

From positive landscape experiences to subjective well-being: A serial mediation model via physical activity and extraversion

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Abstract

This study investigates the relationships among positive landscape experiences, physical activities, extraversion, and subjective well-being in rural areas of Mid-North Vietnam. Grounded in environmental behavior and restorative landscape theories, the research explores how rural landscapes influence residents' well-being through behavioral and psychological pathways. Structural equation modeling (SEM) was employed to examine the direct and indirect relationships among the proposed constructs. The findings revealed that positive landscape experiences encourage residents to engage in physical activities within rural environments. Participation in physical activities subsequently strengthens extraverted characteristics, including greater social interaction, openness, and active engagement with the environment. Positive landscape experiences also directly enhance extraversion, suggesting that restorative rural landscapes provide both behavioral and psychosocial benefits. Furthermore, extraversion significantly contributes to subjective well-being, indicating that socially active and outward-oriented individuals tend to experience greater life satisfaction and emotional well-being. The study also confirms that physical activities indirectly improve subjective well-being through the mediating role of extraversion. In addition, positive landscape experiences influence subjective well-being both directly and indirectly through multiple mediation pathways involving physical activities and extraversion. The sequential mediation effect demonstrates that restorative rural landscapes promote active lifestyles, strengthen positive personality traits, and ultimately enhance overall well-being. The findings highlight the importance of restorative rural landscapes in supporting healthy behaviors, fostering psychosocial development, and enhancing residents' quality of life, providing important implications for sustainable rural landscape planning and environmental design.

1. Introduction

Extraversion (EXT) is one of the most consistent predictors of subjective well-being (SWB), showing strong associations with positive affect, life satisfaction, and social engagement (Buecker et al., 2023; Busseri & Erb, 2024). Individuals high in EXT are generally more responsive to rewards and more likely to seek stimulating social experiences, both of which could contribute to higher well-being (Kroencke et al., 2023; Steel & Klingsieck, 2016). Consequently, extraversion has traditionally been conceptualized as a stable dispositional antecedent of SWB (Steel, Schmidt, & Shultz, 2008).

Recent perspectives, however, challenge this purely trait-based view by highlighting the dynamic interplay between personality, behavior, and environmental contexts. Growing evidence suggests that personality traits may exhibit situational variability and can be shaped by repeated behavioral experiences and environmental exposure (Rhodes & Smith, 2006). From this perspective, extraversion may function not only as a determinant of well-being but also as an outcome of environmental and behavioral processes.

Within environmental psychology, positive landscape experiences (PLEs) provide a promising yet underexplored context for understanding such processes. Landscapes characterized by aesthetic quality, naturalness, and perceived safety can reduce stress, promote exploration, and facilitate social

interaction. Through these experiences, individuals may develop behavioral and psychological tendencies associated with greater extraversion. Although environmental experiences are known to influence emotional and cognitive functioning (K. Korpela, Savonen, Anttila, Pasanen, & Ratcliffe, 2017), their potential role in shaping personality traits has received limited empirical attention.

Physical activities (PAs) may represent a key mechanism linking landscape experiences to EXT. Attractive and accessible outdoor environments encourage walking, recreation, and other forms of physical engagement (Sugiyama, Leslie, Giles-Corti, & Owen, 2008; Thompson et al., 2012). Importantly, many of these activities occur within socially interactive settings, creating opportunities for communication, cooperation, and shared experiences. Repeated participation in such activities may strengthen social confidence, positive affect, and outward-oriented behavioral tendencies characteristic of EXT.

This proposition aligns with the behavioral pathway framework, which posits that environmental characteristics influence psychological outcomes through their effects on behavior (Markevych et al., 2017). However, previous research has primarily examined direct associations between physical activity and well-being, paying relatively little attention to personality as an intervening mechanism. Consequently, the potential mediating role of EXT in the PAs–SWB relationship remains insufficiently understood.

Integrating these perspectives suggests a sequential process through which environmental, behavioral, and personality factors jointly contribute to well-being. Specifically, PLEs may promote PAs by providing supportive environmental affordances; PAs may foster extraverted tendencies through repeated social and behavioral engagement; and EXT may subsequently enhance SWB by strengthening positive affect and social connectedness. Yet empirical studies examining these relationships within a unified framework remain scarce, resulting in a fragmented understanding of how environmental experiences are translated into psychological outcomes (De Groot, 2019; Hartig et al., 2010; Liu et al., 2023).

Addressing this gap, the present study conceptualizes EXT as both a consequence of landscape experience and PAs and a psychological mechanism linking these factors to SWB. By positioning EXT within a serial mediation framework, this study advances a more integrated understanding of the pathways through which landscape environments contribute to human well-being.

2. Materials and Methods

2.1. Extraversion as a behavioral construct in the context of environment and subjective well-being

Extraversion (EXT) can be understood not only as a stable personality trait but also as a behaviorally expressed construct reflected in individuals' tendencies to seek stimulation, explore environments, and engage in social interaction. This perspective is consistent with environmental psychology, which views

behavior as emerging from interactions between personal characteristics and environmental affordances (Gibson, 1985; K. M. Korpela, Ylén, Tyrväinen, & Silvennoinen, 2010). Accordingly, extraversion influences how individuals perceive, utilize, and respond to environmental settings.

Research has shown that individuals with higher levels of EXT are more likely to engage in environmental exploration, social interaction, and diverse patterns of space use (Rhodes & Smith, 2006; White, Elliott, Gascon, Roberts, & Fleming, 2020). These findings suggest that extraversion is closely linked to active engagement with landscape environments and may represent an important mechanism through which environmental experiences influence psychological outcomes.

Physical activity (PA) provides a key pathway in this process. Green and natural environments encourage physical activity by offering attractive and supportive settings (Ki & Lee, 2021; Sugiyama et al., 2008; Thompson et al., 2012). In turn, PA contributes to psychological well-being and has been identified as a mediator between greenspace exposure and mental health outcomes (Markevych et al., 2017; Martin et al., 2020; Twohig-Bennett & Jones, 2018). Because outdoor physical activities frequently involve social participation and positive emotional experiences, they may also reinforce characteristics associated with extraversion, including social engagement, energy, and positive affect (Rhodes & Smith, 2006). This perspective suggests that extraversion is not merely an antecedent of behavior but may be strengthened through repeated behavioral engagement in supportive environments (Gerber et al., 2025). Consequently, landscape settings that encourage physical activity and social interaction may indirectly foster extraverted tendencies over time.

In the present study, EXT is conceptualized as a central mediating mechanism linking positive landscape experiences (PLEs), physical activity, and subjective well-being (SWB). Specifically, PLEs are expected to promote physical activity, which reinforces extraverted behavioral tendencies and, in turn, enhances well-being through greater positive affect and social connectedness (Diener, Sandvik, Pavot, & Fujita, 1992; Musek, 2024; Steel et al., 2008). By positioning extraversion within this environment–behavior–well-being pathway, the study advances a more dynamic understanding of personality as both a product of environmental experiences and a contributor to subjective well-being.

