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Moving towards carbon neutral lifestyle through FinTech social media platform: a case study of Ant Forest

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Introduction: The escalating environmental crisis resulting from high carbon consumption has led to severe consequences. Urgent measures to reduce carbon emissions are needed. Ant Forest integrates technology to promote low-carbon behaviors, but limited knowledge exists regarding its impact on environmental behaviors.

Methods: This study constructed an integrated theoretical framework based on TRA, DIT, KAB, and RL. SEM analysis was conducted on survey data. Semi-structured interviews provided qualitative data on lifestyle changes.

Results: Beliefs, norms, entertainment interaction, and commonweal significantly and positively impacted citizens' use of Ant Forest. Knowledge sharing through Ant Forest promoted environmental attitudes and low-carbon behaviors.

Discussion: This study shows how fintech social media can facilitate low-carbon lifestyles and provides inspiration for businesses and governments seeking to enable a low-carbon society. Limitations are the study's reliance on self-reported data and constraints around generalizability. Further research should build on these findings.

KEYWORDS

carbon neutral lifestyle, social media, Ant Forest, behaviour change, theory of reasoned action, diffusion of innovation theory, knowledge-attitude-behaviour theory, reinforcement learning

1 Introduction

China is one of the many countries that are making lots of efforts to achieve carbon neutrality target. As a country with the largest population in the world (Worldometer, 2023), it is very important to guide its citizens to a carbon-neutral lifestyle. In August 2016, Alipay, with over one billion active users, is one of the most popular payment platforms that has fully integrated in every aspect of people's lives. A project known as Ant Forest was also developed and launched by Alipay (Zhang et al., 2020; Zhang, 2023). Being an innovative scheme focusing on transferring the concept of environmental protection and a low-carbon lifestyle, Ant Forest combines online and offline scenes to encourage users to participate in public welfare activities, preventing desertification through Alipay payment, offline low-carbon behaviour and online tree planting games (Yang et al., 2018; Chen and Cai, 2019; Shen et al., 2021; AntGroup, 2022; Zhang et al., 2022; Chen et al., 2023; Zhang, 2023). A gamified participatory communication program, Ant Forest, has promoted the spread of concepts of

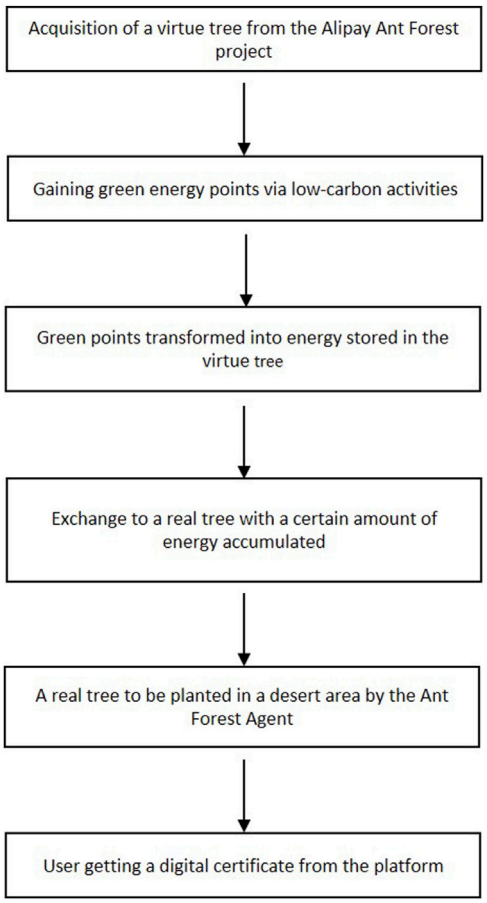

FIGURE 1
Operating Diagram of the Ant Forest program.

"Internet + public welfare" (Zhang, 2023), "low-carbon behaviour + public welfare", "game + public welfare" by associating users' low-carbon behaviours in real world with the online tree planting game (Chen et al., 2023). The process, as shown in Figure 1, covers all aspects of consumers' lives, and involves industries including finance, service, education, health, entertainment, travel, catering, and so forth (Zhang et al., 2020).

The user is assigned a virtual sapling on the platform (as shown in Figure 2) and can water and fertilize the tree with the green "energy" accumulated from converting their low-carbon activities conducted in real life on Alipay (Chen et al., 2023), such as choosing low-carbon transportations, making hospital appointment online, and digital payments in online and offline purchases (Li and Peng, 2019). Through this mobile application, Alipay introduces low-carbon lifestyle into people's lives.

By combining the tree planting game with users' real-life behaviours, Ant Forest demonstrates the impact of personal behaviour on the environmental protection in a virtualised way, thereby encouraging the users to reduce their carbon emissions. Through the game experience, users can have a deep understanding on to what extent certain real-life behaviours protect the environment by 'earning' the different amount of green "energy" points that are allocated to each specific behaviour. After participating in the Ant Forest project, users are motivated to adopt a low-carbon lifestyle to gain green energy points. With these incentives, users are more likely to accept the low-carbon life behaviours promoted by the programme (Shen et al., 2021).

The interactive attribute of social relationships is one of the attractiveness of Ant Forest. The social bonding among users can be strengthened in settings such as "co-planting", where users can contribute their green points to planting a common tree, and "Stealing Energy" where friends can visit other people's virtual home and steal energy points. All these settings promote social interaction between users and their friends, enabling them to enjoy interpersonal communication (Chen and Cai, 2019).

By the year 2022, Ant Forest is reported to generate over 20 million tons of 'green energy' with over 500 million users (AntGroup, 2022). Matching the "green energy points" created by users' low-carbon activities, Alipay has protected a total area of 12,000 hectares of conservation area and planted more than 223 million real trees in northwest China (Yang et al., 2018; Li and Peng, 2019; Zhang et al., 2020; Zhang et al., 2022), covering a total area of 112,000 hectares, improving the ecology of desert areas, and creating ecological benefits (United Nations, 2021). As an innovative programme of "Internet + environmental protection + public welfare", the Ant Forest seamlessly connects virtual world and the reality, and combines public welfare with games (Chen and Cai, 2019; Chen et al., 2023), so that everyone can use their fragmented time to contribute to public welfare if they wish (Zhang et al., 2022; Zhang, 2023). It was awarded 'Champions of the earth award' by the United Nations UNEP (UNEP, 2021). Ant Forest encourages participants' low-carbon environmental protection behaviours, raises the environmental awareness of the society, and promotes the green and low-carbon lifestyle in China.

