Chapter 12
Use Patterns of Medicinal Plants by Local Populations

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12.1 Introduction

The growing number of ethnobotanical studies has revealed an important finding: behaviors related to the use of plant resources are recurrent in different human populations. These repeated behavioral tendencies in plant use are also known as use patterns. A pattern may be expressed in the general characteristics of the pharmacopoeia[1] (habits of dominant plants, main therapeutic indications of the plants, etc.), and it may also be observed in the ways by which different human populations use the same plant species.

In this chapter, we use medicinal plants as a model to discuss the factors leading to the formation of these patterns. However, it is important to note that such patterns may be observed in studies focusing on any natural resource. Many of the questions approached here may potentially be applied to other research areas, including ethnozoological research because little is known of the behavioral patterns related to animal use.

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[1] Local pharmacopoeia or traditional pharmacopoeia are defined here as the repertoire of products used for health care by a given population, and they may include animals, plants, and/or minerals.

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12.2 Factors Leading to the Formation of Use Patterns

In general, patterns may be generated in two ways: (a) diffusion and (b) convergence (Bletter 2007). Diffusion is the process of information transmission between individuals belonging to the same or different human groups. Patterns generated through diffusion may occur because of contact between individuals and exchanges of information between close or distant populations, which occurs for members of a local population who migrate[2] to a distant location and transmit their knowledge to the inhabitants of this new location.

When information on plant use crosses community borders and reaches new locations, the resulting plant-use patterns do not result from independent discoveries by the communities. Instead, the information shared between different populations has a common origin. This process characterizes the diffusion of knowledge. Different communities may also acquire the same plant-use behavior independently in a process known as convergence.

It might appear as if independent discoveries related to plant use are coincidental, chance events; however, these discoveries are influenced by certain key factors that eliminate the effect of chance and provide valuable information. Thus, the environment plays a key role in stimulating exploration for similar resource appropriation solutions according to different populations in similar environmental contexts. In addition, because chemical efficiency is an important factor for species selection and the same species can be found in geographically distant regions, processes of trial and error[3] may lead different human populations to the same conclusions on the therapeutic indications of a species.

In practice, it is difficult to conclude whether the formation of a pattern resulted from diffusion or convergence because it is not possible to map all of the pathways of information entry into a social-ecological system. However, theories of the origins of such patterns may be developed. Bletter (2007), for example, studied the plants used to treat diseases such as malaria, Chagas disease, Leishmaniasis, and diabetes by two human populations in Mali and Peru and observed that the two populations used related plant species as treatment for the same therapeutic indications.

This example is useful because of its discoveries as well as its interpretations. Bletter selected communities in those two countries precisely because they are distant from each other and have little historical relation to one another, which implied a lower probability of information exchange between the two populations and higher probability that the discoveries are independent. To assure this independence, Bletter (2007) excluded exotic plants from the analysis because their use was more likely to be associated with cultural diffusion.

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[2] The importance and strategies of medicinal plant use by migrant peoples may be found in Medeiros et al. (2012).

[3] The expression "trial and error" is frequently used in ethnobotany to describe the learning process in medicinal plant use; in this process, subjects use plants for a given end until one (or more) plant shows positive results and is effective in treatment.

Thus, cases occur in which patterns are likely to have originated from convergence, although unequivocal conclusions of convergence cannot be made. Diffusion is not always direct because several communities may constitute a knowledge distribution network and two communities may share information from the same origin, even if they are not directly linked.

12.3 Taxonomic Patterns

Because chemical compounds with medicinal value are not equally distributed among different botanical families (Gottlieb et al. 2002), at least two behaviors can be expected: (a) certain families have higher medicinal value and are therefore more frequently used than others and (b) different families are used to treat different afflictions. If the same botanical families are more frequently used for medicine in different settings, this trend would be strong evidence that plant use by local populations does not occur randomly (Moerman 1979) and is inconsistent with the placebo effect hypothesis[4] of popular medicine.

