Article

Quantitative Research Methods of Linguistic Niche and Cultural Sustainability

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Abstract: Building Sustainable Cities and Human Communities is one of the 17 Sustainable Development Goals of the United Nations. And the sustainability of culture plays an important role in the sustainable development of cities and human communities. Language is an important carrier of culture, and the sustainability of language is the key factor in the sustainability of culture. How to measure the sustainability of language and its niche is key to achieving sustainable cities and communities. This paper systematically summarized the concept of niche and the theory of ecolinguistics as a theoretical basis for the quantitative study of the linguistic niche, and at the same time, the methods of niche measurement were summarized to provide mathematical support for the quantitative study of the linguistic niche. The Shannon-Wiener index and Pianka index were used to quantitatively study a particular linguistic niche for the first time, based on the use of Hmong and Mandarin in Jianhe County, Guizhou Province, China. The results showed that in the temporal dimension, the niche overlap indexes of Hmong and Mandarin were all above 0.9 in the sample villages, but in the spatial dimension, the niche overlap indexes of both languages were between 0.5 and 0.6. The spatial niche separation moderated the high temporal niche overlap, which made the two languages’ spatio-temporal niche overlap at a medium-high level. The quantitative study of a linguistic niche proved helpful in quantifying the level of sustainable development of language and culture, thus providing timely, accurate, and dynamic reference data to inform macro-control policies on the sustainable development of cities and human communities.

Keywords: linguistic niche; ecolinguistics; linguistic ecology; landsenses ecology; linguistic landsense ecology

1. Introduction

Niche refers to the temporal and spatial position of a population in a community and its functional relationship with related populations [1], which is an important index reflecting the relationship among species and between species and the environment [2]. Niche theory has been widely used to evaluate interspecific relationships, community structure, biodiversity, succession, and population evolution in ecosystems [3]. A language and its environment constitute a language ecosystem, which is more commonly called a speech/language community. The status and function of a language in its language community also determines its succession and ecology. In 1970, Haugen introduced the concept of ecology to linguistics and proposed the notion of “the ecology of language” [4]. In 1972, he defined “language ecology” as “the study of interactions between any given language and its environments” and argued that “languages do have life, purpose, and form, each of which can be studied and analyzed as soon as we strip them of their metaphorical or mystical content and look upon them as aspects of human behavior” [5]. The explanatory power of niche theory in explaining interspecific relationships makes it a powerful tool for revealing interlingual relationships. At present, some research on linguistic niches, also known as language niches, has been carried out [6–8], but has mainly focused on...
qualitative research or conceptual references, while few studies have yet sought to carry out quantitative research on linguistic niches. Quantitative study of the linguistic niche will be the key to transforming the study of language ecology from a metaphorical model to real ecological science. Therefore, the research question in this study is concerned with how to quantify the notion of linguistic niche.

The aim of this paper was to extend niche measurement methods from interspecific relationships to interlingual relationships so as to establish the theoretical basis and methodology for the quantitative study of linguistic niches. By measuring niche breadth and niche overlap, this paper quantified the niche characteristics of language and revealed the relationship among languages and between languages and their social and demographic environments in which they were learned and used. This can provide timely, accurate, and efficient digital information for language planning and its sustainable development, and truly apply ecological methods to the study of language ecology.

2. The Expansion of Niche Concept in Ecolinguistics

Streere of the University of Michigan was interested in the ecological implications of “niche” as far back as 1894, when he tried to explain the separation of bird species in the Philippine islands, but he did not provide any real explanation of the concept of niche [9,10]. Johnson (1910) was the first one to use the term “niche” in ecology, but he did not define it in detail or develop it into a comprehensive concept [10,11]. Grinnell of the University of California was the first to define niche specifically in his study of the niche relationships of California long-tailed songbirds [10]. Grinnell (1917) explained “the ultimate associational niche occupied by the California Thrasher” as “one of the minor niches which with their occupants all together make up the chaparral association” [12], and concluded that “no two species regularly established in a single fauna have precisely the same niche relationship” [12]. In 1924, he further revised the definition of niche as the ultimate unit occupied by just one species or subspecies [13]. Grinnell’s definition of niche was called Space Niche [14–16]. Charles Elton (1927) described niche as the functional role and position of a species in the community to which it belonged, emphasizing the nutritional relationship between species. He believed that an animal’s niche indicated its status in the biological environment and its relationship with its food sources and natural enemies, which was called the Trophic Niche or Functional Niche [15,16]. Hutchinson (1957) proposed an n-dimensional hypervolume model of niche, and believed that a niche was the selection range of multi-dimensional environmental variables for each organism, which was the so-called Hypervolume Niche [14,17]. On this basis, he also proposed the concepts of fundamental niche and realized niche. Odum (1959) further defined niche as the status and condition of a species in its community and ecosystem.