In recent years, there has been a growing body of research focusing on various aspects of sustainable development, including carbon reduction, environmental protection, and low-carbon behavior. Scholars have conducted studies on the operation mechanism of Ant Forest, examining its connections to green finance and internet public welfare (Zheng and Meng, 2018; Zhang, 2021; Filieri and Zhou, 2023; Zhang, 2023). Additionally, several researchers have explored factors influencing users' intentions to use Ant Forest (Yang et al., 2018; Ren, 2021; Zhang and Zhang, 2022), sparking a branch of research in understanding usage intentions. Subsequently, Zhang et al. (2020) and Ashfaq et al. (2021b) have focused on the impact of Ant Forest on users' behavior changes. Although these studies have shed light on the project's operation and user development, there is still a gap in understanding the impact of Ant Forest on individuals' lifestyles. To fill this gap, this paper uses an integrated new theoretical framework to explore the mechanism behind how Social Mobile Application (i.e., Ant Forest) changes people's long-term behaviour towards the low-carbon lifestyle. The remaining sections of the paper present the theoretical background and the development of hypotheses. To conduct empirical analysis, a mixed methods approach was utilized, involving surveys and semi-structured interviews with Ant Forest users to collect primary data. The findings of this study are expected to provide valuable insights for the development of carbon-neutral lifestyles and serve as a reference for future research on the impact of social mobile applications on lifestyle choices.

Green Travel

Walk

Public Transit (80g Reward per Transaction)

New Energy Vehicles (891g Reward per day)

Green Flying

Shared Bike (Up to 159g Reward)

Subway Trips (52g Reward per Transaction)

Public Charging Stations (Up to 262g Reward per Transaction)

Stay Tuned (More Low-Carbon Scenarios)

Reduce Travel

Online Train Ticket Booking (136g Reward per Transaction)

Online ticket purchase (180g Reward per Transaction)

Green Government Services (15g Reward per Transaction)

Utility Bill Payments (262g Reward per Transaction)

Green Healthcare (Up to 277g Reward)

Eco-Friendly Office (Up to 51g Reward per Day)

Vehicle Parking (819g Reward per Week)

Green Banking (Up to 639g Reward)

Credit Card Payments (21g Reward per Transaction)

Stay Tuned (More Low-Carbon Scenarios)

Recycling

Green recycling (Superior Energy)

Eco-Friendly Accommodation (92g Reward)

Paper and Plastic Reduction

Green Packaging

Offline payment (Up to 5g Reward)

Electronic Payments

Environmental Plastic Reduction

Direct Drinking Water

Eco-Friendly Cups

Green Takeout

Electronic Receipts (4g Reward per Transaction)

Electronic Invoices (5g Reward per Transaction)

Electronic Billing (4g Reward per Time)

Scan-to-Order (7g Reward per Transaction)

Scan-to-Purchase Tickets (5g Reward per Transaction)

Online Shipping (4g Reward per Transaction)

Electronic Signing (6g Reward per Transaction)

Electronic Insurance Policies (59g Reward per Insurance Policy)

Credit Accommodation (5g Reward per Transaction)

International Tax Refund(4g Reward per Transaction)

Paperless Reading(5g Reward per Transaction)

Green Venues(Up to 25g Reward per Day)

Stay Tuned (More Low-Carbon Scenarios)

Energy Conservation

ETC Payments (18g Reward per Transaction)

Shared Power Banks (13g Reward per Transaction)

Parking Payments (18g Reward per Transaction)

Green Appliances (Superior Energy)

Close-to-Expiration Food (New)

Stay Tuned (More Low-Carbon Scenarios)

FIGURE 2
Actions for gaining Green Energy Points.

2 Literature review

Ant Forest, as an innovative "Internet + public welfare" social media Fintech App, has gained increasing interest among scholars (for example, Zhang, 2023; Chen et al., 2023; Zhang and Zhang, 2022; Ashfaq et al., 2022; Zhang et al., 2021; Song et al., 2021; Mi et al., 2021; Ashfaq et al., 2021a; Yang et al., 2018). A variety of theories have been adopted to explore how Ant Forest is affecting its users' behaviour and lifestyle. Among these studies, the majority focuses on the basis of practical frameworks, such as Theory of Planned Behaviour (TPB) and Theory of Reasoned Action (TRA) (Ren, 2021; Zhang and Zhang, 2022), Diffusion of innovation theory (Yan et al., 2020), Motivation theory (Yang et al., 2018), Behaviour setting theory (Li, 2018), Technology Acceptance Model (TAM) (He, 2020), Behavioural Reasoning Theory (BRT) (Ashfaq et al., 2021b); Unified Theory of Acceptance and Use of Technology (UTAUT) (Shahzad et al., 2022) and the use and gratifications theory for analyzing the psychology behind the Continuous Use Behaviors (CUBs) of Ant Forest users (Mi et al., 2021).

Beyond applying the theoretical framework to "Ant Forest Phenomenon", another stream of research investigates the impact of Ant Forest as a social media and Fintech mobile app. For instance, Zhou (2019) and Xie (2020) analyze the impact of Ant Forest on the

user's behaviour from the perspective of communication. In other studies of this steam, Chen et al. (2023) ascertained that the utilization of gamification affordances yields a constructive impact on users' assessments of value, consequently fostering heightened consciousness among individuals regarding environmental conservation. Cao et al. (2019) provide a reference for the establishment and development of China's personal carbon account by analyzing the operation mechanism and incentive measures of Ant Forest. Zhang et al. (2021) has confirmed the possibility of advancing green finance through Fintech innovations like Ant Forest. Xu et al. (2022) verifies the possibility of encouraging green lifestyle using game-driven green e-commerce through the research of online ethnography. Ant forest has been found to have the positive impact in the environmental aspect. Chen and Cai (2019) linked afforestation with haze, and proved that Ant Forest has played an encouraging role in users' environmental awareness and behaviour through the game participation method. Song et al. (2021) also found that the planting and afforestation project of Ant Forest in the east of Qinghai has improved the regional vegetation coverage and increased regional biodiversity.

Nonetheless, the impact of Ant Forest on long-term changes, namely, lifestyle, has not been investigated yet. In this study, we combine the reinforcement learning theory with Theory of Reasoned Action (TRA), Diffusion of Innovation Theory (DIT), and Knowledge-Attitude-Behaviour Theory (KAB), so to develop an integrated theoretical framework which can better explore the impact of innovative mobile App (i.e., Ant Forest) on users' environmental behaviour and further the changes in carbon-neutral lifestyle.