2.2. Hypothesis development

2.2.1. Positive landscape experiences and physical activities

Research in environmental psychology has consistently demonstrated that the quality of landscapes plays a crucial role in shaping human behavior, particularly in relation to physical activities (PAs). Landscapes that are perceived as aesthetically pleasing, restorative, and accessible are more likely to encourage individuals to engage in outdoor movement and exercise (Kaplan & Kaplan, 1989; Ulrich, 1983). Positive landscape experiences (PLEs)—defined as favorable perceptions of natural or designed environments that evoke feelings of comfort, safety, and enjoyment—function as catalysts for increased

PAs by fostering both psychological motivation and behavioral engagement (Hartig, Mitchell, De Vries, & Frumkin, 2014; Yeh et al., 2016).

Empirical evidence suggests that exposure to well-designed green and blue spaces not only enhances psychological restoration but also reduces barriers to participation in PAs (White et al., 2020). Residents who report higher levels of satisfaction with nearby landscapes are more likely to walk, cycle, or engage in recreational exercise, indicating a strong linkage between positive environmental appraisals and active lifestyles (Sallis et al., 2016; Sugiyama et al., 2008). Furthermore, the experiential qualities of landscapes—such as diversity, coherence, and naturalness—have been associated with greater frequency and duration of outdoor PAs (Bratman et al., 2019; Mouratidis, 2021). This evidence underscores that PLEs do not merely provide aesthetic appreciation but act as direct enablers of PAs by shaping attitudes, perceived affordances, and behavioral intentions.

Hypothesis 1

(H1). Positive landscape experiences directly affect physical activities.

2.2.2. Positive landscape experiences, physical activities and extraversion

Empirical studies have shown that positive landscape experiences (PLEs), including perceptions of visual appeal, relaxation, and a sense of belonging to the place, are positively correlated with the level of participation in physical activities (PAs). For example, the study by Sugiyama, Thompson, and Alves (2009) showed that the quality of residential landscapes is significantly related to recreational walking and regular PAs. Similarly, Kaczynski and Henderson (2007) emphasized that high-quality green spaces stimulate outdoor activity behavior. Furthermore, personality traits, particularly EXT in the Big Five model, have been shown to influence how individuals interact with their environment. Individuals with high levels of EXT tend to seek social stimulation, active participation, and experiential environments (McCrae & Costa, 2008; Roberts & Yoon, 2022). Research by Rhodes and Smith (2006) showed that EXT is positively correlated with the frequency of PAs. Additionally, extroverted individuals tend to evaluate their surroundings more positively and are more easily attracted to appealing landscape elements (Wilt & Revelle, 2023).

Hypothesis 2

(H2). Physical activities directly affect extraversion.

Notably, several recent studies suggest that PLEs not only directly influence behavior but may also be involved in the activation or expression of personality traits within specific contexts. From a person-environment interaction perspective, the environment can amplify pre-existing behavioral tendencies, particularly traits such as EXT, which is associated with seeking stimulation and social interaction (Anglim, Horwood, Smillie, Marrero, & Wood, 2020).

Hypothesis 3

(H3). Positive landscape experiences directly affect extraversion.

Hypothesis 4

(H4). Positive landscape experiences indirectly affect extraversion through the mediating effect of physical activities.

2.2.3. Physical activities, extraversion and subjective well-being

Numerous studies have confirmed that physical activities (PAs) have a positive influence on subjective well-being (SWB) through both physiological and psychological mechanisms. According to Edward Diener et al., SWB includes life satisfaction, positive affect, and negative affect, and PAs can improve all three components (Diener, Oishi, & Tay, 2018). Systematic reviews and meta-analyses show that PAs are positively correlated with SWB, and also helps reduce stress and depression (De Nys et al., 2022; Pearce et al., 2022). Furthermore, a longitudinal study by Sallis, Floyd, Rodríguez, and Saelens (2012) showed that individuals who maintain regular physical activity have higher levels of life satisfaction. Notably, PAs often impacts not only directly but also through psychological mediating variables such as self-esteem, self-efficacy, and social connectedness (Lubans et al., 2016). This suggests that individual traits such as EXT may play a mediating role in this relationship. In the Big Five Personality Traits model, EXT is one of the strongest predictors of SWB (Sudden and Submissive Relationship). According to Costa (1992), extraversion reflects a tendency to seek stimulation, social interaction, and positive emotional experiences. Empirical studies indicate that extraversion is strongly associated with positive affect and life satisfaction (Buecker, Maes, Denissen, & Luhmann, 2020; Steel et al., 2008). According to Lucas and Diener (2001), extroverts tend to experience more positive emotions because they participate more in social activities and stimulating environments.

Hypothesis 5

(H5). Extraversion directly affects subjective well-being.

Furthermore, according to Larsen and Ketelaar (1991), EXT increases sensitivity to rewards and positive emotions, thereby enhancing SWB. These findings are particularly relevant in the context of sustainable communities, where social interaction and community cohesion are core elements. The relationship between PAs and extraversion has been demonstrated in numerous meta-analysis studies. According to Rhodes and Smith (2006), EXT is significantly positively correlated with the level of physical activity participation. Extroverts tend to: participate more in socially engaging PAs, prefer dynamic and interactive environments, and maintain more consistent exercise habits. Several recent studies suggest that PAs may reinforce extroverted behavioral traits through enhanced social interaction and positive experiences (Lox, Ginis, Gainforth, & Petruzzello, 2019; Wilson, 2019). This opens the possibility of

viewing EXT not only as a predictor but also as a dynamic mediator. Based on the above evidence, it can be argued that PAs promote social engagement and a positive effect. These factors are closely related to EXT. In turn, extraversion increases SWB. Mediating models in health psychology also support the idea that the influence of PAs on subjective well-being often goes through psychosocial variables (Lubans et al., 2016). In this context, EXT can play a crucial mediating role, especially in community environments that encourage interaction and outdoor activities.

Hypothesis 6

(H6). Physical activities indirectly affect subjective well-being through the mediating role of extraversion.

2.2.4. Positive landscape experiences, physical activities, extraversion and subjective well-being

In environmental psychology and architectural behavior research, the relationships among Positive Landscape Experiences (PLEs), Physical Activities (PAs), Extraversion (EXT), and Subjective Well-Being (SWB) have been interpreted through multiple theoretical perspectives, including Attention Restoration Theory (Kaplan & Kaplan, 1989), Stress Reduction Theory (Ulrich, 1983), and personality theories (Costa, 1992). Together, these perspectives provide a framework for understanding both the direct and indirect effects of PLEs on SWB. PLEs, characterized by natural elements, aesthetic qualities, and restorative experiences, have been consistently linked to enhanced SWB. Attention Restoration Theory suggests that natural environments replenish attentional resources and alleviate cognitive fatigue (Kaplan & Kaplan, 1989), whereas Stress Reduction Theory emphasizes their capacity to reduce physiological and emotional stress (Ulrich, 1983). Empirical studies further indicate that frequent exposure to high-quality landscapes is associated with greater positive affect, life satisfaction, and mental health (Diener et al., 2018; Hartig et al., 2014; Wyles et al., 2019). In addition to these direct benefits, PLEs may indirectly influence SWB through behavioral pathways. Attractive and accessible landscapes encourage participation in outdoor physical activities, such as walking, jogging, and social interaction (Calogiuri & Chroni, 2014; Sugiyama et al., 2008). In turn, physical activity contributes positively to SWB by improving mood, reducing anxiety, and enhancing overall health (Diener et al., 2018; Rhodes, Janssen, Bredin, Warburton, & Bauman, 2017).

