Dear Reviewer

First and foremost, I would like to express my heartfelt gratitude for taking the time out of your busy schedule to review our manuscript. Your invaluable feedback and professional suggestions have played a pivotal role in enhancing the quality and integrity of our research. We have given utmost consideration to each of your comments and have made targeted revisions to the manuscript accordingly. Below are our responses and explanations to your feedback. Should there be any oversight or areas that are not adequately addressed, we kindly ask for your further guidance. Once again, thank you for your efforts and contributions.

(1) The title needs to be modified and shortened. It refers to spatio-temporal characteristics of sustainable development pathways too, which is not correct. Spatio-temporal characteristics are for carbon emissions only. Also, please add the country name in the title.

- Re：We have adjusted the original title and changed it to "Spatial-Temporal Characteristics of Carbon Emissions in Mixed-Use Villages: A Sustainable Development Perspective in the Yangtze River Delta Region, China".

(2) Abstract: This section needs to be rewritten. No information about the study design and major numerical findings are reported here. The whole paragraph seems like an explanation of the problem taken by the authors and then each objective. No information about what this study yielded and its significance to currently available knowledge is justified.

- Re：We have rewritten the abstract, incorporating the study design and major numerical findings. Additionally, we have elucidated the significance of this research at the end. The revised abstract is as follows:

  With the progression of novel urbanization, rural regions are increasingly characterized by mixed-use features, where work and living activities intersect, resulting in a significant surge in per capita carbon emissions. This research aims to elucidate the spatio-temporal relationship of carbon emissions in rural areas and its association with mixed-use intensity, from a sustainable development perspective. The study selected four of the most representative mixed-use village types in the Yangtze River Delta region. Using the STING method, each rural space was delineated into micro-level mixed-use units. Subsequently, a quantitative evaluation model was constructed to gauge the relationship between mixed-use intensity and carbon emissions. This was complemented by employing GIS simulations to analyze the spatio-temporal attributes of carbon emissions in mixed-use villages. Our findings indicate that: (1) Different types of villages display considerable disparities in mixed-use intensity and carbon emissions. Their correlation also varies significantly, with traditional agricultural villages exhibiting the lowest values of 0.338 and 0.356, while E-commerce-centric villages recorded the highest at 0.674 and 0.653. (2) The carbon emissions of rural units manifest diverse patterns including dispersed distribution, core aggregation, linear decay, and dissipative fragmentation. These correspond, respectively, to traditional agriculture, industrial production, tourism service, and e-commerce villages. (3) The carbon emissions of mixed-use villages exhibit cyclical fluctuations over time, with different magnitudes observed across villages. Traditional agricultural villages display the smallest fluctuations, within 30%, while those centered around tourism services can experience fluctuations exceeding 150%. Building on these insights, we delved deep into the challenges faced by each village type in enhancing the quality of work and living while concurrently achieving energy

conservation and emission reduction. From a perspective of sustainable development, the findings of this study offer significant insights into the evolution of mixed-use rural development in China.

(3) Introduction: This section should be enriched with recent studies that addressed the problem individually or collectively.

- Re：In the introduction section, we have incorporated recent studies that addressed the problem, with specific details as follows:

  China has introduced a series of policies related to eco-agricultural development [8], green rural housing construction [9], clean energy promotion [10], and rural domestic wastewater treatment [11], indicating that the control of rural carbon emissions has been placed on the agenda.

  Notably, these areas exhibit prominent features of a thriving private economy and distinctive local characteristics. The transformation of rural mixed-use functions has led to a significant influx, transfer, and concentration of high-energy, high-pollution, and high-input industries into villages, resulting in a sharp increase in overall carbon emissions in rural regions [15]. Scholars have posited that mixed-use villages have become one of the main sources of China's carbon emissions [16], which could hinder China's efforts towards its "Dual Carbon" goals.

  In the literature review section, we have also reorganized the literature relevant to rural carbon emission issues:

  The former encompasses energy consumption attributable to agricultural machinery and the application of chemical fertilizers and pesticides [27,28]. Studies have identified a U-shaped Environmental Kuznets Curve (EKC) relationship between agricultural production and emissions [29]. Conversely, carbon emissions from the rural living environment encompass energy consumption related to cooling, heating, transportation, and other daily life activities [30,31]. With the aging of the rural population, there has been a marked increase in carbon emissions resulting from residential energy consumption [32]. Scholars have observed that between 2012 and 2018, per capita carbon emissions in rural areas increased, even though overall emissions witnessed a decline [33]. Presently, research strategies for reducing rural carbon emissions primarily focus on enhancing the carbon sequestration capabilities of rural ecosystems (such as forests, wetlands, and farmlands) and curbing carbon emissions from rural residential living. For instance, in-depth investigations have been conducted on the carbon balance and reserve fluctuations within forest ecosystems [34,35]. Additionally, studies have proposed strategies to amend rural consumption habits to reduce per capita carbon emissions [36].

(4) The linking of a problem with a hypothesis about the correlation between carbon emissions and SDG seems not very strong.

- Re： In the manuscript, we have incorporated discussions related to carbon emissions and sustainable development, which include:

  At the same time, this has led to various social, economic, and environmental problems, such as harm to the rural environment, negative effects on villagers' health, and a widening gap between urban and rural areas, rendering rural development unsustainable.

  Mainstream scholarship posits that sustainability is shaped by three pillars: economy, environment, and society. In the context of this study, we define the sustainability of mixed-use villages as a balanced act between ecological environmental protection and industrial economic growth, aiming to achieve sustainable development and enhance the quality of rural living and working.

