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Impacts of Policy-Driven Transformation in the Livelihoods of Fishermen on Agricultural Landscape Patterns: A Case Study of a Fishing Village, Island of Poyang Lake

Minghui Ou, Yexi Zhong *, Hongzhi Ma, Wenhui Wang and Manyu Bi

School of Geography and Environment, Jiangxi Normal University, Nanchang 330022, China
* Correspondence: zhongyexi@jxnu.edu.cn

Abstract: The agricultural landscape patterns of fishing village have undergone visible transformations in recent decades. Scholars pay less attention to fishermen with diverse livelihoods. Therefore, it is necessary to sort out the changing characteristics of fishermen' livelihoods and agricultural landscape patterns under different policy periods. We use in-depth interviews, remote sensing technology, and mathematical analysis to systematically study the changes in fishermen's livelihoods and in agricultural landscape patterns in a typical fishing village. The results show that policy have profoundly affected fishermen' livelihoods. Livelihood transformation have altered local land use practices, which had a direct impact on agricultural landscape patterns. The livelihood of fishermen has changed from diverse to single, and their cropping structure were gradually becoming simpler and more specialised. After grazing ban and comprehensive fishing ban, many fishermen migrated to towns and cities, it accelerated the loss of population in the fishing village, which caused the amount of abandoned land increasingly. Left-behind fishermen became rice farmers by contracting abandoned paddy fields. The expanses of abandoned land and bamboo woodland had increased, which caused agricultural landscape patterns gradually becoming fragmented, heterogeneous and complex.

Keywords: Poyang Lake; fishermen; policy; livelihoods; landscape patterns; transformation

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1. Introduction

With Reform and Opening-up being carried out in 1978, China has experienced rapid urbanization and industrialization. In addition, the departure of large numbers of labourers from the rural has led to the abandonment of large amounts of arable land, which made the agricultural landscape increasingly fragmented, heterogeneous and complex [1]. At the same time, changes in the livelihoods of farmers have led people to abandon arable land as they have stopped growing food. Human activities have profoundly impacted how agricultural landscape patterns have changed worldwide [2,3]. Socioeconomic development is a significant driver of change in land use and land cover and has had a substantial impact on the structure and function of landscapes [4–6]. Numerous studies have shown that socioeconomic factors determine landscape pattern change [7–10]. Moreover, socioeconomic development is usually driven by governmental policies and planning [11]. Such policies are important drivers of the evolution of natural and human factors, such as the natural environment, socioeconomic conditions, land use, landscape patterns, and farmers' livelihoods [12]. The development gap between rural and urban areas has resulted in a variety of issues related to land and livelihoods [13]. As powerful national macro-control instruments, governmental policies constitute viable solutions to these problems. Livelihoods entail a selective use of resources that is closely related to specific environmental, social, and cultural conditions [14]. Farmers' livelihoods can serve as an important lens through which to view the changes taking place in regional agricultural landscape patterns.

There is a close relationship between farm household types and changes in agricultural landscape patterns, and different types of farm household decisions can passively or

actively influence the structure of agricultural landscapes [15,16]. Therefore, to realise the integrated value function of agricultural landscapes and to alleviate human-land conflicts, attention must be paid to the role played by farmers' livelihoods in landscape development [17]. Farmers' non-agricultural livelihoods fundamentally lead to the sustainable use of agricultural land [18,19], which affects the function and structure of agricultural landscapes as they adapt their livelihood strategies and land use decisions to reduce their vulnerability [20–22]. Indeed, policies play an important role in guiding farmers' livelihood strategies and land use practices [18,20]. Studies have shown that there is a strong correlation between changes in agricultural landscape patterns and farmers' incomes [23], that changes in incomes are caused largely by changes in agricultural livelihoods and that policy interventions play an important role in influencing the livelihood choices of farm households [24,25].

Research on the relationship between policy, livelihoods and agricultural landscapes has focused on traditional agricultural areas, poor areas and ecologically fragile areas and has mainly targeted farmers with a single livelihood [12,26–28]. In most parts of the world, inland fisheries have been shown to be critical for food security, environmental health and economic development [29], but scholars have paid little attention to the agricultural landscapes of inland freshwater fishing regions and fishing communities with diverse livelihoods. Therefore, to shed light on the human-land relationship in inland freshwater fishing regions, it is necessary to sort out the changing characteristics of fishers' livelihoods and agricultural landscape patterns in different policy periods.

Since the 1990s, Poyang Lake has been the most important fishing area in the Yangtze River basin [30]. It is the richest lake in China in terms of freshwater fish resources, and the lake islands have fertile marsh soil and sufficient water for irrigation. People living on the lake islands not only rely on fishing for their livelihood but also engage in farming activities. Thus, their livelihoods are diversified. The Chinese government has paid close attention to the depletion of fishery resources, environmental degradation and frequent floods in Poyang Lake in recent years [31]. With the continuous adjustment of national policies such as flood relocation policy, grazing ban and comprehensive fishing ban, fishermen have changed their traditional livelihoods. Many have migrated to towns and cities, large amounts of arable land have been abandoned, and the agricultural landscape has changed dramatically.

As Hexi village is located at an island in Poyang Lake, boats are the only means of travel here, and travel to the island is extremely inconvenient. Therefore, it is rarely disturbed by the outside world. The villagers have been fishing for a living for generations; thus, they all have an extremely similar way of life. Furthermore, the high degree of overlap between Hexi village's administrative boundaries and the actual extent of Hexi Island, as well as the large amount of arable land and the variety of agricultural land on the island, suggests that Hexi village is a great reflection of changes in land use and land cover on the other islands of Poyang Lake. This case study focuses on Hexi, a typical fishing village on Poyang Lake, and builds a scientific and rational research framework to investigate the transformation taking place in agricultural landscape patterns on the Poyang Lake islands. The aims of this study are (1) to analyse the transformation of agricultural landscapes by fishermen in different policy periods and the relationship between fishermen's livelihoods and agricultural landscapes, and (2) to reveal the dynamic changes and transformation of agricultural landscape patterns in fishing villages. These aims have theoretical and practical significance for gaining insight into changes in agricultural landscape patterns in inland freshwater fishing regions in order to develop and enrich land use transformation theory. Furthermore, this study provides a scientific basis for optimising the agricultural landscape patterns on the islands of the Poyang Lake, revealing the relationship between humans and the land in this unique geographical environment.