The first upsurge of niche research took place in the 1970s [15], with scholars such as Pianka (1973), Grubb (1977), Colinvaux (1986), and Wang et al. (1984) defining niche from different perspectives. Liu and Ma (1990) put forward Extended Niche Theory and summarized three deficiencies in the previous definitions of niche. Firstly, only species were considered as the users or occupants of niches, without including other biological units that held niches, such as biomes, ecosystem, age groups, genders, and cells. Secondly, only environmental factors such as food, temperature, humidity were considered, while time factors were ignored. Thirdly, only the actual utilization of niches was discussed, but potential and non-existent forms of niches were not considered [10]. Extended Niche Theory made up for these three deficiencies and promoted the development of the concept of niche. From the 1990s, the concept of niche started to attract unprecedented attention [15,18], and research on niche theory entered its second phase of development. Although there are many interpretations of the concept of niche and no consensus on the definition of the term has been reached, the development of the concept of niche and research into niche theory have been carried out simultaneously, and have shown a tendency to infiltrate into other fields, such as the applied research in urban ecology [19], and human ecology [20].
In the first upsurge of research into niche theory, Norwegian American scholar Haugen (1970) produced an academic report entitled “On the ecology of languages” which introduced the concept of ecology into the study of linguistics. In 1972, he further defined language ecology as the study of interactions between any given language and its environment and pointed out that the true environment of a language was the society which used it as one of its codes [5]. At the beginning of the second phase of niche research, in talking about the relationship between language and environment, Halliday (1990) pointed out that “classism, growthism, destruction of species, pollution and the like [ . . . ] are not just problems for the biologists and physicists. They are problems for the applied linguistic community as well” [21]. Although Haugen and Halliday had different perspectives, they both focused on the position and function of language, that is, the niche of language. Haugen and Halliday represent the two main research paradigms of ecolinguistics and their approaches brought a rise in the development of ecolinguistics which coincided with the two research upsurges of niche. In the 1970s, Haugen’s research brought ecolinguistics to attention for the first time, and it was at this time that the concept of niche also began to arouse major research interest. When niche research was in its second phase of development in the 1990s, Halliday’s research also led to rapid development in ecolinguistics. It can be seen that the rise and development of ecolinguistics have synchronized with and been influenced by niche theory, although neither Haugen nor Halliday used the term niche explicitly in their research.

According to Fan and Ma (2018), in the 1980s, P. Finke, W. Trampe, and H. Strohner, from the University of Bielefeld in Germany, put forward the Theory of Language World System [22]. In this theory, they established the concept of “language world system”, i.e., language ecosystem, based on the model of ecosystem, and pointed out that in language world systems, as in ecosystems, there were language organisms, language habitats, languages, language groups, language niches (like ecological niches), and language circles (like ecological circles). In this theory, the concept of language niche refers to the position of languages, including dialects, in time, space, and community in the multilingual ecosystem of language groups and to their functional relationships with related languages [22]. The niche of a language is related to the environment of its community. The niche of a language is the position and function of a language in its community, as reflected by the number of language users in the community and the distribution range of the occasions on which the language is used. As Fan and Ma (2018) said, due to competition, each language has different functional niches in the cluster ecosystem, but as long as its niche is stable, the survival vitality of the language can be maintained. For example, in a multilingual community, the population and the occasions of use of different languages are not balanced, and some are widely different. A language may have a small population and may be used on a few occasions, but as long as its population and its occasions of use are stable, the language has the necessary language niche and “niche breadth” to survive [22]. Linguistic niche breadth, also known as linguistic niche width, refers to the sum of resources used by a language in its language community. Therefore, the quantification of linguistic niche breadth is crucial to measure the vitality of languages, perform language planning, and protect endangered languages.