Thus, studies have been performed to determine whether certain families are used in a greater proportion than others and whether these families are the same in different locations. Daniel Moerman was a pioneer in this line of research. In his first work on the topic, which was published in 1979, he compared a list of native medicinal plants of North America with a list of plants used by native North American populations. These lists of North American species were used for an important reason: the analysis of the families with a greater number of medicinal species could not be performed in absolute terms but had to be performed relative to the size of the family.

According to this reasoning, if family A has ten species and all (100 %) are medicinal, this family has greater proportion of medicinal plants than family B, for which 30 of its 60 species (50 %) are medicinal. If this information was analyzed in absolute terms (ten medicinal species from A against 30 species from B), family B would be incorrectly considered to have a greater proportion of medicinal plants.

Using relatively simple statistics, Moerman (1979) identified families that did not have the expected proportion between the total number of species and the number of medicinal species, with some of these families having more medicinal species than predicted and others having less. The families of the first group were referred to as overused, and the families of the second group were referred to as underused.

[4] The myth of the placebo effect refers to the belief that medicinal plants used by local populations do not, in fact, have healing pharmacologic properties and are kept in these pharmacopoeias because of their symbolic value and psychological effect, which may help reduce the effects of the disease (placebo effect). This myth has been advocated by several medical doctors, especially before the performance of scientific studies with plants used in popular medicine.

The method proposed by Moerman (1979) was developed further in several additional studies. More robust statistical methods were used to identify the overused and underused families (see Bennett and Husby 2008; Weckerle et al. 2011, 2012). A consistent finding among these studies was overused and underused families by the human populations studied are always found.

In addition, certain families have strong overuse and underuse patterns, which was observed in several studies performed in different regions. Families such as Asteraceae, Piperaceae, and Rosaceae have been reported in several studies as overused, and Poaceae, Orchidaceae, and Cyperaceae have been reported as underused. The high use of families frequently observed as overused is explained by their production of bioactive compounds, which has been supported by chemistry studies (Gottlieb et al. 2002). Families such as Poaceae and Cyperaceae have low biological activity (Amiguet et al. 2006), which would explain their lower medicinal use.

However, overused or underused families are not always the same in different studies. Families such as Fabaceae, for example, have been classified as overused in certain studies and underused in others. If evident patterns occur, why do certain families appear to behave so discrepantly? Additional information must be gathered by scientists to explain whether these discrepancies are caused by cultural or other factors or whether certain botanical families (especially those with wide distributions) include species that are strongly divergent in terms of chemical composition. Such discrepancies, however, do not invalidate the evident and universal patterns observed for the taxonomy of medicinal species.

The second case in which different families could be used to treat different afflictions has not received much attention by the scientific community; therefore, patterns related to this definition have yet to be discovered. However, studies have already shown that different diseases tend to be treated with different botanical families (Weckerle et al. 2011; Medeiros et al. 2013). For example, there is little similarity between different systems of the body in terms of the families used to treat them, which means that there is a tendency to use different plant families to treat different anatomical systems (Medeiros et al. 2013). In our previously cited study, we observed that a greater number of similar body systems (disorders, infections and parasitic diseases of the respiratory system) have greater similarities in their cure requirements (in this case, plants with antimicrobial properties, which can be used for conventional infectious diseases and certain respiratory problems related to colds, bronchitis, etc.).

12.4 Patterns Related to Plant Habit

Reports have suggested that plant selection for medicinal purposes is also related to plant habit. One of the premises advocated by scientists is that herbaceous habits are the most important from a medicinal perspective (Stepp and Moerman 2001), and it is derived from observations of the predominance of herbs, especially ruderals, in pharmacopoeias worldwide, and intimately associated with the application of the ecological apparency hypothesis (EAH) to plant chemistry. According to the EAH, apparent plants (more visible or abundant in the environment and generally woody) invest in high-molecular weight compounds (quantitative defense), whereas non-apparent plants (herbaceous) invest in low-molecular weight compounds (qualitative defense) (Albuquerque and Lucena 2005). Qualitative compounds are more bioactive, explaining the success of herbs as medicinal products.