3 Theoretical framework and hypothesis development

We develop the hypothesis in this study based on four well-known psychological theories, namely, Theory of Reasoned Action (TRA), Knowledge–Attitude–Behaviour (KAB) Theory, Diffusion of Innovation Theory (DIT), and Reinforcement Learning Theory. The development of TRA facilitates the comprehension of the relationships between attitudes, intentions and behaviours (Fishbein, 1967). The theory holds that individual behaviour is affected by the intention of behaviours, which is affected by behavioural attitude and subjective criteria. Behavioural attitude refers to people's positive or negative emotional tendency towards a behaviour; object norm refers to the motivational impact of people who have more influence on individuals (Chin et al., 2018). Despite the limitations pointed out by Karahanna and Straub (1999) and Fishbein and Middlestadt (1995), the operability of the TRA structure derives from the long-term attitude measurement theory. Attitude measurement theory believes that it is the expectations or beliefs on, as well as the assessment of the attributes of an object or action that determine an attitude toward this object or action. This expectation conceptualization has been successfully utilized in the prediction and explanation of a great variety of health behaviours and intentions, such as healthy diet and road safety (Nilsson and Küller, 2000). The research results have been applied to the development of numerous effective interventions to behaviour change (Fishbein, 1990) and the area of environmental protection and environmentally conscious behaviour (Chen and Chiu, 2016). Therefore TRA can be employed in developing the hypothesis that investigating the mechanism of the mobile App (i.e., Ant Forest) affecting users' environmental behaviour.

Amongst the contributing factors to behaviour change, attitude plays a determining role (Fishbein and Ajzen, 1977). Knowledge, as mentioned in previous studies (for example, Cincera and Kraijhanzl, 2013; Goldman et al., 2020), is positively associated with attitude change, thereby effectively promoting the change of behaviour. Based on such logical framework, Kallgren and Wood, (1986) proposed the Knowledge-Attitude-Behaviour (KAB) theory, most commonly applied in the medical literature, examining areas ranging from primary care (Tolvanen et al., 2012; Yang et al., 2020) to prevention of AIDS (Li et al., 2014). KAB model composes of three key elements, knowledge, attitude, and behaviour (Ahmad et al., 2020), among which knowledge represents all the information acquired and accumulated related to a specific domain (Schrader and Lawless, 2004). Attitude is defined in a behavioural sense as a state of psychological and neural preparation with a directing impact on one's response to related objects and situations (Buck et al., 2014). Behaviour refers to the way a person, organism or group reacts to specific conditions (Schrader and Lawless, 2004). In recent decades, KAB theory has been widely applied to exploring the impact of knowledge on one's attitude toward environment related issues (Paço and Lavrador, 2017) as well as one's environmental friendly behavioural changes (Dhir et al., 2020). Numerous studies have confirmed the relationship between knowledge, attitudes and behaviours (Li et al., 2014; Heeren et al., 2016), some research (Cincera and Krajhanzl, 2013), on the other hand, challenges this theory. For example, Fotopoulos and Krystallis (2002) found that the knowledgeable consumers still engaged in low level of organic products consumption in Greece. Nevertheless, as pointed out by Hungerford and Volk (1990), more knowledgeable people are more likely to make more suitable choices even though ecological knowledge may not directly affect people's intention in environmental behaviours.

In 1903, Gabriel Tarde first discussed the diffusion of innovation theory (DIT) (Toews, 2003). Later, Ryan and Gross (1943) introduced the category of adopters later used for innovation, while Everett Rogers promoted the current theory in his book "Diffusion of Innovations" in 1983. As a well-established theory in both academia and practice, DIT is widely applied in sociology, communication, management and other fields (Smerecnik and Andersen, 2011). As explained in Rogers et al. (2014), diffusion of innovation is a process by which members of a social system communicate innovation via particular channels (Mobile App, for instance). The advance of Internet technology has accelerated the spread of the issue of environmental protection and improved public participation. In addition, the Internet-based commonweal provides activities closer to the daily life, which enables the public to participate in environmental protection activities in a timely manner with such characteristics as timeliness and interactivity. By numerous studies, Rogers pointed out that five distinct characteristics of innovation, including complexity, relative advantage, observability, trialability and compatibility, are the contributing factors to diffusion of innovation. In terms of

relative advantage, Ant Forest, a representative of Internet public welfare, was the first project of Internet public welfare in China, launched by Alipay platform with 870 million active users. In terms of compatibility, Ant Forest conforms to the trend of social life and is compatible with the concept of "green travel", low-carbon and environmentally-friendly". Ant forest is compatible with the life circle, combining life related behaviors such as urban services and transportation with the game, imperceptibly integrating consumption scenarios with low-carbon actions, and successfully integrating low-carbon concepts into the daily life. Additionally, Ant Forest quantifies the public welfare indicators and effects, so that users can directly see the tree ranking and energy points data of their own and friends', which has an impact on the social influence of public welfare projects and the formation of networked social relations. In terms of complexity, Ant Forest automates the production of green energy, and the simple and convenient operation can rapidly complete the closed-loop of all the functions.

Reinforcement Learning (RL) Theory is a behaviourism theory proposed by Skinner (1969) on the basis of in-depth research on the characteristics of conscious behaviour. It plays a vital role in today's behavioural and brain sciences (Yin and Knowlton, 2006), and the research of artificial intelligence (Sutton and Barto, 1998), widely applied in the fields of medical health (Zhang et al., 2021), diet improvement (Yu et al., 2021), fitness habit cultivation (Zhou et al., 2018), driving safety (Schmidt et al., 2021) and protection of the environment (Vlaev and Dolan, 2015; Frankenhuis et al., 2019). It reveals the fact that human behaviour has the characteristics of conscious conditional reflex, which means that human behaviour promotes the changes in the environment, which, in turn, impacts human behaviour. When one certain behaviour is consciously affirmed and strengthened, it can promote the recurrence of such behaviour, whereas the repetition of a certain behaviour can be corrected or prevented with negative reinforcement, summarized as law of effects (Thorndike, 1932). Webb and Sheeran (2006) show evidence showing that the behaviour change effects produced by standard intervention models on the basis of changing beliefs and attitudes are comparable with those by interventions which utilize the contextual impact on automatic behaviours. The above mentioned response shows that outcome learning, also known as goal-directed learning, is accompanied by habit learning process, which is stimulus-response learning (Yin and Knowlton, 2006). The real-world environment such as jobs, workplace and social cultures are repetitive, providing constant contextual influence, it does not require goal-directed control that is computationally intensive. Hence, it is likely that interventions based on innate and habitual activities caused by contextual cues are long-term (Vlaev and Dolan, 2015). As pointed out by Gardner (2014), such goal-related factors of behaviour as attitude and intention will cease their influence on behaviour when a behaviour has become a habit.