The Theory of Language World System is no longer merely the metaphorical application of ecological concepts. It also reveals possible parallels and isomorphism between language environment systems and ecological environment systems [22]. The theory holds that in the language world system, a language and its implications in situational, individual, social, cultural, and environmental contexts can also be revealed and described in terms of reciprocity, circulation, network of relationships, symbiosis, diversity, succession or evolution, process, balance, pollution, and extinction. The quantitative study of linguistic niches is the concrete embodiment of the isomorphism between language environment systems and ecological environment systems. In 1972, Haugen pointed out that “the ecology of a language is determined primarily by the people who learn it, use it, and transmit it to others” [5]. It can be said that the three main elements of the ecology of a language
are learning it, using it, and transmitting it. Based on the Shannon-Wiener index and Pianka index, this paper discussed the three elements of language ecology in terms of the temporal niche, spatial niche, and spatio-temporal niche of the two languages of Hmong and Mandarin in the sample villages.

3. A Quantitative Study of Linguistic Niche

Located in the southeastern part of Guizhou Province in southwest China, Jianhe County is a multi-ethnic region where ethnic minorities, such as Miao, Dong, account for 96 percent of the total population of the county, and it has formed a multilingual community in which minority languages coexist with Mandarin and dialects. In areas with such high linguistic diversity, the relationship among languages and their social functions are of great significance to the maintenance of linguistic diversity. In this study, five ethnic Miao villages in Jianhe County were used as sample villages to compare the social status of Hmong, the language of the Miao people, and Mandarin. For both Hmong and Mandarin, temporal niches, spatial niches, and spatio-temporal niches were elucidated, with the Shannon-Wiener formula used to calculate their niche breadths and the Pianka formula to calculate their niche overlap indexes. This paper is the first quantitative study of this linguistic niche, which provides some basic data and a theoretical basis for analyzing the functions and status of languages in the community and their relationships.

3.1. Materials and Methods

3.1.1. Data Collection and Questionnaire Design

In October 2020, a survey on subjects’ listening and speaking ability in Hmong and Mandarin was conducted in four Miao ethnic villages in the Jianhe County (i.e., Dangyi village, Dongku village, Liufu village, and Nanshao village). A total of 440 questionnaires were distributed, with 356 valid questionnaires collected. After the initial sampling survey and analysis were completed, based on the first questionnaire, the feasibility of the study was evaluated, and the questionnaire was adjusted according to problems found. After being reviewed and approved by experts in the field of ecology, in May 2021, random stratified sampling was conducted for the residents of the five Miao villages of Dangyi village, Dongku village, Liufu village, Nanshao village, and Mashan village divided according to age range. In each sample village, seven age ranges were set according to the ages from below 10 to 60 and above, and 33 questionnaires were distributed to each age range. A total of 1155 questionnaires were sent out and 1153 were collected, with an effective recovery rate of 99.83%. Two languages of Hmong and Mandarin were investigated.

The questionnaire included four aspects: subjects’ basic information, their bilingual proficiency, their bilingual usage, and their bilingual attitude. Two questions were set for language proficiency, namely, “how well do you know Mandarin?” and “how well do you know Hmong?”. According to the method of Huang et al. (2018), each question had six options, that is, “Able to talk fluently without any obstacles”, “Able to talk skillfully with occasional obstacles”, “Basically able to talk, but not skilled”, “Able to understand, but can’t speak well”, “Able to understand some, but can’t speak”, and “Neither understand nor speak”. The first three options can all be classified as knowing at least a certain language, while the last three options can be classified as not knowing the language [23]. Based on this standard, the proficiency of subjects’ Hmong and Mandarin was determined, and the temporal niche width of each language was calculated according to the proportion of the number of individuals in each age range who knew this language (See Appendix A) in relation to the number of all the individuals who knew this language. Five spatial domains were set according to the language usage: i.e., at home, at school/at work, at recreation venues, at the supermarket, and in the village. The spatial niche width of each language was calculated according to the proportion of the number of individuals using the language in each spatial domain (See Appendix B) in relation to the number of all the individuals using the language. The temporal niche and spatial niche of Hmong and Mandarin were
calculated by setting the time domain based on the subjects’ age intervals and setting the spatial domain according to where the languages were used.