2. Policy Review and Research Framework

Policy has guided the livelihoods and productive activities of farmers. In 1952, private agriculture was banned and replaced by a collective agriculture system, which was the basis of economic and social life in rural China for a long time. Land in this period was owned by both the state and the collective [32]. Peasants could only work collectively in rural areas, and private profit-making activities and freedom of movement were severely restricted [33]. Agricultural cultivation and grain production flourished under the influence of the "grain as the key link" policy. In the early 1980s, with the introduction of the family contract responsibility system, Chinese farmers were granted long-term land tenure [34]. The decentralisation of land contributed to the rapid growth of agricultural production in the early stages of reform [35]. Farmers were given the right to make their own production decisions and to earn an income from farming. The "vegetable basket" project was proposed by the Chinese Ministry of Agriculture in 1988 to alleviate the short supply of agricultural and side-line products in China, with a focus on solving the market supply shortage [36]. Subsequently, in 2010, the Chinese State Council issued a circular on strengthening the "vegetable basket" project that emphasised advances in agricultural cultivation techniques, resulting in a significant increase in the area of vegetable greenhouses [37,38].

The uncontrolled reclamation of arable land and creation of fields around lakes over a long period led to the reduction of the reservoir capacity and flood storage function of many lakes, which in turn caused frequent floods [31]. In 1998, a huge flood in the middle and lower reaches of the Yangtze River caused enormous agricultural losses and destroyed many villages [39]. Subsequently, the government proposed a policy of migrant relocation and returning the fields to the lake, concentrating on relocating residents of low-lying areas and prohibiting them from reclaiming arable land in the wetlands of Poyang Lake in a disorderly manner. This policy was intended to reduce the impact of the livelihood behaviour of small farmers on the ecological environment. In addition, the capture fisheries of the Yangtze River provide an important source of food for many people in the basin [40,41]. During the long period of uncontrolled fishing, the fishery resources of the Yangtze River rapidly declined, and some fish species became functionally extinct. There were even times when there were no fish to be caught. For this reason, in 2003, the Chinese Ministry of Agriculture implemented a closed season policy for the Yangtze River, prohibiting fishing from April to June each year [42]. However, the implementation of the closed season did not allow the fishery resources of the Yangtze River basin to recover. Starting in 2021, the government imposed a 10-year comprehensive ban on fishing throughout the Yangtze River basin [30,43], and fishermen switched their productive activities to other industries.

Cattle breeding is also an important source of income for agricultural smallholders. Schistosomiasis has been virtually eliminated in China, but areas with infected snails and the number of afflicted animals are on the rise [44]. Domestic animals, mainly cattle, are the main infectious source of schistosomiasis, and more than 90% of schistosomiasis cases in the Poyang Lake grassland are in cattle [45]. To prevent and control schistosomiasis, the Jiangxi provincial government implemented the policy of closing the area to grazing in 2013 and stipulated that farmers cannot raise raw cattle in livestock pastures along Poyang Lake, which has made many farmers' incomes decrease.

Agricultural landscape patterns transformation refers to changes in the composition and structure of agricultural landscapes that accumulate over time and lead to fundamental changes in the form and function of agricultural landscapes and their evolution [46]. Indeed, government policy decisions, livelihood changes, and land use transformation all cause changes in the spatial and temporal distribution of agricultural landscape elements, ultimately leading to significant changes in agricultural landscape patterns [47,48].

Figure 1 illustrates the research framework for the transformation of agricultural landscape patterns, which demonstrates the gradual change from homogeneity and high agglomeration to fragmentation, heterogeneity and complexity. Policy contributes to changes in the livelihoods of fishermen and a massive migration of labour to urban areas.

Increased abandonment of arable land, as well as changes in agricultural cultivation behaviour, lead to changes in the structure and function of the agricultural landscape. Such change ultimately causes a transformation in agricultural landscape patterns.

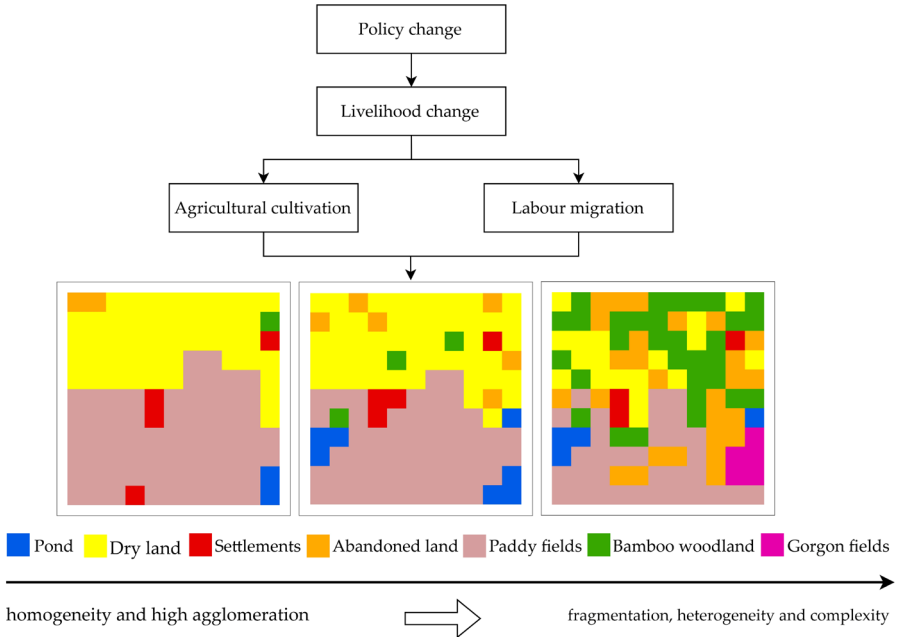

Figure 1. Sketch of the fishing village of transformation of agricultural landscape patterns.