Despite the wide acceptance of herbs as the main components of local pharmacopoeias, exceptions have been found, especially in semiarid regions. In a study conducted in a semiarid region of Ethiopia, a higher number of trees used for medicinal purposes was observed than any other plant habit (Zone et al. 2007). In addition, studies conducted in the Brazilian Caatinga (seasonal dry forest) showed that although more herbaceous plant species were present in the pharmacopoeias, which included a great number of exotic herbs, trees had higher versatility of use or greater importance for the local populations (Albuquerque et al. 2007; Almeida et al. 2010). Caatinga pharmacopoeias are not consistent with the expected chemistry because the trees that are considered medicinal include quantitative compounds and have qualitative metabolites associated with herbaceous species (see Almeida et al. 2005; Alencar et al. 2009).

There are still gaps in the ethnobotanical knowledge of the main habits of medicinal plants. First, if the presence of herbs in pharmacopoeias is so high, then it is unclear why exceptions occur. Can these exceptions be explained by environmental (e.g., semiarid environments) or cultural factors? Do environments with different characteristics lead to different patterns related to plant habits? Increased scientific research on this topic, especially in regions where these studies are scarce, will certainly lead to conclusive answers.

12.5 Patterns Related to Species' Origin and Biogeographical Distribution

Scientists have speculated whether the function of native and exotic species in traditional pharmacopoeias may follow the same logic in different local communities. For example, although it is believed that the inclusion of exotic species in traditional medicine is necessarily connected to acculturation processes,[5] it may be part of the pharmacopoeias' evolution to adapt to cultural and ecological changes (Palmer 2004; Medeiros 2013).

Assuming that traditional knowledge is dynamic and the inclusion of exotic species may enrich pharmacopoeias, hypotheses have been developed to explain why these species are included in the local repertoire of medicinal plants. According to Bennett and Prance (2000), exotic species enter the daily life of local populations for non-medicinal uses, such as for food and ornamental uses, and medicinal uses

[5] The term "acculturation" has been used in the literature to describe cultural change processes experienced by local communities (see Eyssartier et al. 2008).

are developed a posteriori; thus, these species are usually introduced to communities for non-medicinal reasons. Therefore, exotic species that have more versatile uses have a higher probability of entering a new location and being subsequently used for medicinal purposes. This hypothesis was termed the versatility hypothesis, and it was tested by Alencar et al. (2010).

Another attempt at explaining the inclusion of exotic plants in traditional pharmacopoeias is the diversification hypothesis, which was originally proposed by Albuquerque (2006) and later tested by his research group (see Alencar et al. 2010). This hypothesis was one of the first formal attempts to defy the acculturation hypothesis (discussed above). According to the diversification hypothesis, exotic plants are included in traditional pharmacopoeias to fill gaps left by native species. The hypothesis was tested in the Caatinga and supported by chemical and ethnobotany evidence in which exotic species were exclusively cited for certain therapeutic indications and certain compounds were only present in these plants (Alencar et al. 2010; Almeida et al. 2010).

Gaps may occur in a pharmacopoeia if a disease is recent to a location or difficult to diagnose (such as cancer, high blood pressure, and diabetes); thus, they may not be related to the inefficiency of native species in treating certain diseases. In these cases, the challenge of diagnosing the disease prevents experimenting with and applying native species for its treatment. Often, the diagnosis of such diseases is determined from outside of the community, such as through biomedicine, which may also introduce exotic species that are widely used for the treatment of maladies with difficult diagnoses. Therefore, these types of disease are expected to be treated predominantly by exotic plants. A study conducted in southeast Morocco with plants used for the treatment of diabetes and hypertension showed that most of these plants were exotic, although they may have been wild, cultivated, or brought from other locations in Morocco (Tahraoui et al. 2007).

If the diversification hypothesis is true, then the entry of exotic plants into pharmacopoeias does not occur randomly but follows a general pattern of gap filling. However, further studies are required to test this hypothesis in multiple settings.

12.6 Patterns Related to Therapeutic Indications

One of the most evident patterns observed by scientists and researchers is the emphasis on the digestive system among the body systems treated with plants; thus, there is a higher number of plants used as treatments for digestive disorders as well as a higher number of citations for such disorders (for examples, see Ankli et al. 1999; Molares and Ladio 2009). Respiratory and skin diseases are also among the most represented in local medical systems (see Heinrich et al. 1998; Rehecho et al. 2011).