3.1.2. The Measurement of Niche and the Quantification of Linguistic Niche

Niche measurement includes two aspects. One is the measurement of niche breadth, and the other is the measurement of niche overlap.

Niche Breadth

Niche breadth refers to the sum of various resources used by a species (or other biological units) in a community. Niche breadth is mainly measured by the index of niche breadth [24]. The Shannon-Wiener index (1963) [25], Levins index (1968), and Smith index (1982) are commonly used for measuring niche breadth, and linguistic niche breadth can also be measured by these indexes. In this paper, the Shannon-Wiener index has been used to calculate linguistic niche breadth. Based on the number of language users, a resource matrix was constructed, which took the age intervals of language users and the use occasions of the language as resource states to calculate the corresponding temporal niche breadth and spatial niche breadth respectively. The formula [25] is as follows:

\[ B_i = -\sum_{j=1}^{R} P_{ij} \ln(P_{ij}) \] (1)

In this formula, \( B_i \) represents the niche breadth of language \( i \). \( P_{ij} = n_{ij}/N_{ij} \), that is, the ratio of the number of language \( i \) appearing in the resource \( j \) to the total number of language \( i \). In the calculation of temporal niche breadth and temporal niche overlap, \( j \) represents the age intervals under investigation, while in the calculation of spatial niche breadth and spatial niche overlap, \( j \) stands for the investigated classified occasions of language use. \( R \) is the total number of age intervals or the total number of classified occasions of language use. The larger \( B_i \), the larger the number of language users, and the larger the social function of the language.

Niche Overlap

Niche overlap occurs when two species make use of the same resources or share certain resource factors; niche overlap is mainly measured by the coefficient of niche overlap [24]. Commonly used niche overlap indexes include the Morisita overlap index (1959), Horn overlap index (1966), Levins overlap index (1968), Pianka overlap index (1973) [26], Schoener overlap index (1974), and Hurlbert overlap index (1978). In this study, the Pianka niche overlap index formula has been used to calculate the temporal niche overlap and the spatial niche overlap of languages. The resource matrix construction is the same as above, and the calculation formula [26] is as follows:

\[ O_{ik} = \frac{\sum_{j=1}^{R} P_{ij} \cdot P_{kj}}{\sqrt{\sum_{j=1}^{R} P_{ij}^2 \cdot \sum_{j=1}^{R} P_{kj}^2}} \] (2)

In this formula, \( O_{ik} \) represents the niche overlap index of language \( i \) and language \( k \) in relation to resource \( j \). \( P_{ij} \) and \( P_{kj} \) represent the utilization ratio of language \( i \) and language \( k \) to resource \( j \) respectively. \( O_{ik} \) is between 0 and 1, and according to Krebs (1999), niche overlap can be divided into three levels: 0.6 ≤ \( O_{ik} \) ≤ 1, which means there is a high niche overlap between two populations; 0.3 ≤ \( O_{ik} \) < 0.6, which indicates moderate overlap; and 0 ≤ \( O_{ik} \) < 0.3, which indicates non-overlap.

Spatio-Temporal Niche

Spatio-temporal niche refers to the status and function of a species on the comprehensive dimensions of time and space. Spatio-temporal niche can be measured by May’s method [27].

\[ \text{Spatio-temporal } B_i = \text{Temporal } B_i \times \text{Spatial } B_i \] (3)

\[ \text{Spatio-temporal } O_{ik} = \text{Temporal } O_{ik} \times \text{Spatial } O_{ik} \] (4)
3.1.3. Methods of Data Analysis

Niche breadth indexes and niche overlap indexes of Hmong and Mandarin were calculated using Microsoft Excel 365.

3.2. Result and Analysis

3.2.1. Niche Breadth

Based on the Shannon-Wiener niche breadth formula and May’s method, the temporal niche breadth, the spatial niche breadth, and the spatio-temporal niche breadth of Hmong and Mandarin respectively in the five sample villages were calculated (see Table 1).