Hypothesis 7

(H7). Positive landscape experiences directly affect subjective well-being.

Next, EXT characterized by sociability, positive affectivity, and a preference for stimulating experiences, has been consistently associated with higher levels of physical activity participation and SWB (Larsen & Ketelaar, 1991; Rhodes & Smith, 2006; Shiota et al., 2017). Extroverted individuals are more likely to respond positively to socially and environmentally stimulating landscapes, facilitating greater activity engagement and positive emotional experiences (Kobylińska, Zajenkowski, Lewczuk, Jankowski, & Marchlewska, 2022). Moreover, EXT is widely recognized as one of the strongest predictors of SWB

(Diener et al., 2018). Recent studies in environmental psychology further suggest that the relationship between environmental experiences and well-being is often mediated by behavioral and personal factors (Hartig et al., 2014). In this context, PLEs may encourage physical activity and foster extroverted patterns of environmental interaction, thereby indirectly enhancing SWB.

Hypothesis 8

(H8). Positive landscape experiences indirectly affect subjective well-being through the mediating effect of physical activities and extraversion.

Based on the above arguments, the study proposes the following research structure in Fig. 1:

2.3. Methods

2.3.1. Study site

An Hoa Thinh Commune was selected as the study site because it represents a rural community that has undergone substantial environmental and socio-economic transformation under Vietnam's National New Rural Development Program. Established through the recent administrative merger of the former Son An, Son Hoa, and Son Thinh communes in Huong Son District, Ha Tinh Province, Central Vietnam, the commune is predominantly agricultural, with most residents relying on farming as their primary source of livelihood.

Before the implementation of the New Rural Development Program, the area experienced persistent economic constraints, largely due to its agricultural dependence, geographical remoteness from urban centers, and limited transportation infrastructure. Residents had relatively low living standards, while public spaces, recreational facilities, and opportunities for community interaction were scarce. Consequently, both outdoor activities and social participation were limited. The successful completion of the National New Rural Program has fundamentally transformed the commune. Investments in transportation networks, public infrastructure, landscape quality, and community open spaces have significantly improved both the physical environment and residents' quality of life (Fig. 2). Beyond these physical changes, local residents have become more receptive to community development initiatives and increasingly engaged in collective and social activities. These behavioral and social changes, which had not previously been documented in the area, suggest that improvements in the built and natural environment may have contributed not only to greater physical activity but also to more outward-oriented patterns of social engagement. This combination of environmental improvement and emerging behavioral change makes An Hoa Thinh an appropriate setting for examining how positive landscape experiences contribute to subjective well-being through physical activity and perceived extraversion. The commune therefore provides a valuable real-world context for investigating the dynamic interplay among environmental, behavioral, personality, and well-being outcomes in rural communities undergoing rapid development.

2.3.2. Item and reliability analysis

A questionnaire comprising 33 items was developed to measure positive landscape experiences (PLEs), physical activities (PAs), subjective well-being (SWB), and extraversion (EXT) among rural residents. Specifically, 16 items (A01–A16) assessed PLEs, five items (B01–B05) measured PAs, and six items each evaluated SWB (C01–C06) and EXT (D01–D06). All items were rated using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The reliability of the measurement scales was examined using SPSS 24. Internal consistency was assessed through Cronbach's Alpha, with 0.60 adopted as the minimum acceptable threshold. In addition, the Cronbach's Alpha if Item Deleted value for each indicator was required to remain below the overall Cronbach's Alpha, while the Corrected Item–Total Correlation had to exceed 0.30, ensuring the reliability and coherence of the measurement scales (Hair, Black, Babin, & Anderson, 2019).

2.3.3. Exploratory factor analysis (EFA)

Next, the 33 items were subjected to EFA using principal component extraction and varimax rotation to identify their latent structures and obtain a parsimonious factor solution. Dataset suitability was assessed using the KMO measure and Bartlett's test of sphericity, while the reliability of the extracted factors was evaluated through Cronbach's alpha coefficients according to established psychometric criteria (Hair et al., 2019).

2.3.4. Measurement validity test

AMOS 25 was employed to perform CFA and assess model fit and construct validity. Model adequacy was evaluated using χ^2/df (< 3), GFI, AGFI, CFI, and NFI (> 0.90), PNFI (> 0.50), RMR (< 0.05), and RMSEA (< 0.08). Convergent validity was supported by significant factor loadings (> 0.50), composite reliability (CR > 0.70), and average variance extracted (AVE > 0.50), whereas discriminant validity was confirmed when the AVE of each construct exceeded its squared correlations with other constructs (Hair Jr et al., 2021).

2.3.5. Structural equation modeling (SEM)

Structural equation modeling (SEM) was then conducted to simultaneously examine the causal relationships among the four constructs. This approach enables the assessment of direct effects between constructs and the evaluation of their corresponding effect sizes (Hair Jr et al., 2021).

3. Results

3.1. Demographic characteristics

Table 1 presents the demographic characteristics of the respondents. The sample was relatively balanced in terms of gender, with 54.3% males and 45.7% females. The age distribution was concentrated among middle-aged and older adults. Most participants had completed high school

education (59.8%). Reflecting the rural context of the study area, agriculture was the dominant occupation, accounting for 57.7% of respondents. Residential tenure was notably long, with 82.5% of participants having lived in the commune for more than 20 years. In contrast, fewer than 10% reported residing in the area for less than 15 years. Overall, the sample was characterized by long-term residency, agricultural livelihoods, and a predominance of middle-aged and older adults, providing a stable basis for examining environmental behavior in a rural setting.

Table 1
Demographic characteristics.

Characteristics	N	%	Characteristics	N	%
Gender			Occupation		
Male	258	54.3	Student	15	3.2
Female	217	45.7	Agriculture	274	57.7
Age			Construction/Manufacturing	36	7.6
18 ~ 24	17	3.6	Business/ Service	38	8.0
25 ~ 34	57	12.0	Pedagogy/Office	36	7.6
35 ~ 44	90	18.9	Retirement	39	8.2
45 ~ 54	109	22.9	Others	37	7.8
55 ~ 64	114	24.0	Residential time		
above 65	88	18.5	under 3 years	5	1.1
Education level			3–5 years	1	0.2
Primary/Secondary school	99	20.8	5–10 years	10	2.1
High school	284	59.8	10–15 years	28	5.9
Undergraduate	84	17.7	15–20 years	39	8.2
Postgraduate	8	1.7	above 20 years	392	82.5
			Total	475	100

3.2. Item and reliability analysis

Descriptive analysis indicated that rural residents perceived their living landscapes positively, participated moderately in physical activities (PAs), and reported favorable levels of subjective well-being (SWB) and extraversion (EXT)-related tendencies.