These four theories help to build a basis to understand how the use of mobile Apps affects users' behavioural changes thus long-term lifestyle changes. Ant Forest sets a very good case study for us to explore this. Ant Forest encourages users to take low-carbon behaviours and choose green lifestyle with the aim of collecting the 'energy points' reward. Such continuous incentivised eco-friendly behavioural changes may lead to long-term carbon neutralization lifestyle. Ant forest combines life related behaviours such as urban services and transportation with the game, imperceptibly integrating consumption scenarios with low-carbon actions, and successfully integrating low-carbon concepts into the daily life. It also makes full use of live pictures, virtual animation, data, and other narrative elements for visual presentation. Users can view their tree planting status in real time through satellite images. The virtualisation of the output optimizes the users' game experiences. The quantified public welfare each user makes can be seen among the user's social network through tree-ranking and energy points, which has an impact on the social influence of public welfare projects and the formation of networked social relations. Based on the theories reviewed in this section, an integrated conceptual framework (as shown in Figure 3) is developed to explore the research questions in this study.

This study constructs an integrated theoretical framework that departs from established models such as the Technology Acceptance Model (TAM) (He, 2020), Theory of Planned Behaviour (TPB) (Zhang and Zhang, 2022), Unified Theory of Acceptance and Use of Technology (UTAUT) (Shahzad et al., 2022), Task-Technology Fit Model (TTFM) (Ashfaq et al., 2022) and Motivation Theory (Yang et al., 2018). We develop the following hypothesis to explore the research questions in this study based on the above framework we propose.

Hypothesis 1. *Entertainment positively affects decision of using Ant Forest.*

Zolkepli and Kamarulzaman (2015) suggest that entertainment is a crucial factor in the adoption of social media, as well as in the reading and sharing of news on social media. Furthermore, Ashfaq et al. (2022) posit that entertainment can also influence users' adoption of technology, as users may sometimes use new technologies for entertainment rather than performance enhancement. Therefore, it is hypothesized that when a user uses Ant Forest to promote a green environment, the user's pleasant experience will be enhanced.

Hypothesis 2. *Carbon Neutralisation positively affects decision of using Ant Forest.*

Staats et al. (2004) found that social interaction can effectively promote people to take environmental protection measures and that the deteriorating ecological environment can affect people's awareness and behaviour. Ant Forest continuously disseminates information about environmental protection concepts and tree planting and carbon reduction to the public through the internet, encouraging online public welfare. Therefore we hypothesise that carbon neutralization is likely to cast the positive impact on the decision to use Ant Forest.

Hypothesis 3. *Interaction positively influences decision of using Ant Forest.*

The growth of the internet has not only facilitated greater public engagement, but also facilitated the dissemination of environmental concerns. As a representative of internet-based public welfare, Ant Forest, an activity that is closely connected to everyday life, allows the public to promptly engage in environmental protection activities. We hypothesise that the interaction is positively associated with the decision to use Ant Forest.

Hypothesis 4. *Subjected Norm positively influences decision of using Ant Forest.*

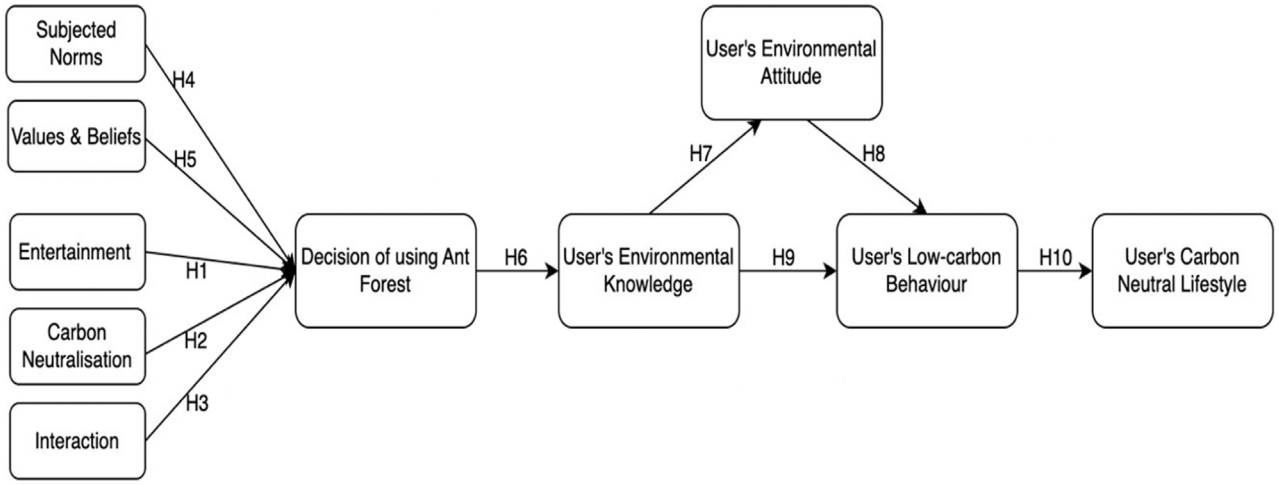

FIGURE 3
Conceptual Framework on how mobile App (Ant Forest) can affect people's lifestyle.

It has been well established in the literature that social norms and social support play a significant role in shaping individual behaviour. Subjective norms, defined as the perceived pressure from the social environment to engage in or refrain from certain behaviours, can significantly influence an individual's actions. This pressure can come from significant others, such as family and friends, who may exert a strong influence on an individual's behaviour through their expectations and beliefs. On the other hand, social support refers to the emotional, practical, and informational support provided by an individual's social network. This support can be an important factor in promoting healthy behaviours and environmentally friendly actions, as individuals may be more motivated to engage in these activities if they feel supported by their social network. Previous research has also demonstrated that people's adoption of new products can be influenced by their perceptions of social norms and the support they receive from their peers (Zhang et al., 2021). Specifically, individuals may be more likely to use a new product if they believe it is expected or approved of by their social network and if they feel supported by friends and family in doing so. Ant Forest is a program that promotes environmental conservation by allowing users to connect with friends and engage in activities such as "stealing" energy and watering trees for each other. The social characteristics of the program, including the ability to add friends and interact with others, may promote users' participation through the use of social influence. Subjective norms are likely to have a positive impact on an individual's decision to use Ant Forest and engage in environmentally friendly behaviours. Ant Forest, which incorporates social elements, is hypothesised be effective in promoting healthy and environmentally conscious behaviours through the use of social influence and subjective norms.