| Sample Villages | Languages | Temporal Niche Breadth | Spatial Niche Breadth | Spatio-Temporal Niche Breadth |
|-----------------|-----------|------------------------|-----------------------|------------------------------|
| Dangyi village  | Mandarin  | 1.9233                 | 1.4665                | 2.8206                       |
|                 | Hmong     | 1.9447                 | 1.4012                | 2.7249                       |
| Dongku village  | Mandarin  | 1.9300                 | 1.5216                | 2.9367                       |
|                 | Hmong     | 1.9454                 | 1.3870                | 2.6983                       |
| Liufu village   | Mandarin  | 1.9191                 | 1.5274                | 2.9311                       |
|                 | Hmong     | 1.9336                 | 1.4582                | 2.8196                       |
| Nanshao village | Mandarin  | 1.9216                 | 1.5174                | 2.9159                       |
|                 | Hmong     | 1.9415                 | 1.4661                | 2.8466                       |
| Mashan Village  | Mandarin  | 1.9344                 | 1.4593                | 2.8230                       |
|                 | Hmong     | 1.9450                 | 1.3960                | 2.7153                       |

Temporal niche breadth reflects the distribution of a species in the temporal dimension. In this study, the temporal niche breadth of a language reflects its distribution within each age range. The wider the temporal niche of a language, the greater the number of people at all ages who speak it, and the more stable the number of people who have learned the language. In the five sample villages, the temporal niche breadths of Hmong were slightly higher than those of Mandarin, which indicated that Hmong had certain advantages in the age range. That is to say, Hmong was more widely distributed and even across age groups, which meant Hmong had a more stable group of speakers. However, the difference was not more than 0.02. This indicated that the number of speakers of both languages was roughly the same across the age ranges, and the number of speakers of Hmong was slightly higher than that of Mandarin but the difference was not significant. The slight advantage in the temporal niche of the Hmong suggests that the considerable number of Hmong speakers is one of the reasons why the local Hmong is so vibrant. This is the importance of “learning it”, one of the three main elements of the ecology of a language. On the one hand, the temporal niche of Hmong in the sample villages verifies this one major element of language ecology, i.e., “learning it” and points the direction for the maintenance of language sustainability; on the other hand, it provides a monitoring index of language ecology and an effective means for real-time detection of the language ecosystem, that is, to calculate the temporal niche breadth of a language by the Shannon-Wiener formula, based on the number of language speakers in the age intervals.

Spatial niche breadth reflects the distribution of a species in the spatial dimension. In this study, the spatial niche breadth of a language reflects the distribution of the language in each spatial domain investigated. The wider the spatial niche of a language, the wider the spatial distribution of the language and the more stable the use of the language. In the five sample villages, the spatial niche breadths of Hmong were lower than those of Mandarin, with differences between 0.05 and 0.13. This indicated that the distribution of spatial resources was not uniform in the case of Hmong, and it tended to be used on special occasions. The use of Hmong tended to be concentrated in domestic environments such as in familial contexts. However, as pointed out by Fan and Ma (2018), as long as its use occasions are stable, the language has the necessary language niche and niche breadth...
to survive [22]. This is the importance of “using it”, the second element of the ecology of a language. Although Mandarin was used on slightly more occasions than Hmong in the sample villages, it did not seem to be that different. This paves the way for language ecology supervision and sustainable level detection. Regular or periodic measurement of the linguistic spatial niche can be used to make dynamic assessments and qualitative judgments on the ecology of a language as well as its development trend and vitality.

Spatio-temporal niche breadth reflects the distribution of a species on the comprehensive dimensions of space and time. The spatio-temporal niche of a language can reflect the overall sustainability of a language in terms of the number of speakers and the occasions on which it is used. The wider the spatio-temporal niche of a language, the more stable the suitable population and occasions of use of the language, and the stronger its sustainability. The spatio-temporal niche breadths of Hmong in the five sample villages were all slightly lower than those of Mandarin. Their spatio-temporal niche breadth indexes were 2.7249, 2.6983, 2.8196, 2.8466, 2.7153, and 2.8206, 2.9367, 2.9311, 2.9159, 2.8230 respectively. This showed that Mandarin had wider applicable scopes and broader social functions, while the social status and function of Hmong was slightly lower than that of Mandarin, but the difference was between 0.07 and 0.24, which showed that Hmong was still adapted to the specific social environment, possessing a certain social status and function. This indicated that the vitality of Mandarin across different age intervals and occasions of use was slightly higher than that of Hmong in the five sample villages, although the difference was not huge. This means that at present, Hmong and Mandarin in the sample villages generally complement each other, and the local language diversity is in an ideal state. This has benefited from the relatively stable population learning Hmong, i.e., its temporal niche, and the fairly stable occasions on which Hmong is used, i.e., its spatial niche. This can provide a reference for the maintenance and measurement of language ecology in other areas. However, it should be remembered that “language as an ecological phenomenon is dynamic, situated, and holistic” [28]. Therefore, it is necessary to conduct regular monitoring and quantification of the ecology of a language. The spatio-temporal niche of a language is a comprehensive reflection of “transmitting it”, the third element of the ecology of a language. The assessment and measurement of spatio-temporal niche of a language can provide timely and accurate information as to the ecology and sustainability of the language.