As shown in Table 2, PLEs demonstrated excellent internal consistency ($\alpha = 0.949$) and received consistently positive evaluations. Natural attributes, particularly the amount and diversity of greenery, obtained the highest ratings, followed by accessibility, proximity to the center, landscape harmony, and street design. Built-environment characteristics, including building layout, spacing, and street materials, received slightly lower but still favorable evaluations. These findings suggest that vegetation quality and spatial harmony are central components of residents' positive landscape experiences.

Table 2
Constructs and measurement items for research.

Item	Mean	Std. Deviation
Positive landscape experiences ($\alpha = 0.949$; KMO = 0.957)		
<i>Green space quality</i> (McDonald et al., 2023; Nguyen, Astell-Burt, Rahimi-Ardabili, & Feng, 2021)		
A01 - Amount of green spaces	4.33	0.73
A02 - Diversity of trees	4.25	0.75
A03 - Well-taken care of greenery	4.06	0.84
<i>Accessibility of buildings and open spaces</i> (Mouratidis, 2021; Sugiyama et al., 2009)		
A04 - Accessing the buildings	4.11	0.82
A05 - Layout of buildings	3.92	0.86
A06 - Distance from the center	4.14	0.88
<i>Density of buildings</i> (McDonald et al., 2023; Sallis et al., 2012)		
A07 -Distance between buildings	3.86	0.84
A08 - Number of households	4.00	0.86
A09 - Size of buildings	3.86	0.85
<i>Architectural aesthetics</i> (Jennath & Nidhish, 2016; Ulrich, 1983)		
A10 - Attractiveness of buildings	3.95	0.82
A11 - Colors of buildings	3.98	0.78
A12 - Design of gates and fences	4.01	0.82
A13* - Harmony surroundings	4.06	0.85
A14* - Size of open spaces	3.95	0.85
<i>Streetscape appeal</i> (Ogawa, Oki, Zhao, Sekimoto, & Shimizu, 2024)		
A15 - Street landscape design	4.03	0.82
A16 - Street material	3.83	0.88
Physical activities ($\alpha = 0.788$; KMO = 0.759) (Z. Zhang et al., 2022)		
B01 - Running	3.76	0.68
B02 - Walking	3.79	0.64
Note: Extraction method – Principal component Analysis; Rotation – Varimax; * item was eliminated due to factor loading under 0.5.		

Item	Mean	Std. Deviation
B03 - Playing ball games	3.31	0.81
B04 - Playing badminton	2.97	0.81
B05 - Fitness dance	2.97	0.86
Subjective well-being ($\alpha = 0.867$; KMO = 0.896)		
<i>Life-work balance</i> (Gröpel & Kuhl, 2009)		
C01 - Energy and fatigue	4.51	0.78
C02 - Daily activities	3.80	0.81
C05 - Spirituality	3.65	0.84
<i>Self-actualization</i> (Waterman, 2024)		
C03 - Positive feelings	3.77	0.83
C04 - Self-esteem	3.69	0.78
C06 - Relationships	3.92	0.79
Extraversion ($\alpha = 0.832$; KMO = 0.862) (Robbins, Francis, & Edwards, 2010)		
D01 - Enjoy social activities	4.51	0.78
D02 - Cooperation	3.80	0.81
D03 - Helping	3.77	0.83
D04 - Sharing	3.69	0.78
D05 - Pro-sociality	3.65	0.84
D06 - Comforting	3.92	0.79
Note: Extraction method – Principal component Analysis; Rotation – Varimax; * item was eliminated due to factor loading under 0.5.		

PAs showed acceptable reliability ($\alpha = 0.788$) and moderate participation levels, with walking and running being the most common activities. Participation was lower for socially or equipment-dependent activities, indicating a preference for individually performed and easily accessible forms of exercise compatible with rural lifestyles.

SWB exhibited good reliability ($\alpha = 0.867$) and generally positive ratings, particularly regarding energy levels and reduced fatigue, while evaluations of social relationships, daily activities, self-esteem, and spirituality remained moderately high. EXT also demonstrated good reliability ($\alpha = 0.832$), with enjoyment of social activities receiving the highest score. Other prosocial tendencies, including cooperation,

helping, sharing, and comforting others, were similarly rated positively, suggesting a socially engaged and supportive behavioral orientation among residents.

Overall, these findings indicate that rural residents experience their landscapes as restorative environments, engage regularly in outdoor activities, maintain favorable levels of well-being, and exhibit strong social orientations, providing preliminary support for the role of PLEs in fostering active behaviors and extroverted tendencies.

3.3. Exploratory factor analysis

3.3.1. Positive landscape experiences

Table 2 presents the exploratory factor analysis (EFA) results for the study constructs. For PLEs, two items—harmony with surroundings (A13) and size of open spaces (A14)—were removed due to factor loadings below 0.50. The remaining items yielded a clear five-factor structure with excellent sampling adequacy ($KMO = 0.957$, Bartlett's test: $p < 0.001$). The extracted dimensions were interpreted as accessibility of buildings and open spaces, green space quality, architectural aesthetics, building density, and streetscape appeal. For SWB, the EFA also demonstrated excellent sampling adequacy ($KMO = 0.896$, Bartlett's test: $p < 0.001$). The six items were grouped into two dimensions, namely life–work balance and self-actualization, with all factor loadings exceeding the recommended threshold of 0.50 (Hair et al., 2019).

3.4. Measurement validity analysis

3.4.1. Confirmatory analysis (CFA)

Table 3 presents the confirmatory factor analysis (CFA) results for the measurement model. The model exhibited a good fit to the data ($\chi^2 = 213.781$, $df = 114$, $\chi^2/df = 1.875$, $p < 0.001$), with all goodness-of-fit indices meeting the recommended thresholds ($CFI = 0.981$, $GFI = 0.954$, $NFI = 0.960$, $AGFI = 0.931$, $PNFI = 0.715$, $RMR = 0.018$, and $RMSEA = 0.043$) (Hair Jr et al., 2021). All standardized factor loadings exceeded 0.50, ranging from 0.570 to 0.894, indicating acceptable item reliability. Composite reliability (CR) values for PLEs, EXT, SWB, and PAs were all above the recommended threshold of 0.70, while average variance extracted (AVE) values were satisfactory for SWB, PLEs, and EXT. Although the AVE of PAs (0.452) was slightly below the recommended level, its CR and Cronbach's alpha exceeded 0.70, and all factor loadings remained acceptable, supporting the convergent validity and retention of this construct in the model (Fornell & Larcker, 1981; Hair Jr et al., 2021).

Table 3
Confirmatory analysis results.