Therapeutic indications with a higher number of plants used as treatment tend to have one (or both) of the following characteristics: (a) among the most recurrent in the community, with individuals having developed more thorough repertoires for the treatment of diseases that are a part of their daily lives, and (b) include a variety of different possible treatment paths using several (and different) bioactive compounds, which would explain the higher number of plants that can be used for their treatment.

Let us consider the example of digestive disorders and their predominance in ethnobotany studies. These disorders are frequent in several local communities because of a lack of adequate sanitary conditions and bad water quality, and the high incidence of species and use citations for digestive problems may be related to the greater effort dedicated to establishing plant repertoires to cure these frequent diseases. However, digestive diseases may be treated with a wide range of bioactive compounds, which might also explain the large number of plants associated with their cure. If this reasoning is valid, then complex diseases whose treatment is associated with only one or a limited number of bioactive compounds will tend to have a small number of species used for their treatment, which is the case for cancer, certain diseases of the nervous system, and many others.

However, the study of therapeutic indication patterns may be impaired by theoretical and methodological problems. Ethnobotanical studies generally do not focus on therapeutic indications, which are usually only used to compose lists of plants or calculate indexes of species importance. Studies that only record the medicinal properties of each plant without considering local disease concepts, which may be very different from western models, are common. A condition that is considered a disease by western society may be considered a different type of condition by a local community; thus, the definition of what constitutes a disease varies. In communities of northern Argentina studied by Hurell (1991), disease is not considered a transitory state from a normal condition; instead, health and disease are considered two states of an individual's life.

In addition, the way in which plants act on the disease may be approached superficially in different studies. Many studies do not differentiate among plants that can be used to heal a disease, mitigate its symptoms, or prevent it. Thus, clear and detailed presentations and discussions of therapeutic indications in ethnobotanical studies are essential for the study of their patterns.

12.7 The Role of the Environment

In the previous sections, we discuss medicinal plant use behavior patterns and their possible causes. However, these behaviors may differ from one location to another depending on many factors, including the role of the environment in which human groups are included. Thus, we discuss how the environment may bring different communities closer or separate them in terms of similarity in medicinal plant use. We also show how the previously discussed patterns relating to origin, plant habit, and plant therapeutic indications may differ between communities located in different environmental settings.

Different studies have shown that the environment plays an important role in the selection of medicinal plants and reported that individuals from different ethnic groups or origins inhabiting nearby or neighboring regions in similar environments tend to use similar repertoires of medicinal plants. Coe and Anderson (1999) compared two neighboring indigenous groups of different ethnicities in Nicaragua and observed that 80 % of their medicinal plant repertoires was shared between the two groups. Similarly, Albuquerque et al. (2008) compared the plant components of pharmacopoeias from an indigenous group and rural community of the Caatinga of the state of Pernambuco, Brazil, and noted similarities among the plants used, with even greater similarities when the native plants were analyzed separately. More recently, Saslis-Lagoudakis et al. (2014) studied 12 ethnic groups in Nepal and found that local pharmacopoeias are more similar when cultures are placed in similar floristic environments.

The importance of the environment on plant selection can also be observed in studies showing differences in the pharmacopoeias of peoples of the same origin that live in different environments. Ladio et al. (2007) compared the knowledge of medicinal plants of the Mapuche people inhabiting arid steppe and humid forest areas of the Argentinean Patagonia and observed that only 40 % of the plants were used by both groups. The high discrepancy was attributed to the two communities inhabiting different ecosystems, which limits the acquisition of and contact with the same plants by the two groups.

Migrations also provide interesting examples of how the environment can limit species acquisition or decrease similarities between pharmacopoeias (see Medeiros et al. 2012), even between people of the same origin. A particularly enlightening case study was conducted with the Akha people, who were separated between 100 and 120 years ago among China, Thailand, and other Southeast Asian countries (Inta et al. 2008). The study showed that although they maintained similar practices and traditions, the movement towards different areas forced the Akha to use a different group of medicinal plant species.