Hypothesis 5. *Values and Beliefs positively affects decision of using Ant Forest.*

Values and beliefs are fundamental to an individual's perception of themselves, others, and the world around them. According to Ibtissem (2010), sanctions and rewards related to personal norms are attached to the concept of self and can influence self-evaluation. Conformity to personal norms can lead to positive self-evaluations, such as self-esteem, pride, and security, while non-conformity can result in negative self-evaluations, including a loss of self-esteem, self-depreciation, and guilt. Research has also suggested that under certain conditions, an individual's values and beliefs about the environment can drive the development of environmentally friendly behaviours (Yan et al., 2020). Therefore we hypothesise that values and beliefs may have a positive impact on the decision to use Ant Forest.

Hypothesis 6. *Decision of using Ant Forest positively influences user's environmental knowledge.*

Environmental awareness includes the public's understanding of and knowledge about environmental protection (Polonsky et al., 2012). Through the creation of virtual environmental protection scenarios, Ant Forest positively guides people to cultivate good environmental awareness, including the development of low-carbon lifestyles, such as what low-carbon behaviours can earn green energy points and improve environmental knowledge. Therefore we hypothesise that the use of Ant Forest is likely to have a positive impact on a user's environmental knowledge.

Hypothesis 7. *User's environmental knowledge positively affects user's environmental attitude.*

Environmental knowledge refers to an individual's understanding of environmental protection, environmental risks, and environmental crises (Paço and Lavrador, 2017). Research has shown that consumers with higher levels of environmental knowledge are more likely to engage in positive actions on environmental issues (Flamm, 2009). Environmental knowledge is considered a necessary foundation for the development of environmental attitudes, and plays a moderating role in determining the impact of attitudes (Ashfaq et al., 2021a), which can in turn influence environmental behaviour (Oreg and Katz-Gerro, 2006). This process involves the mediating role of attitudes. Therefore we

hypothesise that an individual's environmental knowledge is likely to positively impact their environmental attitude. In other words, individuals who have a strong understanding of environmental issues may hold more positive attitudes towards the environment and be more likely to engage in behaviours that protect it.

Hypothesis 8. *User's environmental attitude positively influences user's low-carbon behaviour.*

Previous research suggest that changes in attitudes can affect an individual's behaviours (Pooley and O'Connor, 2000; Crano and Prislin, 2006; Ashfaq et al., 2021b). Therefore we hypothesise that an individual's environmental attitude is likely to positively influence their low-carbon behaviours.

Hypothesis 9. *User's environmental knowledge positively affects user's low-carbon behaviour.*

Environmental knowledge, including understanding of carbon offsetting, has been shown to be related to environmentally responsible behaviours (Polonsky et al., 2012). An increased awareness of global warming and climate change, as well as the environmental impacts of actions, can also lead to more responsible behaviours (Sheth et al., 2011). We hypothesised that Ant Forest is effectively promoting environmental consciousness with related knowledge to the users.

Hypothesis 10. *User's low-carbon behaviour positively influences user's carbon neutral lifestyle.*

Li (2018) found that users of Ant Forest develop a habit of green behaviour in addition to satisfying their desire to plant trees. Hu (2018) suggests that online public welfare activities like Ant Forest can change daily habits and promote environmentally friendly lifestyles. The App can create new routines for users, such as the use of offline payments, public transportation, and shared bicycles, which may become habitual. Gardner (2014) indicates that when a behaviour becomes habitual, it is no longer influenced by factors such as attitude and intention. Therefore, we hypothesised that low-carbon behaviours developed through the use of Ant Forest and similar programs may lead to the adoption of a carbon neutral lifestyle.

4 Data and methodology

4.1 Data collection

This study collected via a random sampling method using WeChat, Alipay, and online forums from Ant Forest users in China through Wenjuanxing, which is a commonly used questionnaire platform in the country (Ashfaq et al., 2022). The survey was conducted from 1st September to 10th November 2022 and the link to the questionnaire was sent to respondents through the aforementioned social network services. A screening question was included to ensure that only Ant Forest users responded to the survey. In total, 489 responses were collected, among which 473 were valid with an effective rate of 96.7%. All survey questions were mandatory in order to prevent missing or incomplete data in the responses.

Furthermore, In-depth semi-structured interviews with 20 participants were conducted online to collect the users' thoughts and views in their own words (Kivits, 2005). Online interviews were preferred to reduce expenses and travel time and to involve participants who may have been unwilling or unable to participate in face-to-face interviews due to time constraints (Salmons, 2009). To ensure fairness and probability of the data, participants were randomly selected and interviewed through surveys on WeChat, Alipay, and Ant Forest online forums, on a voluntary basis, with interviews lasting approximately 15 min on average and conducted at the same time as the questionnaire survey. The interview contained a small number of questions focused on the participants' personal views on their experience using Ant Forest and its impact on their daily behaviour and lifestyle. To avoid respondent bias, both the questionnaire survey and the interview emphasized that participation was voluntary and strict adherence to ethical guidelines were observed.

4.2 Data analysis

Ten items are included in this empirical study. Based on the previous studies, four items are adopted to measure Entertainment (Venkatesh et al., 2003; Hsu and Lu, 2007), User's Environmental Attitude (Bagozzi et al., 2001; Yang et al., 2018), User's Environmental Knowledge (Qu and Lee, 2011), and User's Carbon Neutral Lifestyle (Ashfaq et al., 2022). Another four items are employed to measure Carbon Neutralisation (Yang et al., 2018), Subjected Norms (Venkatesh et al., 2003; Zhang and Zhang, 2022), and Values and Beliefs (He, 2020). The last two items are used to measure Interaction (Zhang et al., 2020), Action of using Ant Forest (Qu and Lee, 2011), and User's Low-Carbon Behaviour (Ashfaq et al., 2021a). A 5-point Likert scale ranging from "1-strongly disagree" to "5-strongly agree" was used for all items. Table 1 presents the specific items' means.

Following the previous studies (Yang et al., 2018; He, 2020; Zhang et al., 2020; Ashfaq et al., 2021b), we use Structural equation modelling to analyse the survey data. The hypothesized model was estimated using SmartPLS 3.3.2 and the Bootstrap resampling procedure. The interview data is analysed and discussed based on the transcripts with qualitative method.