Construct/Indicator	Factor loading (a)	Reliability coefficient (b)	Measurement error (c)	CR	AVE
Positive landscape experiences				0.928	0.721
Environmental accessibility	0.894	0.799	0.201		
Green space quality	0.834	0.696	0.304		
Architectural aesthetics	0.855	0.731	0.269		
Density of buildings	0.831	0.691	0.309		
Streetscape appeal	0.829	0.687	0.313		
Physical activities				0.803	0.452
Running	0.659	0.434	0.566		
Walking	0.662	0.438	0.562		
Playing ball games	0.671	0.450	0.550		
Playing badminton	0.570	0.325	0.675		
Fitness dance	0.782	0.612	0.388		
Subjective well-being				0.846	0.734
Life-work balance	0.860	0.740	0.260		
Self-actualization	0.853	0.728	0.272		
Extraversion				0.868	0.526
Enjoy social activities	0.837	0.701	0.299		
Cooperation	0.707	0.500	0.500		
Helping	0.609	0.371	0.629		
Sharing	0.754	0.569	0.431		
Pro-sociality	0.761	0.579	0.421		
Note. a–Standardized Regression Weight; b = (a ²); c = (1-b). CR–Composite reliability = $(\sum a)^2 / [(\sum a)^2 + (\sum c)]$. AVE–Average variance extracted = $(\sum b) / n$ (where n is the number of items) (H. Zhang, Nguyen-Dinh, & Pan, 2020).					

Construct/Indicator	Factor loading (a)	Reliability coefficient (b)	Measurement error (c)	CR	AVE
Comforting	0.661	0.437	0.563		
Note. a–Standardized Regression Weight; b = (a ²); c = (1-b). CR–Composite reliability = $(\sum a)^2 / [(\sum a)^2 + (\sum c)]$. AVE–Average variance extracted = $(\sum b) / n$ (where n is the number of items) (H. Zhang, Nguyen-Dinh, & Pan, 2020).					

3.4.2. Discriminant validity analysis

Table 4 shows strong correlations between four constructs, with coefficients ranging from 0.759 to 0.845. Bootstrap analysis using both bias-corrected and percentile methods indicates that all correlation estimates are statistically significant, as the corresponding confidence intervals are estimated to be 0.001.

Table 4
Discriminant validity analysis results.

Relationship between constructs	Correlation	Bootstrap 1000 CI					
		Bias-corrected method			Percentile method		
Lower		Upper	p-value	Lower	Upper	p-value	
PLEs ↔ PAs	0.779	0.693	0.851	0.001	0.690	0.847	0.001
PAs ↔ EXT	0.792	0.723	0.850	0.001	0.722	0.849	0.001
PLEs ↔ EXT	0.759	0.680	0.825	0.001	0.677	0.821	0.001
PLEs ↔ SWB	0.845	0.766	0.903	0.001	0.766	0.903	0.001
PAs ↔ SWB	0.763	0.649	0.848	0.001	0.645	0.846	0.001
SWB ↔ EXT	0.803	0.735	0.861	0.001	0.731	0.857	0.001
Note. p < 0.001. PLEs–Positive landscape experiences; PAs–Physical activities; SWB–Subjective well-being; EXT–Extraversion. The confidence interval does not include 1, which means there is discriminant validity.							

These results confirmed that the measured model met the condition of the discriminant validity test and supported their suitability for subsequent structural equation modeling (SEM) analysis (Hair Jr et al., 2021; Kline, 2023).

3.5. Structural equation modeling (SEM) analysis

3.5.1. The estimated structural model

The structural model was evaluated using multiple goodness-of-fit (GOF) indices to assess its validity. The results indicated an acceptable to good model fit ($\chi^2 = 479.159$, $df = 130$, $\chi^2/df = 3.686$, $CFI = 0.933$, $NFI = 0.911$, $PNFI = 0.774$, $RMR = 0.026$, $RMSEA = 0.075$, $p < 0.001$), meeting commonly recommended thresholds for SEM analyses (Hair Jr et al., 2021; Ullman & Bentler, 2012). The model explained substantial proportions of variance, with SWB showing the highest explained variance ($R^2 = 0.79$), followed by EXT ($R^2 = 0.76$) and PAs ($R^2 = 0.65$), indicating strong explanatory power. Collectively, these GOF indices and variance estimates confirm the adequacy and validity of the proposed structural model. The standardized path coefficients, including direct effects, are presented in Fig. 3.

3.5.2. The direct and indirect effects

The estimated fit of the structural model is summarized in Table 5, which reports five direct and three indirect effects, collectively providing empirical support for the eight proposed hypotheses.

Table 5
Standardized effect estimates in the structural equation modelling.

Hypothesis	Path	Direct effect	Indirect effect	Total effect	Support
H1	PLEs → PAs	0.80***		0.80***	Accepted
H2	PAs → EXT	0.65***		0.65***	Accepted
H3	PLEs → EXT	0.25*		0.78***	Accepted
H4	PLEs → PAs → EXT		0.53***(1)		Accepted
H5	EXT → SWB	0.47***		0.47***	Accepted
H6	PAs → EXT → SWB		0.31***(2)	0.31***	Accepted
H7	PLEs → SWB	0.47***		0.84***	Accepted
H8	PLEs → EXT → SWB		0.12**(3)		Accepted
	PLEs → PAs → EXT → SWB		0.25***(4)		

Note. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; ns: non-significant ($p > 0.05$). PLEs-Positive landscape experiences; PAs-Physical activities; SWB-Subjective well-being; EXT-Extraversion. Based on the Sobel test (Preacher & Leonardelli, 2001), the indirect effects were examined as follows:

(1) PLEs → PAs → EXT: $(0.80 \times 0.65) = 0.53$, $z = 7.316$, $p = 0.000$.

(2) PAs → EXT → SWB: $(0.65 \times 0.47) = 0.31$, $z = 4.814$, $p = 0.000$.

(3) PLEs → EXT → SWB: $(0.25 \times 0.47) = 0.12$, $z = 2.650$, $p = 0.008$.

(4) PLEs → PAs → EXT → SWB: $[(0.80 \times 0.65) + 0.25] \times 0.47 = 0.37$, $z = 5.062$, $p = 0.000$.

4. Discussion

This study provides robust empirical support for an integrated structural model linking positive landscape experiences (PLEs), physical activities (PAs), extraversion (EXT), and subjective well-being (SWB). Beyond confirming a series of significant direct effects, the findings elucidate a set of multi-layered mediation mechanisms, thereby advancing current understanding in environmental psychology and landscape–behavior research.

4.1. Positive landscape experiences as a behavioral catalyst

One of the key contributions of this study is the reconceptualization of positive landscape experiences (PLEs) as an active behavioral catalyst rather than merely a source of passive psychological restoration. The strong association between PLEs and physical activities (PAs) suggests that high-quality landscape experiences substantially encourage residents' physical engagement within their living environments.