(5) Also, It should provide a strong rationale for investigating carbon emissions and sustainable development pathways in mixed-use villages within the context of the Yangtze River Delta. Why this region was selected?

- Re：In Section 3.1, we elaborate on the reasons for selecting the mixed-use villages in the Yangtze River Delta. The specific details are as follows:

  As a pioneer in the implementation of rural revitalization strategies, the Yangtze River Delta region has undergone rapid socio-economic transformations, with industrial diversification emerging as a prominent feature [38]. This evolution has given rise to a variety of mixed-use rural typologies. Within these villages, family handicrafts, modern commerce, and tourism services have progressively supplanted traditional agriculture as dominant industries. This shift has also fostered an integration of living and non-agricultural working activities within the rural milieu. Presently, mixed-use villages constitute no less than 60% of the total rural communities in the Yangtze River Delta region [39], marking the highest proportion nationwide. However, the proliferation of mixed-use villages has precipitated a notable surge in per capita carbon emissions in the region, witnessing a growth rate of 3.56% over the past decade. Additionally, energy consumption in rural areas accounts for approximately 40% of the total, with carbon emissions surpassing 45% of the aggregate [40]. Under the "Dual Carbon" goals, achieving a balanced development between the economy and the environment in the Yangtze River Delta region becomes increasingly crucial. Simultaneously, as a demonstration zone for integrated ecological and green development, the Yangtze River Delta region bears the responsibility to set an exemplary precedent and provide incentives for the low-carbon transition in other regions [41]. Hence, the mixed-use villages of the Yangtze River Delta region were selected as the focus of this research.

(6) Results and discussion: The manuscript does not adequately discuss the broader implications of the research beyond the study area. It should explore how the findings might be relevant to other regions facing similar challenges.

- Re：This is indeed an issue that was not addressed in the paper, and it's challenging to draw a concrete conclusion. Therefore, we have added the following discussions in Section 5 (Discussion) and Section 6 (Conclusion):

  This study offers actionable policy implications for the sustainable development of specific mixed-use villages in the Yangtze River Delta region, and these strategies can be applied to the majority of villages with similar characteristics. However, the types of mixed-use villages vary significantly across China and even globally, often leading to increased complexity in mixed characteristics and carbon emissions. Strategies such as eliminating "carbon islands", guiding the balance of "carbon flow", and inhibiting the growth of "carbon entropy" can provide valuable insights for other regions. Nevertheless, the actual planning or construction strategies should be adjusted and formulated based on the specific characteristics of individual villages at particular times and locations.

  Our research has certain limitations, which pave the way for further exploration in future studies:(1) Refining the computational evaluation model for mixed-use intensity and carbon emissions. (2) Analyzing and quantifying specific factors influencing carbon emissions in mixed-use villages. (3) Investigating the applicability of the study's conclusions when extended to

other regions.

(7) The discussion should be enriched with a sufficient number of supporting references. I can see authors made several claims in this section without proper justification and supporting literature. Not a single reference is available in this section.

- Re：We have incorporated relevant literature in Section 5 (Discussion) to substantiate some of the strategies proposed. Additionally, we have introduced a new subsection within the Discussion, titled 5.1 Interpretation of Findings, where we have also added corresponding references.

(8) Conclusion: It looks like a repetition of the abstract and discussion. The conclusion should provide a clear summary of the key findings and their implications, and it should also suggest directions for future research in this area. It should leave the reader with a clear takeaway message from the study. Better to write it concisely within 250 words.

- Re：We have revised the conclusion section. Firstly, the presentation of research results is now more explicit and clear. Furthermore, we have articulated the value of the research findings and potential directions for future studies. The overall length of the conclusion has also been condensed. The specific content is as follows:

  Diverging from prior studies, this research adopts a bottom-up approach, leveraging the micro-level perspective of mixed-use units to quantitatively analyze the spatio-temporal characteristics of mixed-use vitality and carbon emissions across four distinct village typologies. The construction of mixed-use units, grounded in property rights and actual utilization, offers a unique lens for village examination and has proven effective in delineating the disparities among the four village categories:

  (1) Different village typologies manifest marked differences in mixed-use intensity and carbon emissions, with the relationship between them also varying. E-commerce operation villages have the preponderance of units exhibiting high mixed-use intensity, whereas industrial production villages feature the most units with pronounced carbon emissions.

  (2) Carbon emissions in rural contexts display clear typological structural traits: scattered distribution in traditional agricultural villages, core aggregation in industrial production villages, linear diminution in tourism service villages, and dissipative dispersal in E-commerce operation villages.

  (3) Owing to the cyclical nature of industries, the volatility in carbon emissions varies significantly among rural categories, with tourism service villages registering the highest fluctuations and E-commerce operation villages the least.

  While certain regions in China have initiated policies and regulations to foster the development of mixed-use villages, the practical implementation of mixed-use planning and construction remains in its infancy. In light of this, our study specifically proposes sustainable development pathways for mixed-use villages, focusing on eliminating "carbon islands", guiding "carbon flow" and inhibiting the growth of "carbon entropy".

  Our research has certain limitations, which pave the way for further exploration in future studies:(1) Refining the computational evaluation model for mixed-use intensity and carbon emissions. (2) Analyzing and quantifying specific factors influencing carbon emissions in mixed-use villages. (3) Investigating the applicability of the study's conclusions when extended to other regions. Moreover, due to space constraints, various details and data within the research

could not be thoroughly elaborated upon. Nonetheless, we hope this study can provide perspectives and insights for the low-carbon development of mixed-use rural areas in the Yangtze River Delta and broader regions in China.