5 Empirical results

5.1 Survey

To determine whether common method bias is present in the data, a Harman's single factor test was conducted by SPSS 26.0 (Harman, 1976). The variance percentage of the first factor was 46.469%, which is below the 50% threshold. This suggests that common method bias is not present in the data (Podsakoff et al., 2003).

Table 2 presents the profiles of the final sample of participants. The sample is evenly distributed between genders and is generally young and well-educated, with a majority located in eastern and central China. Their monthly incomes are uneven, with a large deviation.

TABLE 1 Variables description and questions.

Variables	Items	Code	Source
Entertainment	Using Ant Forest is fun for me	ENT01	Hsu and Lu, (2007); Venkatesh et al., (2003)
	I feel joyful when using Ant Forest	ENT02	Hsu and Lu, (2007); Venkatesh et al., (2003)
	I consider Ant Forest as an entertaining program and voluntarily use it	ENT03	Hsu and Lu, (2007); Venkatesh et al., (2003)
Carbon Neutralisation	Using Ant Forest helps me gradually achieve my public welfare goals	CN01	Yang et al. (2018)
	Using Ant Forest satisfies my need to participate in environmental protection	CN02	Yang et al. (2018)
	Compared to others, Ant Forest has encouraged me to participate in more environmental public welfare activities	CN03	(Self-developed)
	Ant Forest enables me to engage in public welfare without incurring any costs	CN04	He (2020)
Interaction	I often steal my friends' green energy	INT01	Zhang et al. (2020)
	Using Ant Forest can increase my connection with friends	INT02	Zhang et al. (2020)
Subjected Norms	Those who are important to me support me using Ant Forest for public welfare and protecting the environment	SN01	Venkatesh et al. (2003)
	My relatives and friends around me support me using Ant Forest	SN02	Venkatesh et al. (2003)
	I want to introduce Ant Forest to my relatives and friends around me	SN03	(Self-developed)
	I want to introduce Ant Forest to my relatives and friends around me	SN04	Zhang and Zhang (2022)
Values and Beliefs	I feel a sense of accomplishment when I "plant" a tree	VAL01	He (2020)
	In my opinion, Ant Forest can promote low-carbon emission reduction and carbon neutrality	VAL02	(Self-developed)
	I believe that when the virtual tree matures, Ant Forest will plant a real tree	VAL03	He (2020)
	I believe that Ant Forest can change the desert	VAL04	He (2020)
Action of Using Ant Forest	Since using Ant Forest, I often take low-carbon actions to generate more green energy	AU01	Qu and Lee (2011)
	Since using Ant Forest, my daily behaviour has become more green and healthy	AU02	Qu and Lee (2011)
User's Environmental Attitude	After using Ant Forest, I think environmental protection behaviours are beneficial	EA01	Yang et al. (2018), Bagozzi et al. (2001)
	After using Ant Forest, I think implementing environmental protection behaviours is enjoyable	EA02	Yang et al. (2018), Bagozzi et al. (2001)
	I think I can find joy in protecting the environment	EA03	Yang et al. (2018), Bagozzi et al. (2001)
User's Environmental Knowledge	After using Ant Forest, I have learned more about low-carbon environmental protection knowledge	EK01	Qu and Lee (2011)
	After using Ant Forest, I have realized what a green life is and more low-carbon behaviours in my daily life	EK02	Qu and Lee (2011)
	After using Ant Forest, I have learned about desertification and how to improve it through daily life	EK03	(Self-developed)
User's Low-carbon Behaviour	After using Ant Forest, I will intentionally reduce high-carbon emitting behaviours	LBC01	(Self-developed)
	Even if I don't use Ant Forest for a long time, I will still maintain low-carbon behaviours	LBC02	Ashfaq et al., (2022)
User's Carbon Netural Lifestyle	Ant Forest has helped me have a lower carbon lifestyle than others	CNLS01	(Self-developed)
	Even if I don't use Ant Forest anymore, I can still maintain a low-carbon lifestyle	CNLS02	Ashfaq et al. (2022)
	Green environmental protection and low-carbon travel have influenced my lifestyle subconsciously	CNLS03	(Self-developed)

TABLE 2 Sample characteristics (N = 473).

Variable	Options	Frequency	Proportion (%)
Gender	Males	213	45.0
	Females	260	55.0
Age	18–25	162	34.2
	23–35	152	32.1
	Over 36	159	33.6
Education	Lower Secondary and below	6	1.3
	High School and Secondary School	62	13.1
	College	115	24.3
	Undergraduate	217	45.9
	Master and above	73	15.4
Area	Eastern China	281	59.4
	Central China	189	40.0
	Western China	3	0.6
MonthlyIncome	Under 1,000	162	34.2
	1,000–4,999	30	6.3
	5,000–0,000	81	17.1
	10,000–19999	58	12.3
	20,000 or more	142	30.0

Table 3 shows the characteristics of Ant Forest users, with 83.1% of respondents indicating that they are aware of carbon neutrality and related concepts. Among them, 74.4% of users were introduced to Ant Forest through media publicity and recommendations from friends. The majority of respondents logged into Ant Forest on a daily basis, and those who have used it for more than 6 months made up 68.9%. Of the participants, 301, or 63.6%, planted more than 3 trees. Most respondents obtained green energy points through walking (45%), offline and online payment (56.4%), and shared bikes (67%). When it comes to stealing green energy points from friends, the majority of respondents did so every week or every month.

As shown in Table 4. The values for factor loading of all items meet the empirical standard of 0.7. Reliability was assessed using Cronbach's alpha (CA) and composite reliability (CR), while construct validity was evaluated through standardized factor loading and average variance extracted (AVE), following Fornell and Larcker's recommendations. The Cronbach's alpha (Hair et al., 2019), composite reliability (CR), and the average variance extracted (AVE) (Fornell and Larcker, 1981; Hair et al., 2019) for all constructs are above the recommended threshold value of 0.7, 0.7, and 0.5, respectively. Therefore, the reliability and consistency of the construct were confirmed.

In addition, the discriminant validity of all constructs was tested. As shown in Table 5, the square roots of the AVE values were higher than all correlations between constructs, and the values of the heterotrait-monotrait ratio were lower than 0.9, which shows that the discriminant validity of all constructs is satisfactory.