This finding extends classical frameworks, such as Attention Restoration Theory (ART) and Stress Reduction Theory (SRT), which primarily emphasize cognitive recovery and emotional regulation (Hartig et al., 2014; Kaplan & Kaplan, 1989; Ulrich, 1983). Instead, the present results support an affordance-based perspective, whereby landscape environments provide opportunities for action that facilitate health-promoting behaviors (Gibson, 1985; Kyttä, 2004). This interpretation is consistent with emerging behavioral pathway frameworks, which propose that environmental qualities influence health outcomes through increased behavioral engagement (Dzhambov et al., 2018; Markevych et al., 2017).

Previous studies have similarly shown that attractive, accessible, and well-designed green environments promote recreational and routine physical activities (McCormack, Rock, Toohey, & Hignell, 2010; McDonald et al., 2023; Sugiyama et al., 2008). More recent evidence further suggests that spatial characteristics, including accessibility, openness, and small-scale green infrastructure, can stimulate everyday physical activities by enhancing environmental usability and place-based engagement (K. Zhang, Shang, De Vos, Zhang, & Cao, 2025). Collectively, these findings underscore the importance of experiential landscape qualities, particularly greenery, openness, and accessibility, in fostering active lifestyles and supporting public health, a conclusion also reinforced by recent systematic reviews and meta-analyses (Chen, Yan, & Hu, 2025; Lee & Maheswaran, 2011; Twohig-Bennett & Jones, 2018).

4.2. Physical activity as a psycho-social mediator

The findings further suggest that physical activities (PAs) serve as an important psycho-social mediator linking environmental experiences and extraverted tendencies. The strong association between PAs and extraversion (EXT), together with the significant indirect effect of positive landscape experiences (PLEs) on EXT through PAs, indicates that regular participation in physical activities within supportive environments may foster outward-oriented behavioral expressions.

This result challenges the traditional view of personality as a largely stable disposition and instead supports contemporary perspectives that emphasize the dynamic and context-dependent nature of personality (Fleeson, 2001; Thielmann, Spadaro, & Balliet, 2020; Wrzus & Roberts, 2017). Landscape settings that encourage movement and social interaction may provide opportunities for interpersonal contact and social vitality, thereby facilitating extroverted behavioral tendencies (Jennings & Bamkole, 2019; Sugiyama et al., 2008).

Previous studies have likewise reported positive associations between physical activity and extraversion. Meta-analytic and longitudinal evidence suggests that individuals who engage more frequently in physical activities tend to exhibit higher levels of extraversion over time, reflecting a reciprocal relationship between behavior and personality (Rhodes & Smith, 2006; Stephan, Sutin, & Terracciano, 2014; Stieger, Robinson, Bisson, & Lachman, 2020). In addition, outdoor and socially interactive activities have been associated with greater positive affect, energy, and social engagement, which are characteristic features of extraversion (Buecker, Simacek, Ingwersen, Terwiel, & Simonsmeier, 2021; Reed & Buck, 2009). Collectively, these findings support behavioral pathway frameworks proposing that environmental experiences influence psycho-social outcomes through behavioral engagement (Markevych et al., 2017).

4.3. Extraversion as a proximal determinant of well-being

The findings further suggest that the contribution of physical activities (PAs) to subjective well-being (SWB) is partly explained by their association with extroverted behavioral tendencies, highlighting the importance of incorporating personality dynamics into environment–behavior–well-being frameworks. Consistent with previous studies, extraversion (EXT) emerged as a proximal predictor of SWB. Extraverted individuals generally report greater life satisfaction and positive affect due to their higher propensity for social interaction and responsiveness to rewarding experiences (Anglim et al., 2020; Diener et al., 1992; Ng, 2025; Steel et al., 2008). However, the present study extends this perspective by positioning EXT within an environmentally grounded pathway rather than treating it solely as a stable dispositional characteristic.

The significant indirect association between PAs and SWB through EXT suggests that the well-being benefits of physical activity extend beyond physiological gains to encompass psycho-social processes, including enhanced social interaction, positive affect, and increased vitality. This interpretation is consistent with studies showing that participation in outdoor and socially interactive activities promotes emotional well-being and social connectedness (Buecker et al., 2021; Reed & Buck, 2009). It also aligns with broader theoretical perspectives emphasizing the importance of social connectedness and psychological engagement in shaping well-being (Jennings & Bamkole, 2019; Kroencke et al., 2023; Maas, Van Dillen, Verheij, & Groenewegen, 2009). Accordingly, EXT may represent an important mechanism through which behavioral engagement contributes to subjective well-being, supporting the view that well-being is influenced not only by activity participation itself but also by the social and outward-oriented experiences associated with such activities.

4.4. Multiple pathways linking landscape experience and well-being

Another important contribution of this study is the identification of multiple pathways through which positive landscape experiences (PLEs) influence subjective well-being (SWB). Besides a substantial direct association, two indirect pathways were supported: one operating through extraversion (EXT) alone and another through a sequential process involving both physical activities (PAs) and EXT.

These findings advance a multi-pathway framework that integrates environmental, behavioral, and psycho-social mechanisms in explaining the relationship between landscape experience and SWB. Previous studies have primarily emphasized either the restorative benefits of nature exposure (Kaplan & Kaplan, 1989; Ulrich, 1983) or behavioral pathways through PAs (Markevych et al., 2017). By demonstrating both parallel and sequential mediation effects, the present study extends these perspectives beyond single-mechanism explanations and highlights the interdependence of environmental, behavioral, and psycho-social processes.

Importantly, the proposed framework positions PAs and EXT as interconnected mediators operating at different levels. PAs represent a behavioral pathway through which environmental affordances are enacted, whereas EXT reflects a psycho-social pathway associated with repeated behavioral engagement and social interaction (Fleeson, 2001; Thielmann et al., 2020; Wrzus & Roberts, 2017). This finding is consistent with contemporary perspectives that conceptualize personality as a dynamic and context-sensitive system rather than a fixed dispositional trait.

The results also contribute to a growing body of literature advocating integrative models in environmental psychology, in which well-being emerges through multiple interacting pathways rather than singular causal mechanisms (Bratman et al., 2019; Dzhambov et al., 2018; Hartig et al., 2014; Markevych et al., 2017). The stronger influence of the sequential pathway further emphasizes the importance of behavioral engagement as an intermediary process linking environmental experiences and well-being. Together, these findings suggest that landscape environments support well-being not only through restorative qualities but also by encouraging active lifestyles and social interaction.

4.5. Theoretical contributions

This study makes several theoretical contributions to environmental psychology and behavioral science. First, it develops and empirically validates a multi-pathway framework integrating environmental, behavioral, personality-related, and well-being constructs within a unified model. By identifying both parallel and sequential mediation pathways, the study extends conventional bivariate approaches and responds to recent calls for system-oriented frameworks capable of capturing the complexity of environment–health relationships (Hartig et al., 2014; Markevych et al., 2017). This framework provides a more comprehensive understanding of how positive landscape experiences contribute to subjective well-being through interconnected behavioral and psycho-social processes.