3. Materials and Methods

3.1. Study Area

Poyang Lake is located in the lower reaches of the Yangtze River in northern Jiangxi Province. It is the largest freshwater lake in China, with an area of approximately 3960 square kilometres. According to statistics, there are 41 islands in Poyang Lake, and the islands contain 50 administrative villages, which are all fishing villages.

Hexi village is located at Hexi Island, and the extent of the island is the actual extent of the village. Hexi is a typical fishing village of Poyang Lake (Figure 2). The topography is elevated in the north and low in the south. The village is rich in arable land, with dry land in the northern uplands and large expanses of fertile swampy soil in the southern low-lying areas that are ideal for rice cultivation. During a long period of prosperity, Hexi's population continually increased, reaching a peak of 560 households and a total population of 1844 [49]. In terms of population distribution, the fishermen live mainly in the northern highlands, although a few lived in the south until 1998. Fishermen depend mainly on fishing for their livelihoods and supplement their income by farming and raising livestock.

3.2. Data Collection

The survey for this study is based on in-depth interviews conducted in November–December 2021 and January–February 2022 at Hexi village. We interviewed a total of 40 fishermen, spending between 60 and 90 min with each interviewee and recording the interviews. The interviewees included 32 men and 8 women, who were as young as 33 and as old as 85. The 40 fishermen had lived in the village all their lives. Therefore, they were familiar with the history and overall situation of the village and were good informants because of their ability to clearly describe changes in the village in different policy periods. The survey covered agricultural cultivation, fishing, livelihood patterns and population loss.

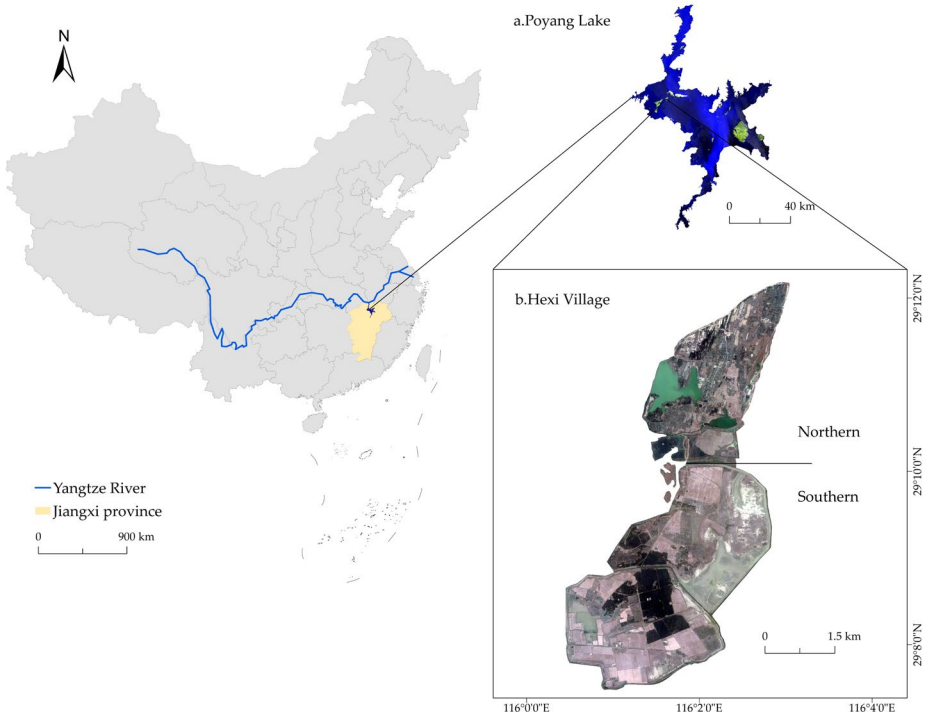

Figure 2. Location of Hexi village.

Through the interviews with the informants, we found that the fishermen's daily travel was very inconvenient and that they were rarely disturbed by the outside world. Each household owned fishing boats of the same size, each household owned roughly the same area of farmland, and their livelihood patterns and agricultural cultivation were highly consistent. In addition, the houses that the fishermen lived in were planned and built by the government. The consistency of livelihood patterns and the reasonable distribution of arable land resources suggested that the gap between rich and poor among the fishermen was relatively small. Therefore, the information from these interviews objectively and truly reflected the actual situation in the fishing village. It is worth noting that the purpose of our survey was to understand the overall livelihood changes and agricultural cultivation under different policies through the informants rather than to explore differences in the livelihood capital and strategies of individual farmers. In addition, we interviewed five relevant township officials and two contracted land traders to corroborate the information provided by the informants.

Another important role of field survey is to help us accurately determine the type and classification of land. We used high-resolution remote sensing images to draw a thematic map representing agricultural landscape changes, and we classified landscape types by comparing physical changes in these images in different years and seasons, as well as the current situation in the region. Using ArcGIS 10.2, we classified the landscape into seven categories: paddy fields, dry land, settlements, bamboo woodland, abandoned land, ponds, and gorgon fields. Gorgon is an annual aquatic herb of the water lily family Gorgonaceae that grows in ponds, lakes and marshes. The seeds of this species are rich in starch and are used for food and medicinal purposes [50]. The 1967 remote sensing image data come from the USGS KH-7 keyhole satellite, the 2003 data from the French SPOT satellite, the 2013 data from Google Earth, and the 2021 data from the official website of China Tianditu.