To ensure the structural model is free of collinearity issues, the variance inflation factors (VIFs) of all constructs were analyzed. The results show that all VIFs are below the recommended threshold of 3.3 (Table 6), indicating that there are no signs of multicollinearity in the structural model. For testing the hypotheses, this study used Smart PLS 3.3.2 and the Bootstrap resampling procedure to estimate the hypothesized model. PLS-SEM model evaluation requires using R^2 to represent the extent to which the independent variables explain the variance in the dependent variable, using Stone-Geisser's Q^2 to represent the predictive relevance of the model, and using Goodness of Fit (GoF) to signify the relationship between the quality of the measurement model and the structural model (Shmueli et al., 2019). According to Shmueli et al.'s (2019) outline to examine the model's predictive power on out-of-sample data. All the Q^2 values exceeded 0, indicating that these values are relevant for predictions. We calculated the effect size f^2 to assess the significant impact of the omitted construct on the endogenous variables (Hair et al., 2019). Cohen (1988) provided cut-off values for effect size f^2, with 0.02 representing a small effect, 0.15 indicating a medium effect, and 0.35 representing a large effect. In our study, the effect size f^2 values for significant paths ranged from 0.000 to 0.000, which signifies a substantive impact of the omitted construct on the endogenous variables (Hair et al., 2019).

The adjusted R^2 values of decision of using ant forest, user's environmental knowledge, user's environmental attitude, user's low-carbon behaviour, and user's carbon neutral lifestyle were 0.545, 0.467, 0.450, 0.438and 0.435, respectively, all higher than 0.25, indicating that the model in the current study has good explanations. The model's predictive accuracy was evaluated using Q^2, which measures the model's predictive ability (Hair

TABLE 3 Description of Ant Forest usage (N = 473).

Variable	Options	Frequency	Proportion (%)
Channels to learn about Ant Forest	Promotion of national green development policies	121	25.6
	Social media platforms, TV broadcasts, etc.	183	38.7
	Direct recommendation from friends/family	169	35.7
Initial thoughts on approaching and using Ant Forest (multiple choice)	Social Needs	257	54.3
	Entertainment needs	297	62.8
	Games	190	40.2
	Good for the environment and charity	198	41.9
Frequency of using Ant Forest	Multiple times a day	83	17.5
	Once a day	109	23.0
	2–3 times a week	84	17.8
	Once a week	79	16.7
	2–3 times a month	73	15.4
	Less than or equal to once a month	45	9.5
Time to use Ant Forest	1 month or less	50	10.6
	1–6 months	97	20.5
	6–12 months	98	20.7
	More than 1 year	133	28.1
	2 years or more	95	20.1
Trees successfully planted to date	0 trees	6	1.3
	1 tree	33	7.0
	2 trees	133	28.1
	3 and above	301	63.6
Main reason for obtaining energy (multiple choice)	Walking	213	45.0
	Utility Bills	246	52.0
	Offline and Online Payment	267	56.4
	Shared Bikes	317	67.0
	Public Transport	162	34.2
	Online train tickets	133	28.1
	Online Ticketing (Movie Tickets)	164	34.7
	Green Packages	186	39.3
	Appointment Booking	129	27.3
	ETC Bill Payment	82	17.3
	Electronic Invoice	142	30.0
	International Tax Refund	48	10.1
	Green Office	51	10.8
Frequency of energy interactions with friends in Antforest	Every day	6	1.3
	Every week	104	22.0
	Every month	171	36.2

(Continued on following page)

TABLE 3 (*Continued*) Description of Ant Forest usage (N = 473).

Variable	Options	Frequency	Proportion (%)
	Every 6 months	83	17.5
	Every year and beyond	109	23.0
The original purpose of Ant Forest (multiple choice)	Holding charity events to give back to the community	238	50.3
	Boosting Alipay's social features to increase daily activity	313	66.2
	Establish the concept of "carbon account" early to capture the "carbon market"	190	40.2
	Build a positive brand image and promote Alipay's other businesses through Ant Forest	168	35.5
	Create a positive environment for the whole community and build a green culture	222	46.9
	Other	43	9.1
Heard of the concept of carbon neutrality	Yes	393	83.1
	No	80	16.9

et al., 2017). A Q^2 value greater than 0 indicates that the model has predictive relevance. Our model's Q^2 values for all endogenous items exceeded 0, with values of 0.433, 0.291, 0.333, 0.322, and 0.343, respectively, indicating that the model has good predictive relevance and is robust. In addition, a measure of the approximate fit of the research model—the standardized root means square residual (SRMR)—was 0.058, below the threshold of 0.08 to suggest a good model fit.

The hypotheses were tested using a bootstrapping method based on 5,000 subsamples (Hair et al., 2019). The results of the path coefficient analyses showed that all of the hypotheses were supported and statistically significant (as shown in Figure 4).

Table 6 shows the path coefficients and the results of hypothesis testing, indicating the significant impact of Entertainment (β = 0.209, $p < 0.001$) and Values and Beliefs (β = 0.205, $p < 0.0001$) on the Action of using Ant Forest, supporting H3 and H4. Further, the results revealed Interaction (β = 0.180, $p < 0.001$), Carbon-neutralisation (β = 0.159, $p < 0.01$), and Subjected norms (β = 0.124, $p < 0.05$) have positive effects on Decision of using ant forest. The results showed that hypotheses H1, H2, and H5 were supported. Decision of using ant forest (β = 0.684, $p < 0.001$) has a positive effect on User's environmental knowledge, supporting H6. User's environmental knowledge has positive effects on User's environmental attitude (β = 0.671, $p < 0.001$) and user's low-carbon behaviour (β = 0.447, $p < 0.001$), supporting H7 and H9. User's environmental attitude (β = 0.273, $p < 0.001$) has a positive effect on User's low-carbon behaviour, supporting H8. User's low-carbon behaviour (β = 0.660, $p < 0.001$) has a positive effect on User's carbon neutral lifestyle, supporting H10.

The largest regression weight was associated with value-belief factors, which is in line with the TRA's assertion that an individual's attitudes towards an object or behaviour are determined by their values or beliefs. This supports the findings of Yan et al. (2020), who posited that in the context of an increasingly severe climate crisis, personal environmental values and beliefs drive individuals to use Ant Forest as a means of contributing to environmental protection. Entertainment was the second most influential factor, with 62.8% of respondents using Ant Forest for recreational purposes and 40.2% of respondents first encountering the app as a game. It should be noted that game-based incentives, such as those used in Ant Forest, have been shown to be effective in promoting environmentally friendly behaviour (Ashfaq et al., 2022). The study also found that Ant Forest's innovative game design, which combines virtual and real-world elements, such as stealing energy and earning certificates for planting trees, attracted many users. Additionally, the platform's popularity, built on the Alipay platform and the appeal of human-computer interaction, not only attracted users with the fun of virtual tree planting, but also increased public interest in index afforestation and environmental protection (He, 2020). Interaction was the third most influential factor, with 36.2% of respondents engaging in monthly energy interactions with friends, and 22% engaging in weekly interactions. This satisfied people's daily social needs and made up for the shortcomings of current public welfare mini-programs in China. Subjected Norms had no significant effect, which is consistent with the findings of Zhang and Zhang (2022). The reason may be that for "Internet + tree planting" behaviour, the public's feeling is that of individual enjoyment, and not a shared enjoyment. The study also found that social media and government promotion of Ant Forest was inadequate, with only 25.6% of respondents learning about Ant Forest from government green development promotion, which easily leads to the public's misunderstanding and non-participation in the project. The above two aspects of the lack of participation are why subjected norm did not play its role.