Second, the findings contribute to emerging perspectives that conceptualize personality as a dynamic and context-sensitive system rather than a fixed dispositional trait (Thielmann et al., 2020; Wrzus & Roberts, 2017). Unlike traditional restorative theories, which primarily emphasize short-term cognitive and emotional benefits of nature exposure (Kaplan & Kaplan, 1989; Ulrich, 1983), the present study suggests that supportive landscape environments and repeated physical activity engagement may also foster extroverted behavioral tendencies. In doing so, the study expands current understanding of the relationship between environmental experiences and personality-related processes.

Third, the study helps bridge environmental psychology and health behavior research by demonstrating that landscape experiences are associated with well-being through both behavioral activation and psycho-social pathways. The findings support previous evidence indicating that green environments enhance well-being not only through restorative effects but also by encouraging physical activity and social interaction, which are positively related to psychological functioning (Maas et al., 2009; Sugiyama et al., 2008; Twohig-Bennett & Jones, 2018). Together, these contributions advance a more integrative perspective on the mechanisms linking environmental qualities and subjective well-being.

4.6. Practical and design implications

From a practical perspective, the findings offer several implications for landscape planning and design. First, landscape environments should be configured to encourage physical activity through walkable networks, accessible open spaces, and multifunctional outdoor settings. Environmental attributes such as connectivity, accessibility, and spatial diversity have been consistently associated with higher levels of physical activity and active lifestyles (Giles-Corti et al., 2016; McCormack et al., 2010; Nieuwenhuijsen, 2021; Sugiyama et al., 2008).

Second, integrating natural elements, including greenery and water features, can enhance experiential quality and emotional engagement. Exposure to nature contributes to stress reduction, attentional restoration, and positive affect, while aesthetically appealing and sensory-rich landscapes further support restorative experiences and behavioral engagement (Hartig et al., 2014; Kaplan & Kaplan, 1989; K. M. Korpela et al., 2010; Korpilo et al., 2024; Twohig-Bennett & Jones, 2018).

Third, landscape spaces should be designed to facilitate social interaction through flexible gathering areas, pedestrian-friendly environments, and visually open settings. Such features can strengthen social cohesion and interpersonal contact, which are positively associated with extroverted behavioral tendencies and subjective well-being (Kroencke et al., 2023; Maas et al., 2009).

Overall, the findings suggest that landscape interventions can serve as cost-effective and scalable strategies for promoting public health. Designing landscapes as active, restorative, and socially supportive environments may simultaneously encourage physical activity, foster social engagement, and enhance subjective well-being, particularly in communities facing increasing psychological stress and sedentary lifestyles.

4.7. Limitations and future research

Despite its contributions, this study has several limitations. First, the cross-sectional design restricts the ability to establish causal relationships among the proposed constructs, as the temporal ordering of effects cannot be fully verified. Future studies should employ longitudinal or experimental approaches to examine the directionality and stability of these relationships over time (Maxwell & Cole, 2007).

Second, EXT was conceptualized as a relatively stable personality trait. Although consistent with the dominant trait-based perspective, contemporary personality research highlights the dynamic and context-dependent nature of personality (Prentice, Jayawickreme, & Fleeson, 2019). Future research could incorporate state-level EXT, momentary social engagement, or experience-sampling methods to better capture the interactions among environmental exposure, behavior, and personality processes.

Finally, the generalizability of the findings remains uncertain. The observed relationships may differ across populations and environmental contexts due to variations in socio-demographic and cultural characteristics (Ployhart & Vandenberg, 2010). Future studies should test the proposed framework across diverse age groups and settings, such as urban parks, university campuses, and residential neighborhoods, to evaluate its robustness and external validity.

5. Conclusion

This study advances understanding of environment–human interactions by examining the relationships among positive landscape experiences (PLEs), physical activities (PAs), extraversion (EXT), and subjective well-being (SWB) within an integrated structural framework. The findings support both direct and indirect pathways, suggesting that landscape experiences contribute to well-being not only through restorative effects but also through behavioral and psycho-social processes.

A key contribution of this research is the identification of PAs and EXT as interconnected mediators linking environmental experiences to well-being outcomes. The results indicate that supportive landscape environments may encourage physical activity, foster extroverted behavioral tendencies, and ultimately contribute to higher levels of subjective well-being. In this regard, landscape experiences function not only as direct determinants of well-being but also as catalysts for active lifestyles and social engagement.

From a theoretical perspective, the study contributes to environmental psychology by proposing a multi-pathway framework that integrates environmental, behavioral, and personality-related mechanisms. It also supports emerging perspectives that conceptualize personality as a dynamic and context-sensitive system, while highlighting the importance of behavioral engagement in the environment–well-being relationship.

From a practical perspective, the findings suggest that landscape interventions can serve as effective strategies for promoting public health and well-being. Designing environments that are accessible, restorative, and socially supportive may encourage physical activity and social interaction, thereby enhancing both physical and psychological health. These implications are particularly relevant for rural

communities undergoing rapid socio-spatial transformation, where landscape planning can play an important role in fostering healthier and more sustainable living environments.

Declarations

Institutional Review Board Statement

Ethics approval was waived because this study involved an anonymous, voluntary questionnaire survey with no physical or psychological intervention, no collection of sensitive personal data, and no involvement of animals or biological materials. Informed consent was obtained from all participants, and the study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Informed Consent

Statement: The study was conducted based on voluntary participation; informed consent procedures; protection of participants' confidentiality and anonymity; assessment and minimization of potential physical, psychological, and social risks; and compliance with the research ethics policies and guidelines.

Conflicts of Interest:

The authors declare no conflicts of interest.

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Author Contribution

Statements and Declarations Author Contributions: Conceptualization, N.N.-D. and H.Z.; methodology, N.N.-D.; software, N.N.-D.; validation, H.Z.; formal analysis, N.N.-D.; investigation, N.N.-D.; data curation, N.N.-D.; writing—original draft preparation, N.N.-D.; writing—review and editing, P.-T.H.-T. All authors have read and agreed to the published version of the manuscript. Funding: This research received no external funding. Institutional Review Board Statement: Ethics approval was waived because this study involved an anonymous, voluntary questionnaire survey with no physical or psychological intervention, no collection of sensitive personal data, and no involvement of animals or biological materials. Informed consent was obtained from all participants, and the study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Informed Consent Statement: The study was conducted based on voluntary participation; informed consent procedures; protection of participants' confidentiality and

anonymity; assessment and minimization of potential physical, psychological, and social risks; and compliance with the research ethics policies and guidelines. Data Availability Statement: The datasets generated and analyzed during the current study, together with the variable descriptions, survey instrument, and analysis resources, are provided in the supplementary Files accompanying this article. Acknowledgments: The research team would like to sincerely thank those who took the time to participate in the interviews and the leaders of the An-Hoa-Thinh commune, Huong Son district, and Ha Tinh province for helping the research team complete the survey and provide valuable research results. Conflicts of Interest: The authors declare no conflicts of interest.

Data Availability Statement:

The datasets generated and analyzed during the current study, together with the variable descriptions, survey instrument, and analysis resources, are provided in the supplementary Files accompanying this article.