3.2.2. Niche Overlap

Temporal niche overlap reflects the similarity, uniformity, and potential competition among species in the temporal dimension. The temporal niche overlap of languages reflects the similarity and the uniformity of the language populations under investigation across all age ranges. The higher the temporal niche overlap of languages, the more similar and consistent the populations who know the two languages. The temporal niche overlap indexes of the two languages in the sample villages were all over 0.9 (see Figure 1) and even as high as 0.99, indicating that language users were extremely similar and overlapped in the age ranges. It should be recognized that niche overlap is only a necessary rather than sufficient condition for exploitative competition [29]. When resources are abundant, species with similar or overlapping niches can still develop together rather than compete against each other. In resource-poor habitats, niche overlap may lead to exploitative competition [30]. Therefore, the high overlap in the linguistic temporal niche does not necessarily mean that there is inter-language competition, but probably reflects that people with multilingual ability are relatively similar, or indicates that the ecology of the investigated languages is in a relatively ideal state. As can be seen from Appendix A, the number of people who can speak Hmong and Mandarin in most age groups in every sample village was relatively similar, indicating that the number of people learning both languages is similar. In other words, the ecology of the two languages is at parity. This may not be a competition, but a sign of the vitality and sustainability of both languages.
Spatial niche overlap index reflects the similarity of interspecies distribution in the spatial dimension [31]. The spatial niche overlap of languages reflects the similarity and the uniformity of the occasions on which these languages are used. The higher the spatial niche overlap of languages, the more similar the occasions on which these languages are used. In the five sample villages, spatial niche overlap indexes of the two languages were not high, basically around 0.5, which indicated that the two languages were almost always used on different occasions. Appendix B further shows that Hmong is mostly used at home and in the village, while Mandarin is mostly used at school/at work, at recreation venues, and at the supermarket. The separation in their spatial niches is not only the reason for each of them to have relatively stable learners and use occasions, but also a focus of ecological monitoring of the two languages in the future.

The spatio-temporal niche overlap index is the product of the temporal niche overlap index and the spatial niche overlap index, which can better measure the interspecies relationship [32]. The spatio-temporal niche overlap indexes of Hmong and Mandarin were between 0.506 and 0.6381. With $0.6 \leq O_{ik} \leq 1$ as the limit of high overlap, the two languages were highly overlapping in three sample villages (Dongku village, Liufu village, Nanshao village), accounting for 60% of the total number of sample villages, indicating that the spatio-temporal niche overlap between Hmong and Mandarin was generally at a medium and high level. The spatio-temporal niche overlap index of Hmong and Mandarin was the highest (0.6381) in sample village 3 (Liufu village), where their spatio-temporal niche breadth indexes were also relatively higher, at 2.9311 and 2.8196 respectively. Their spatio-temporal niche overlap index was the second highest (0.6368) in sample village 4 (Nanshao village), where the two languages also had relatively higher spatio-temporal niche breadths (2.9159 and 2.8466 respectively), indicating that their niche overlap was more likely to occur in the regions where the two languages had higher niche breadth. The niche breadth indexes for Hmong and Mandarin were both lower in sample village 1 (Dangyi village) and sample village 5 (Mashan village), where their niche overlap indexes
were both lower, at 0.506 and 0.5061 respectively, showing that in the areas where the niche breadths of Hmong and Mandarin were both small, they had less common resource status, and different utilizations and requirements of resources.

4. Discussion

4.1. The Necessity of Quantifying Linguistic Niche and the Innovation of this Study

“If diversity is a prerequisite for successful humanity, then the preservation of linguistic diversity is essential, for language lies at the heart of what it means to be human. If the development of multiple cultures is so important, then the role of languages becomes critical, for cultures are chiefly transmitted through spoken and written languages.” [33].