3.3. Research Methods

3.3.1. Landscape Pattern Index

The landscape pattern index reflects the structural composition and spatial configuration and is generally analysed at three levels: patch, type, and landscape. We focused

on the landscape level [51]. To better reflect the spatial pattern characteristics of the landscape and avoid redundancy of information, as well as to account for other studies, we selected the landscape indices characterizing patch density (PD), landscape shape index (LSI), aggregation index (AI), contagion (CONTAG) and Shannon's diversity index (SHDI) for analysis [46].

(1) Patch density (PD) is given by:

$$PD = \frac{n_i}{A_i} \quad (1)$$

where n_i is the number of patches of landscape type i; and A_i is the area of landscape type i [52]. PD is expressed in terms of the number of patches per square kilometre and represents the ratio of the number of patches to the area of the landscape for each landscape type; high PD indicates high fragmentation [53].

(2) Landscape shape index (LSI) is given by:

$$LSI = \frac{0.25E}{\sqrt{A}} \quad (2)$$

where A is the total area of the study area; and E is the length of all the patches in the study region [54]. The LSI reaches a minimum when the patch is perfectly regular in shape and increases as the patch becomes more complex [55].

(3) Aggregation Index (AI) is given by:

$$AI = \left[\frac{g_{ij}}{\max g_{ij}}\right] \times 100 \quad (3)$$

where g_{ij} is the number of adjacent pixels of patch j in landscape type i. The AI reflects the spatial distribution of various landscape types. The AI is lowest if there are no common edges between pixels of a landscape type and highest when all pixels of a given landscape type have a maximum of common edges [55].

(4) The contagion index (CONTAG) is given by:

$$CONTAG = \left[1 + \frac{\sum_{i=1}^{m}\sum_{k=1}^{m}\left[(P_i)\left(\frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}}\right)\right] \times \left[\ln(P_i)\left(\frac{g_{ik}}{\sum_{k=1}^{m} g_{ik}}\right)\right]}{2\ln m}\right] \times 100 \quad (4)$$

where P_i denotes the proportion of the landscape occupied by patch type i, g_{ik} is the number of adjacencies between pixels of patch types i and k, and m is the number of patch types present in the landscape. CONTAG refers to spatial information about the type of landscape. An area with a high CONTAG has a dominant landscape type and good connectivity. Conversely, a low CONTAG indicates multiple landscape types and low connectivity [56].

(5) Shannon's diversity index (SHDI) is given by:

$$SHDI = -\sum_{i=1}^{m}(P_i \times \ln P_i) \quad (5)$$

where P_i denotes the proportion of the landscape occupied by patch type i and m is the number of patch types present. The SHDI represents the degree of diversity of the landscape. If the landscape consists of one type, it is homogeneous and has a diversity index of 0. If the landscape consists of more than two types in the same proportion, the landscape diversity is the highest [52].

3.3.2. Moving Window Approach

We studied the nature, spatial structure, distribution patterns, and dynamics of landscape elements. The main principle was to visualize the spatial analysis of landscape indices at the regional scale by selecting the appropriate landscape indices from raster data and moving through the study area in a systematic manner using a target size window [57–59]. The size of the moving window was determined in relation to the study area. A moving window that is too large obscures details and microvariations in the landscape pattern, while a moving window that is too small makes it difficult to represent the overall characteristics of the landscape pattern.

For this paper, we created output raster images with various grain sizes using ArcGIS 10.2 and observed the stable interval of change in the landscape pattern index value. After repeated verification, we determined that 3 m was the best grain size for creating output raster images. We created separate moving windows with 10 m intervals and 30–150 m amplitude changes for comparison and validation to ensure that the landscape changes in the moving windows are truly reflected and find that the 90 × 90 m^2 window is a good reflection of most of the fluctuations in the indicators.

4. Results

4.1. Livelihood and Agricultural Landscape

After we gathered the recollections of the fishermen, we learned that before the implementation of the household contract responsibility system in 1982, the Hexi village land was owned by the state and by the village collective, and fishermen could engage only in collective agricultural work. Agricultural production was influenced by the idea of "grain as the key link", and fishermen enthusiastically complied with the state's request to construct dikes and enclose lakes to create fields, resulting in a particularly rapid increase in the area of paddy fields, which reached 1863.25 hectares, as shown in Figure 3. The policy of the time severely restricted private productive activities; fishermen were not allowed to fish and raise livestock freely and were confined to collective farming.

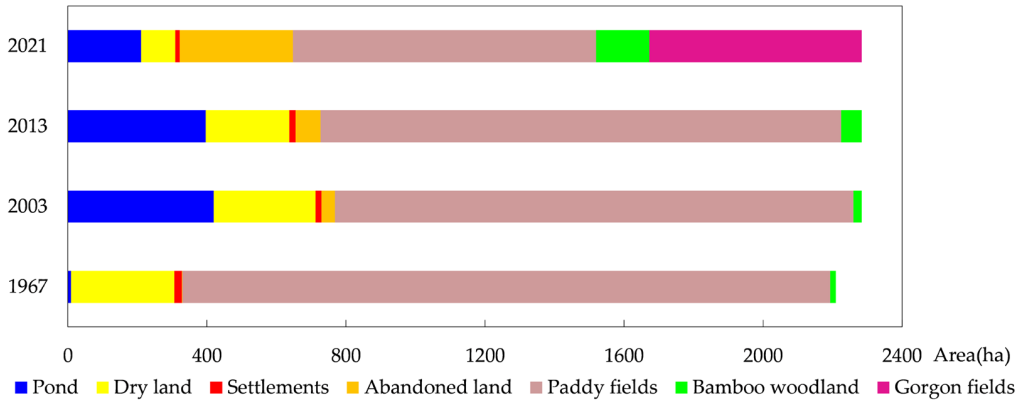

Figure 3. Changes in agricultural landscape area in Hexi village, 1967–2021 (in hectares).

