.614
Oaxaca	Coixtlahuaca	-0.005	0.561
Oaxaca	Dist. Sola de Vega	-0.004	0.789
Oaxaca	Dist. Tehuantepec	-0.004	0.833
Oaxaca	Dist. Etla	-0.003	0.750
Oaxaca	Dist. Yautepec	-0.002	0.857
Oaxaca	Dist. Juxtlahuaca	-0.001	0.642
Oaxaca	Dist. Silacayoapam	-0.001	0.620
Oaxaca	Dist. Tlacolula	-0.001	0.628
Oaxaca	Dist. Juchitan	0.000	0.649
Oaxaca	Dist. Mixe	0.000	0.698
Oaxaca	Dist. Teposcolula	0.002	0.557
Oaxaca	Cuicatlan	0.002	0.798
Oaxaca	Dist. Tlaxiaco	0.005	0.503
Oaxaca	Dist. Ixtlan	0.005	0.872
Oaxaca	Dist. Villa Alta	0.006	0.880

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State	Municipality	Land-conversion rate	Proportion of natural landscape
Oaxaca	Dist. Juquila	0.007	0.609
Oaxaca	Dist. Nochixtlan	0.009	0.445
Oaxaca	Del Centro	0.009	0.264
Oaxaca	Dist. Pochutla	0.009	0.792
Oaxaca	Dist. Putla	0.014	0.749
Oaxaca	Dist. Ejutla	0.024	0.466
Oaxaca	Dist. Zimatlan	0.047	0.776
Oaxaca	Dist. Zaachila	0.084	0.655
Puebla	Amozoc	-0.131	0.011