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Figures

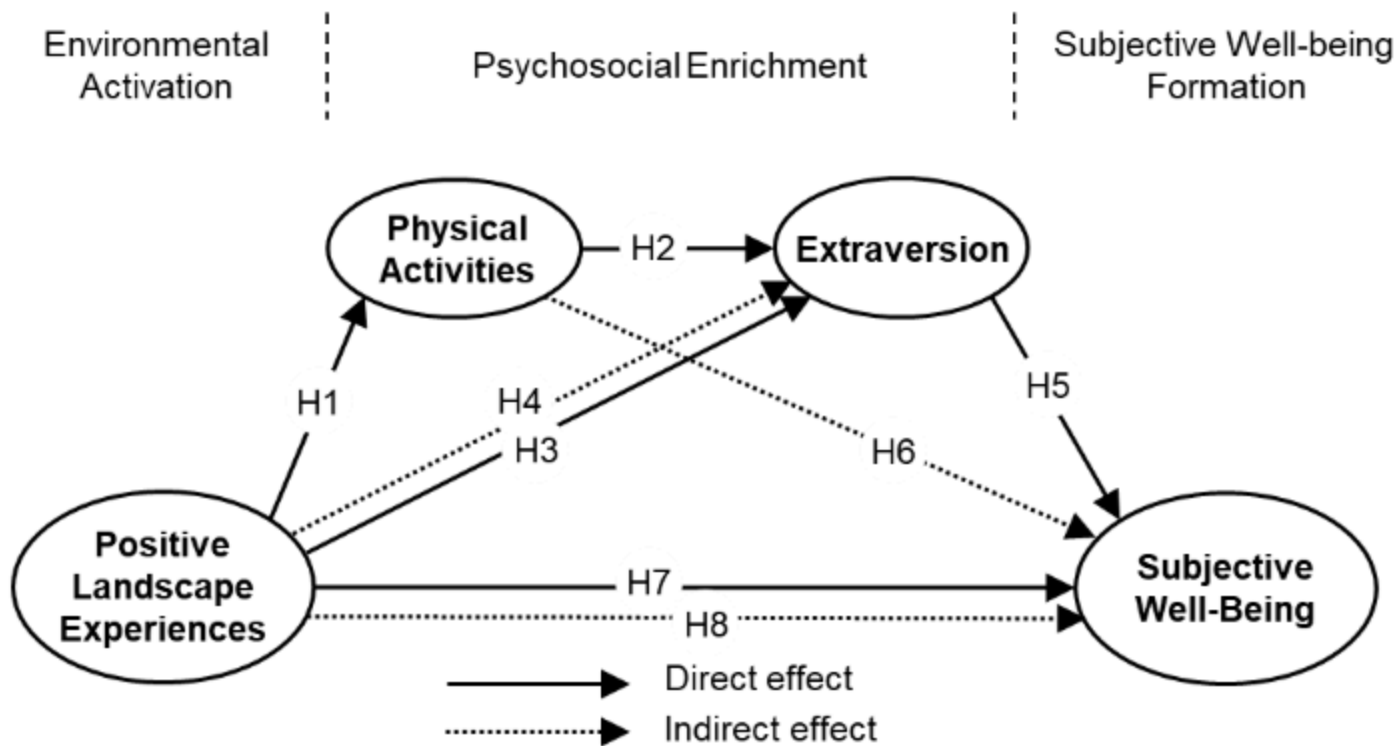


Figure 1

Proposed research structural model



Figure 2

Map of study site, landscape, and activities of rural residents.

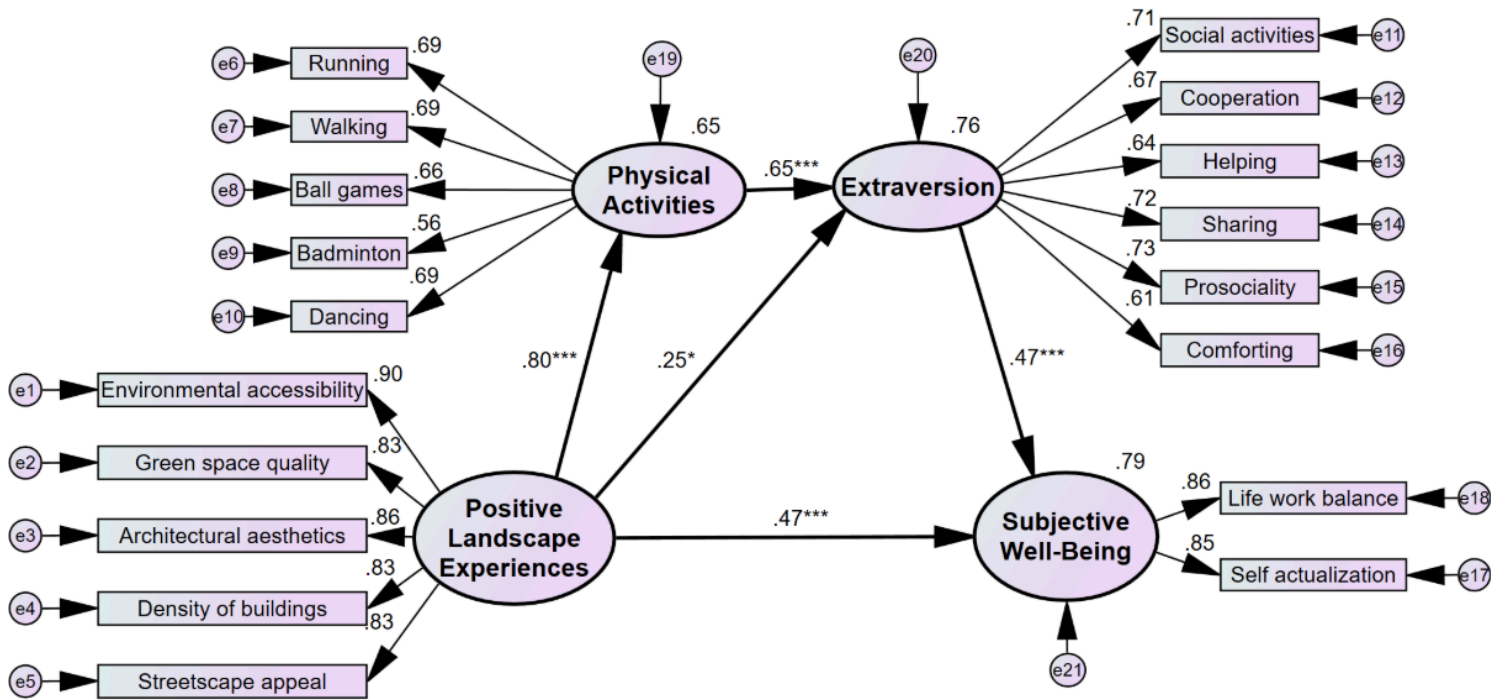


Figure 3

The estimated structural model by AMOS with total effect dimensions.

Supplementary Files

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