After the implementation of the family contract responsibility system, the government did not severely restrict the productive activities of fishermen, and village collectives allocated land based on family size. Fishermen obtained land use rights, and their motivation for agricultural cultivation increased. As the population increased while arable land resources were limited, fishermen adopted aggressive livelihood strategies to maximise the use of arable land for economic gain. According to the recollections of the respondents, double-season rice was planted in paddy fields, and a variety of cash crops were grown in drylands. To maximise the benefits of dryland yield, different crops were grown in rotation. At the same time, Hexi's livestock industry progressed. The cost of raising cattle was low, and animal husbandry became a valuable source of revenue. Furthermore, the government no longer restricted the freedom to fish, so fishermen shifted their main production

activities away from farming and towards the more profitable fishing industry. Fishing production increased year after year, and fishing became the primary source of income. During this time, fishermen's livelihoods were focused on fishing, while agriculture and livestock farming developed simultaneously. One of the older informants said the following:

> *"Apart from fishing and cattle breeding, we would grow a variety of crops on the drylands; we planted garlic in the spring, watermelons and winter squash in the summer, carrots in the fall, and onions and cabbage in the winter. After harvesting, these crops were transported by water to the wholesale market in Nanchang to be sold."*

Figure 4 shows that there are no drylands in the southern part of Hexi village and that the agricultural landscape is dominated by a single paddy fields. According to the recollections of informants in the south, the government implemented a flood relocation policy and a ban on uncontrolled arable land reclamation after the major floods in the middle and lower reaches of the Yangtze River in 1998. Fishermen in the south were relocated to Wucheng town, and their paddy fields were placed under government management and then entrusted to external contractors for cultivation. After the southern fishermen lost their arable land, they were no longer involved in agriculture or livestock raising. Fishermen in the northern area were systematically relocated to dry land on higher ground, with no change in their livelihood. An informant who used to live in the southern part of Hexi village said:

> *"My husband and I cultivated 130 mu of paddy fields here and raised a lot of raw cattle, but after the great flood in 1998, the government banned us from cultivating paddy fields around the lake and asked us to move to a resettlement house at Wucheng town, so we had no more arable land and a way to raise raw cattle."*

To protect the Yangtze River's fishery resources, the government prohibited fishing from April to June each year after 2003. The annual fishing moratorium coincided with the busy agricultural season and had little impact on fishermen's productive lives. The interviewees claimed that after the seasonal restriction on fishing was imposed, fishermen's catch and income declined, but only a small number of young fishermen chose to leave the fishing village for urban non-agricultural occupations. Therefore, only a small amount of arable land was abandoned from 2003 on at Hexi village. As shown in Figure 4, the area of arable land abandoned in fishing village was very low during this period, suggesting that seasonal restrictions on fishing did not lead to a significant loss of fishermen and that agricultural cultivation remained an important livelihood for them.

The government banned cattle farming for residents around Poyang Lake in 2013, and fishermen were forced to stop raising cattle, thus losing their income from livestock farming. When their income decreases, some fishermen will leave their fishing village, which will increase the risk of abandoning their farmland. In addition, cash crops are an important source of income for fishermen. After the government promoted the "vegetable basket" project, the production of greenhouse vegetables outside the village increased, leading to a decrease in the market demand for and purchase price of cash crops. The decline in cash crop returns led to a decline in fishermen's enthusiasm for cultivation, and the dry land gradually began to be abandoned on a large scale. When fishermen lost their income from raising cattle, coupled with the decline in returns from agricultural cultivation, many took on odd jobs during the fishing moratorium to increase their household income, and their livelihoods changed significantly. As shown in Figure 4, abandoned arable land and bamboo forestland in the village increased significantly in 2013 due to population loss and a decline in willingness to farm. One informant said:

> *"The grassy pastures of Poyang Lake provide abundant grass for cattle, and the cost of raising cattle is so low that each fisherman raises about 10 raw cattle, and adult raw cattle can be sold for 10,000 RMB, which is a substantial income. After the ban on grazing, the government stopped allowing us to raise raw cattle. And the purchase price of cash crops became lower, I didn't want to grow so many cash crops, and my income became less and less, so I went out to do odd jobs during the fishing ban."*

In 2021, the government imposed a ten-year comprehensive ban on fishing in the Yangtze River basin, and the fishermen had to stop fishing. Deprived of the income generated by fishing, the vast majority of fishermen chose to leave the village and migrate to towns to work in non-agricultural industries. With the massive loss of fishermen, large areas of arable land in the village were left uncultivated, with a decrease of 626.09 hectares of paddy fields and 142.51 hectares of dry land from 2013 to 2021, indicating that the problem of abandoned arable land has become serious. As shown in Figure 4, the agricultural landscape changed dramatically in 2021, with a rapid increase in abandoned land, a sprawling bamboo woodland and a loss of homogeneity in the agricultural landscape patterns. According to our observations and informants, the remaining fishermen earn their living mainly through rice cultivation and have become full-time farmers. By contracting abandoned paddy fields, they have expanded their rice cultivation to earn more income. Currently, four large rice growers in the north of the village operate 1110 mu of paddy fields (1 hectare = 15 mu) under contract, while the remaining paddy fields in the north of the village are cultivated by another 15 fishermen at a contract price of RMB 100 per mu. In addition, cash crops are no longer grown on a large scale on dry land, and only cabbage and rapeseed are now grown for household use; these cash crops are no longer sold to the public. In the southern part of Hexi village, 611.38 hectares of paddy fields were contracted by businessmen from Anhui Province in 2020 for the cultivation of gorgon, and two fishermen were employed in the village to grow this crop. An informant (a major rice grower) said:

> *"After the comprehensive fishing ban, many fishermen have left the fishing village. I am older, and it is difficult to find a job in the city. Now I am a full-time farmer, and I have contracted a total of 400 mu of paddy fields to grow rice."*

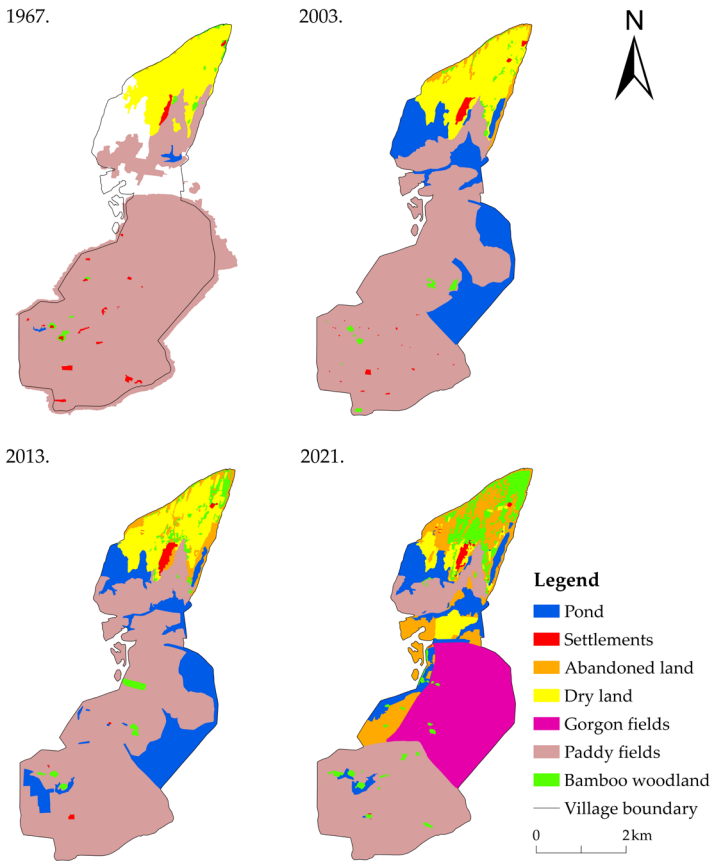

Figure 4. Dynamics of the agricultural landscape in Hexi village, 1967–2021. Note: In 1967, the construction of a dike in the northern part of Hexi village was not completed, and the empty area inside the village boundary represents a mudflat. It was not divided, and some fishermen reclaimed farmland outside the village boundary by creating fields around the lake during that period Hence, the reclaimed paddy fields outside the village boundary are also shown.

4.2. Characteristics of the Spatial and Temporal Change of Agricultural Landscape Patterns

Table 1 shows that from 1967 to 2021, Hexi's overall PD, LSI, SHDI increased each year, while the sprawl index CONTAG and AI decreased. These results indicate that the landscape patches in the study area are fragmented, as their shapes have become more complex and diverse. Moreover, the landscape pattern displays characteristics of diversity, while the overall agglomeration and spread of the landscape have decreased. On a temporal scale, the agricultural landscape pattern changed slowly from 1967 to 2003, remaining relatively homogeneous overall. The grazing ban policy was a turning point in the landscape pattern change, which changed most dramatically in the eight years from 2013 to 2021.

We use the moving window method to visualize the agricultural landscape in the village of Hexi (Figure 5). The agricultural landscape patterns in the north and south shows different trends, with the northern area showing high values on the four landscape pattern indices, PD, LSI, CONTAG, and SHDI. Moreover, the high-value area has expanded every year, and the low-value area of AI in the north has spread every year as well. This result indicates that the northern agricultural landscape is highly fragmented, with complex landscape patch shapes, high landscape diversity, high spread, and low agglomeration. The landscape pattern index has changed less in the south than in the north. The northern regional agricultural landscape pattern index corresponds to the overall trend in agricultural landscape change. Moreover, the agricultural landscape has changed more dramatically in the north than in the south, implying that the northern region is a critical zone for determining the overall agricultural landscape patterns. Anthropogenic disturbances are closely related to changes in the landscape pattern index. Changes in fishermen's agricultural practices and livelihoods have had a profound effect on local agricultural landscape patterns in the northern region.