The ecology of each language in a language community is the cornerstone of the linguistic diversity of that community. Language ecology is an important practical problem. Coping with the natural ecology firstly depends on ecological monitoring and evaluation. In the same way, scientific monitoring and evaluation of language ecology is also the basic premise for dealing with the contemporary problems of language ecology [34]. At present, however, the monitoring of language ecology is still at the exploratory stage, and there is no scientific index system or effective measurement model. Whatever method is used, as long as it is scientific, objective, and operable, is worth trying [35].

The index system of niche measurement has been widely applied to study the relationship between species and their environment. However, due to the heterogeneity of variables and modeling, it is difficult to carry out quantitative study on linguistic niches. The first application of the Shannon-Wiener index and Pianka index to linguistic niches, as carried out by this study, provides a scientific, objective, and operable method for monitoring the ecology of a language. The quantitative study of linguistic niches is an effective way to monitor language ecology and ensure linguistic diversity, which is a necessity for the theoretical development as well as real application of ecolinguistics.

4.2. The Significance of Quantitative Research on Linguistic Niche and Cultural Sustainability

The investigated area belongs to a minority-inhabited area of Guizhou province in China, which has high linguistic diversity. However, the social status and functions of some ethnic minority languages in this region such as Gelao and Monao have been degraded or even endangered due to the decrease in the number of speakers and occasions of use. The Miao nationality in this area, which still retains its traditional culture and distinctive language Hmong, is a typical case of the preservation of a minority language and culture. The in-depth study of the Hmong niche is of a certain enlightenment to the protection of ethnic minority languages and cultural sustainability in the whole country and even the whole world.

Quantitative research on the spatio-temporal niche of languages can effectively reveal the distribution of ethnic minority languages and Mandarin within applicable populations and on applicable occasions, which can provide timely and accurate information for language macro-control and language planning. The measurement of linguistic niche breadth can effectively reveal the position and function of language in its community. The temporal niche breadth of a language can quantify the survival of a language in its specific community, region, or domain, and the spatial niche breadth of a language can digitize the vitality of a language in communicative use, thus revealing whether it has a continuous and stable communicative function. The spatio-temporal niche breadth of a language can show the language vitality comprehensively and systematically. Decay in language vitality often leads to the decline and extinction of the language. The key to sustaining language vitality is to maintain its communicative adaptation in the modern language life of the community [22]. Spatio-temporal niche overlap between languages reflects the similarity of different languages in speakers and occasions of application, while temporal niche overlap and spatial niche overlap can effectively reveal the specific dimensions of language niche overlap, and expose specific factors that affect its overall niche status. Therefore, the combination of the temporal niche, spatial niche, and the spatio-temporal
niche can better reveal interlingual relationships and the particular factors that affect interlingual relationships.

4.3. Prospects of Future Study

The quantitative study of linguistic niches is helpful to coordinate the protection of ethnic minority languages and the promotion of Mandarin, and to implement language policy that takes subjectivity and diversity into account. However, the internal and external drivers that influence linguistic niches require further research in combination with the overall understanding of “landsenses ecology” to maintain linguistic diversity and cultural sustainability in multilingual communities. The concept of landsenses ecology was first proposed by the Chinese scholar Zhao Jingzhu in 2015 [36]. “The core idea of landsenses ecology is that people often integrate certain visions or hopes into a carrier in an appropriate way, so that other people can grasp these visions from the carrier. These visions can change people’s state of mind and ideology, so as to achieve vision resonance, and then guide or regulate people’s words and deeds” [37]. In a multilingual society, the use or prominence of a certain language not only has an information-baring function but also contains the vision of transmitting the language and its culture, thus constituting a linguistic landsense. As Zhang et al. defined, “A linguistic landsense refers to a meaning carrier that contains one or more of speakers’/designers’ visions through appropriate forms of manifestation, through which listeners/readers can graft, understand and resonate with the visions, thus forming a common code of conduct. It is a theoretical extension of landsenses ecology in the field of semiotic studies and a methodology of ecolinguistics” [38]. Based on the basic principles of landsenses ecology and ecolinguistics, linguistic landsense ecology was proposed in this study. Linguistic landsense ecology is a branch of landsenses ecology concerned with the study of the relationship between language and environment. By analyzing the role of linguistic landsenses in creating people’s vision resonance and behavioral norms, the interactive relationship between language systems and ecosystems is revealed. This includes not only the impact of linguistic landsenses on the sustainability of various ecological environments, but also the impact of environment on the sustainability of language. In future, the Shannon-Wiener index and the Pianka index can be used on the one hand to quantitatively study linguistic niches, and on the other hand to study the artificial driving factors affecting linguistic niches from the perspective of linguistic landsense ecology.