In addition to variations in the repertoire of medicinal plants reported according to ecosystem, the richness in medicinal plants itself also varies because certain ecosystems can provide a greater number of different plants for use by local peoples. Plants are often selected for medical practices according to bioenvironmental logic, which is guided by the physicochemical properties of the plants (Johnson 2006), and certain ecosystems favor a greater presence of certain bioactive compounds over others (see Voeks 2004; Albuquerque et al. 2012). Thus, certain ecosystems may support a greater use of native medicinal plants; together with historical and cultural factors, these factors may help explain why certain areas have a higher richness of native species in their pharmacopoeias than others.

Another widely discussed but little tested question regarding medicinal plant richness is whether urbanization has decreased the number of plant species in local pharmacopoeias. In general, increasing urbanization is considered to lower the richness of medicinal plants (Amorozo 2002) because urban environments (a) have a lower availability of species, especially native species, which is supported by urban ecology studies (see McKinney 2008), and (b) favor easy access to allopathic drugs (Amorozo 2002), which may decrease the use of plants for therapeutic ends. However, this hypothesis has not been tested, and authors have proposed scenarios that do not support a decrease in richness with increasing urbanization. Amorozo (2002) suggests that when communities are influenced by urban-industrial societies, an initial increase in the knowledge of plants and their uses may occur because of increased opportunities for contact with exotic species, which may be acquired in pharmacies or public markets (see Hilgert et al. 2010).

Therefore, the dynamics of plant knowledge and/or the use of plant species may be consistent with the intermediate disturbance hypothesis,[6] which states that locations with intermediate degrees of urbanization have a higher richness of known and/or used species because they are at an optimal plateau between the ability to obtain native plants (apparently higher in environments with low urbanization environments) and exotic plants. Thus, urban environments can be expected to have a higher proportion of exotic species than rural environments.

The environment and degree of urbanization may also influence plant habits that are more commonly used by the community, which might be caused by the higher or lower availability of a given plant habit (see Thomas et al. 2011) or different biochemical pathways utilized by plants with different habits in different environments (in the specific case of the environment) (Albuquerque et al. 2012). For example, tree species may present a high incidence of qualitative compounds in certain environments, such as in the Caatinga, whereas these compounds may be restricted to herbaceous plants in other environments, which has been observed in many of the studies supporting the EAH. Such a scenario might result in a pattern based on the use of herbs in certain cases and the use of trees in other cases, such as in the Brazilian Caatinga (see Albuquerque et al. 2012).

Although patterns related to therapeutic indications are clear and based on the dominance of digestive and respiratory systems disorders, different environments may at times lead to different dominant diseases and exhibit different patterns of plant usage. These variations may be directly associated with differences in the environments surrounding the communities. Such differences are primarily caused by the (a) occurrence of diseases that are typical to a certain location and do not occur or are less frequent in other locations and (b) environmental influences that favor certain biochemical pathways and alter the predominant compounds and types of diseases that these compounds can treat.

[6] The intermediate disturbance hypothesis was first proposed within the scope of community ecology to explain why species richness and diversity in environments at the initial stages of anthropization are higher than in completely anthropized or completely natural areas. This hypothesis proposes that areas of intermediate disturbance preserve their original components and gather richness by including pioneer and invasive species.

12.8 Final Considerations

Based on the evidence presented in this chapter, the following conclusions can be drawn:

1. Clear patterns can be observed in medicinal plant use by local populations based on similar forms of resource appropriation by those populations.
2. Although pattern formation is observed, dissonant behaviors will always occur that are inconsistent with the pattern.
3. The environment (among other factors) may play a fundamental role in the observed differences in plant use among different communities and may result in divergent patterns (for example, the higher use of herbs in certain environments and higher use of trees in others.

We believe that future studies will also be presented with the challenge of filling knowledge gaps on this topic. However, studying plant use in humid vs. arid, tropical vs. temperate, or urban vs. rural areas may provide answers to outstanding questions and elucidate subjects that have not been previously investigated.

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