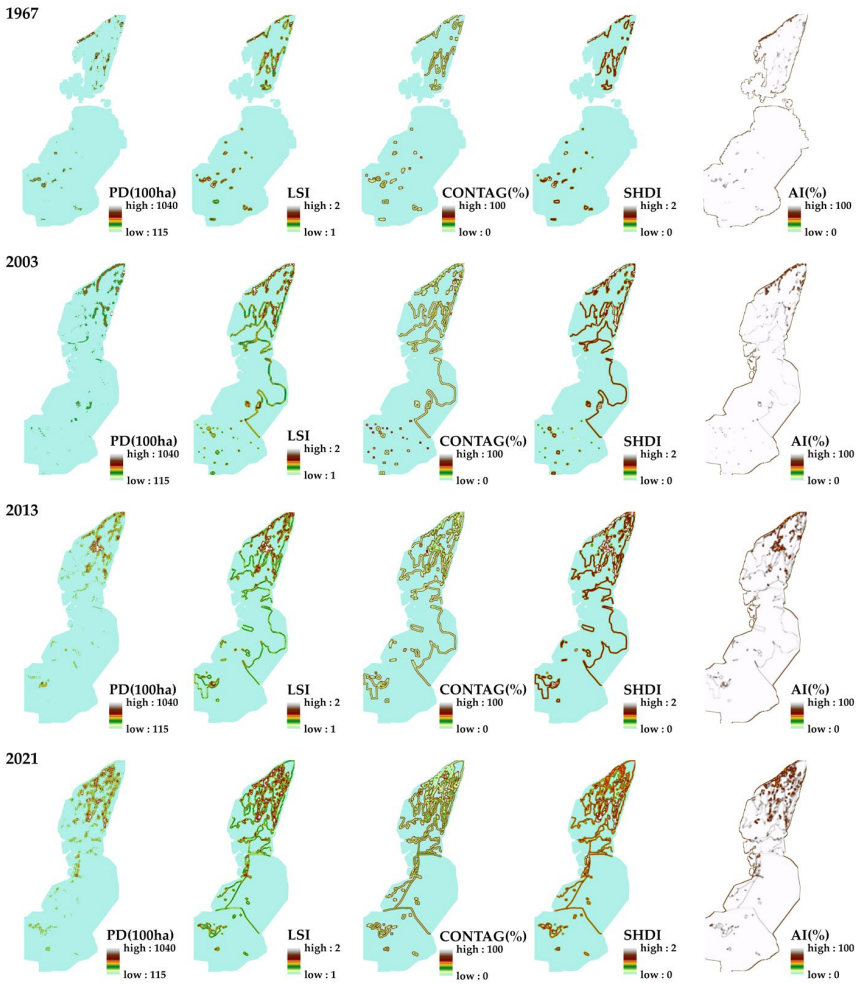

Figure 5. Spatial and temporal characteristics of agricultural landscape patterns in the study area.

Table 1. Changes in agricultural landscape pattern indices at the landscape level in the study area.

Years	PD	LSI	CONTAG (%)	SHDI	AI (%)
1967	1.44	2.27	84.60	0.54	99.79
2003	2.16	3.51	71.33	1.01	99.69
2013	2.16	4.70	69.62	1.06	99.55
2021	3.58	5.78	58.43	1.56	99.16

5. Discussion

5.1. The Hollowing out of Fishing Village

The major agricultural regions of the world, particularly in developing countries, are experiencing a dramatic restructuring of livelihoods, including diversification of farm households, off-farm employment and permanent migration [60–63]. These livelihood transformations reflect complex and multiple influences, ranging from physical constraints such as resource scarcity and environmental change to changes in individual and societal aspirations to national policy interventions [64]. In China, the mass migration of farmers to non-agricultural sectors, the abandonment of rural land, and the massive reduction of the agricultural population have led to the hollowing out of the countryside, which continues to shape the agricultural landscape patterns [65–67].

Freshwater capture fishing was a low-cost, high-yield livelihood for Hexi villagers, and fishing was their primary source of income. Fishing required only small fishing boats and nets. Most small fishing boats were made of wood, and they could usually accommodate 2 to 3 people. Families owned 1 to 2 boats. Fishing operations were often family-based and could bring a family RMB 500–1000 a day under normal circumstances. The fishing income here referred to 2019. People can earn more through fishing than through working or farming. Fishing was a major way for the fishermen of Hexi village to earn a living. Once fishing was restricted or banned, fishermen were undoubtedly forced to change their activities. In general, fishermen have received little education, and those who have lived in the village for a long time generally have only two skills: fishing and farming. These limited skills make it difficult for them to engage in non-agricultural occupations. Faced with depleted fishing resources and declining natural capital, younger fishermen (under the age of 45) aspire to an urban lifestyle, and have taken the initiative to adjust their livelihood strategies, abandoning the fishing industry and choosing to leave their homeland or even relocate their families. This situation that has become increasingly prevalent since the introduction of the grazing ban in 2013. Due to their age and unwillingness to make a living outside the village, middle-aged and older fishermen have been forced to give up fishing and remained in the village to engage in farming activities only after the comprehensive ban on fishing was implemented. As a result, labour shortages and a reduction in agricultural inputs could lead to the shrinkage of arable land, a reduction in the arable land cultivation index, and a further reduction in agricultural output [67–69].

The bans have induced labour migration to towns and cities and caused changes in the price of and demand for cash crops. These changes in turn influenced fishermen to adjust their livelihood strategies. Labour migration is a direct effect of the transformation of fishermen's livelihoods and an important factor influencing changes in agricultural landscape patterns. When many fishermen migrated to cities, villages became empty, and the remaining population was ageing, both of which have accelerated the abandonment of arable land. According to official government data and field research, the residential population of Hexi village was 937 and 246 in 1998 and 2018, respectively [49]. In 2022, it is 98. After the comprehensive ban on fishing took effect in the Yangtze River basin, the 98 remaining villagers were older fishermen who stayed behind and had weak livelihood capital. Fishermen living away from home planted Mao bamboo to demarcate the boundaries of their drylands and prevent encroachment. The bamboo woodland has expanded rapidly as a result of being untended for long periods. The abandonment of dry land has changed the production function, restored the surface vegetation, which is conducive to

soil and water conservation, and has played a positive ecological environmental effect to a certain extent. In short, the abandonment of drylands and the uncontrolled spread of bamboo woodlands have fragmented the agricultural landscape patterns (Figure 6).