5. Conclusions

On the one hand, this paper systematically sorted out the concept of niche and the theory of ecolinguistics, which provided a theoretical basis for quantitative research into linguistic niches. On the other hand, the Shannon-Wiener index and the Pianka index were used to measure niche breadth and niche overlap of languages, which provided mathematical support for the quantification of linguistic niches. Additionally, this paper studied niche breadth and niche overlap of Hmong and Mandarin in five sample villages from the perspective of the temporal, spatial, and spatio-temporal dimensions, which reflected the harmonious relationship between Hmong and Mandarin to a certain extent. The low spatial homology of the two languages degraded the high overlap in their temporal niches, which made their spatio-temporal niche overlap at a medium-high level. It was proved that the spatio-temporal niche could more accurately reveal language ecology and cultural sustainability than a single temporal niche or spatial niche. However, compared with the spatio-temporal niche, the single temporal niche or the single spatial niche can better reveal the specific dimensions that affect language ecology and cultural sustainability. Therefore, the combination of the temporal niche, the spatial niche, and the spatio-temporal niche can fully interpret the interlingual relationship. Quantitative research into linguistic niches can effectively reveal these interlingual relationships, and provide a new perspective on the empirical study of language ecology so as to promote the combination of ecolinguistics and ecology.
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Appendix A

Table A1. The following is the number of individuals in each age range who know Hmong and Mandarin.

| Village       | Language   | Below 10 | 10–19 | 20–29 | 30–39 | 40–49 | 50–59 | 60 and Above |
|---------------|------------|----------|-------|-------|-------|-------|-------|-------------|
| Dangyi Village| Hmong      | 27       | 30    | 31    | 32    | 31    | 31    | 31          |
|              | Mandarin   | 26       | 32    | 33    | 32    | 31    | 25    | 16          |
| Dongku village| Hmong      | 30       | 32    | 31    | 33    | 33    | 32    | 31          |
|              | Mandarin   | 30       | 32    | 31    | 33    | 33    | 27    | 18          |
| Liufu village | Hmong      | 19       | 32    | 33    | 31    | 31    | 31    | 31          |
|              | Mandarin   | 17       | 32    | 31    | 32    | 32    | 27    | 28          |
| Nanshao village| Hmong    | 24       | 32    | 32    | 32    | 32    | 31    | 18          |
|              | Mandarin   | 20       | 33    | 32    | 30    | 28    | 24    | 17          |
| Mashan village | Hmong    | 28       | 32    | 31    | 32    | 32    | 31    | 31          |
|              | Mandarin   | 26       | 32    | 32    | 30    | 32    | 32    | 20          |

Appendix B

Table A2. The following is the number of individuals using the language in each spatial domain.

| Village       | Language   | At Home | At School/At Work | At Recreation Venues | At the Supermarket | In the Village |
|---------------|------------|---------|-------------------|----------------------|--------------------|----------------|
| Dangyi Village| Hmong      | 181     | 60                | 52                   | 25                 | 140            |
|              | Mandarin   | 39      | 141               | 115                  | 155                | 39             |
| Dongku village| Hmong      | 158     | 52                | 40                   | 23                 | 133            |
|              | Mandarin   | 64      | 167               | 131                  | 164                | 58             |
| Liufu village | Hmong      | 165     | 67                | 49                   | 38                 | 136            |
|              | Mandarin   | 51      | 126               | 119                  | 133                | 50             |
| Nanshao village| Hmong    | 170     | 69                | 52                   | 42                 | 141            |
|              | Mandarin   | 46      | 128               | 107                  | 121                | 44             |
| Mashan village | Hmong    | 180     | 59                | 56                   | 22                 | 142            |
|              | Mandarin   | 41      | 149               | 119                  | 152                | 35             |

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