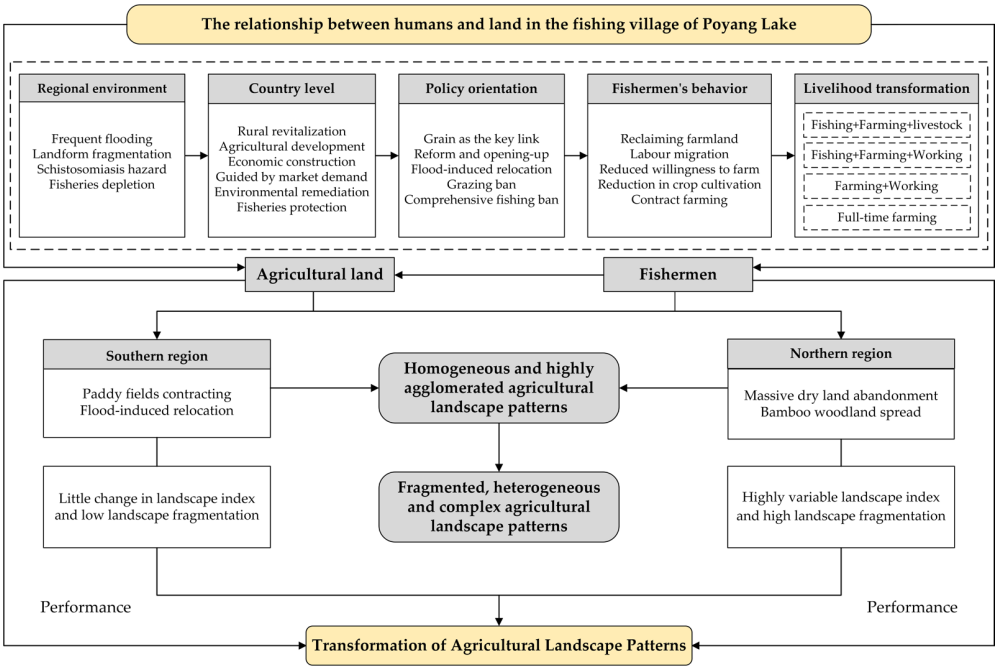

Figure 6. Transformation framework of agricultural landscape patterns.

5.2. Change of Cropping Structure

Competition between agricultural and non-agricultural activities has become increasingly intense in the context of the transformation to non-agricultural livelihoods, with farmers frequently opting for less time-consuming and more efficient methods of land use and moving towards a simpler cropping structure [70]. Moreover, a diverse agricultural landscape with a variety of land use types is seen as a product of the survival strategies adopted by peasant families living in precarious social conditions [71,72].

Study found that fishermen's cropping structure were gradually becoming simpler and more specialised. Since the rise of greenhouse vegetables, the purchase price and demand for cash crops have fallen, resulting in a continued reduction in fishermen's willingness to grow them. Fishermen took less input to cultivate drylands and reduced the cultivation of cash crops. Therefore, fishermen have more time and energy to fish and grow rice. Rice has a relatively stable purchase price and marketing channels, and fishermen have pinned their hopes to rice cultivation since the comprehensive fishing ban. Those who remain in the village have become full-time farmers, contracting abandoned paddy fields to grow rice on a large scale. With the aim of increasing rice yields, rice cultivation has shifted from small-scale operations to contract-based large-scale farming, and the widespread use of machinery, pesticides and fertilisers, which have promoted the intensification of rice cultivation. Contract-based large-scale farming means that left-behind fishermen rent paddy fields abandoned by other farmers, thereby expanding the scale of rice cultivation. Intensification refers to any process of obtaining more output, but is most often interpreted as increasing yields per unit of land [73]. The biggest change of agricultural landscape caused by the livelihood transformation is that the majority quitted farming and rented out paddy fields, and contract farmers managed large farm.

5.3. Innovations and Shortcomings

To understand the reasons for the transformation of agricultural landscape patterns, in-depth case studies are important, in addition to macrolevel studies [74]. Case studies are

used to better integrate and understand the social and physical drivers of land use change at different temporal and spatial scales, and it is important to combine remote sensing data with field research to ensure that the findings are scientifically sound and accurate [75]. Traditionally, studies of agricultural landscape change have focused on changes in spatial patterns based on satellite imagery with little consideration of the social behaviour of farm households [76,77], such as livelihood choices, or the interaction of livelihoods and agricultural landscapes. However, there are some limitations to our study. We analysed only the one-way impact of livelihood transformation on agricultural landscapes and did not explore the impact of transformations of agricultural landscape patterns on livelihoods and the interaction between the two. Although we analysed the relationship between policy, livelihoods and agricultural landscape patterns qualitatively, the results of the study provide an objective picture of the actual situation in the region. Study found that the abandonment of cultivated land, especially dry land, has led to fragmentation, heterogeneity and complexity of agricultural landscape patterns. Therefore, the cultivation of dry land by fishermen is conducive to reducing the abandonment rate of cultivated land and inhibiting the disorderly expansion of bamboo woodland, which plays an important role in the optimization of agricultural landscape patterns.

6. Conclusions

This study quantifies the transformation of agricultural landscape patterns in fishing village by constructing a scientific research framework using long time scale satellite remote sensing imagery and mathematical analysis methods. In addition, we qualitatively analyse the relationship between policy changes and fishermen's livelihoods through in-depth interviews to provide a scientifically sound explanation for the dynamic changes and transformations in the agricultural landscape patterns of a typical fishing village in Poyang Lake.

We obtain the following conclusions: the livelihoods of fishermen have varied over the different policy periods. After grazing ban and comprehensive fishing ban, fishermen could not raise livestock and engage in fishing, so livelihood of fishermen has changed from diverse to single. With many fishermen migrate to towns and cities, the loss of population has been a serious issue. As the village has hollowed, the amount of abandoned land has increased. Since the rise of greenhouse vegetables, the purchase price and demand for cash crops have fallen, so people have become less willing to farm on drylands. We found that fishermen's cropping structure were gradually becoming simpler and more specialised. Those who remain in the village have become full-time farmers, contracting abandoned paddy fields to grow rice on a large scale. On a temporal scale, the agricultural landscape patterns changed slowly and remained relatively homogeneous overall, due to the relatively stable livelihood patterns of fishermen before the ban on grazing and fishing, the low number of population losses and the low abandonment of arable land at Hexi village. The grazing ban policy was a turning point in the landscape pattern change, which changed most dramatically in the eight years from 2013 to 2021. Especially after the implementation of the comprehensive fishing ban, the expanses of abandoned land and bamboo woodlands had increased, which caused agricultural landscape patterns gradually becoming fragmented, heterogeneous and complex.

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