5.2 Interview

During the interview, each participant was asked a list of questions (as shown in Table 7).

The discussion highlights the participants' thoughts and perceptions on how the mobile App "Ant Forest" influences

TABLE 4 Reliability and validity.

Measures	Mean	Standard deviation	Loading	Cronbach's alpha	CR	AVE
ENT01	3.167	1.239	0.796	0.741	0.851	0.656
ENT02	2.93	1.229	0.849			
ENT03	2.632	1.318	0.784			
CN01	2.789	1.129	0.723	0.788	0.862	0.611
CN02	2.867	1.27	0.802			
CN03	2.92	1.148	0.794			
CN04	3.055	1.266	0.804			
INT01	3.171	1.236	0.894	0.739	0.885	0.793
INT02	3.027	1.239	0.887			
SN01	3.019	1.374	0.814	0.804	0.872	0.631
SN02	3.036	1.304	0.843			
SN03	3.057	1.332	0.794			
SN04	3.133	1.299	0.72			
VAL01	3.017	1.353	0.785	0.822	0.882	0.651
VAL02	3.085	1.299	0.81			
VAL03	3.059	1.251	0.814			
VAL04	3.093	1.321	0.818			
DU01	3.03	1.256	0.894	0.762	0.894	0.808
DU02	3.22	1.297	0.904			
EK01	3.14	1.325	0.855	0.803	0.884	0.718
EK02	3.237	1.237	0.849			
EK03	3.197	1.219	0.837			
EA01	3.116	1.205	0.831	0.742	0.852	0.658
EA02	3.072	1.259	0.775			
EA03	3.104	1.261	0.826			
LCB01	3.078	1.263	0.899	0.752	0.89	0.801
LCB02	2.994	1.27	0.892			
CNLS01	3.389	1.325	0.878	0.835	0.901	0.751
CNLS02	3.349	1.292	0.853			
CNLS03	3.315	1.278	0.87			

users' low-carbon lifestyles and the specific actions associated with it. The analysis of the transcripts from the interviews revealed that the sample of participants was primarily from Eastern China, with 12 individuals hailing from major metropolitan areas such as Beijing, Shanghai, Zhejiang, and Guangdong province. Additionally, 6 participants were from Central China, hailing from the provinces of Henan, Hunan, and Hubei. A further 2 participants were from Western China, specifically from the municipalities of Chongqing and Gansu. The majority of participants were female, constituting 60% of the sample, and their occupations were not directly related to low-carbon and environmental protection. The age range of the participants varied, with ages ranging from 21 to over 47. An examination of the data showed that 13 participants (65%) have been utilizing the "Ant Forest" app for over 2 years, while the remaining individuals have been users for 2 years or less. All participants had successfully planted at least one tree, and 8 of them had gone further by planting more than 4 trees. This suggests that the sample population is composed of experienced users of "Ant Forest" and have developed a deep understanding of the app's overall functionality.

Except three people, all other respondents greatly emphasized the promotion effect of the Ant Forest on low-carbon life. The following are the views from the respondents:

TABLE 5 Discriminant validity.

Fornell-larcker criterion										
Construct	1	2	3	4	5	6	7	8	9	10
1Decision of using ant forest	0.899									
2Carbon-neutralisation	0.622	0.781								
3Entertainment	0.622	0.666	0.81							
4Interaction	0.622	0.662	0.597	0.89						
5Subjected norms	0.61	0.628	0.595	0.674	0.794					
6User's environmental attitude	0.549	0.511	0.589	0.576	0.609	0.811				
7User's environmental knowledge	0.684	0.652	0.682	0.659	0.694	0.671	0.847			
8Values and Beliefs	0.632	0.625	0.617	0.633	0.69	0.548	0.723	0.807		
9user's carbon neutral lifestyle	0.697	0.622	0.599	0.674	0.701	0.617	0.719	0.693	0.867	
10user's low-carbon behaviour	0.669	0.582	0.604	0.59	0.585	0.573	0.63	0.624	0.66	0.895
Heterotrait-Monotrait Ratio										
1.Decision of using ant forest	0.899									
2.Carbon-neutralisation	0.622	0.781								
3.Entertainment	0.622	0.666	0.81							
4.Interaction	0.622	0.662	0.597	0.89						
5.Subjected norms	0.61	0.628	0.595	0.674	0.794					
6. User's environmental attitude	0.549	0.511	0.589	0.576	0.609	0.811				
7.User's environmental knowledge	0.684	0.652	0.682	0.659	0.694	0.671	0.847			
8.Values and Beliefs	0.632	0.625	0.617	0.633	0.69	0.548	0.723	0.807		
9.User's carbon neutral lifestyle	0.697	0.622	0.599	0.674	0.701	0.617	0.719	0.693	0.867	
10.User's low-carbon behaviour	0.669	0.582	0.604	0.59	0.585	0.573	0.63	0.624	0.66	0.895

TABLE 6 Path coefficients and hypothesis testing.

Path	Coefficient	T value	*p*-value	VIF	Results
Carbon-neutralisation -> Decision of using ant forest	0.159	3.148	0.002	2.401	Supported
Entertainment -> Decision of using ant forest	0.209	4.632	0.000	2.132	Supported
Interaction -> Decision of using ant forest	0.180	3.504	0.000	2.344	Supported
Values and Beliefs -> Decision of using ant forest	0.205	3.850	0.000	2.354	supported
Subjected norms -> Decision of using ant forest	0.124	2.436	0.015	2.456	Supported
Decision of using ant forest -> User's environmental knowledge	0.684	28.220	0.000	1.000	Supported
User's environmental knowledge -> User's environmental attitude	0.671	28.257	0.000	1.000	Supported
User's environmental knowledge -> user's low-carbon behaviour	0.447	9.181	0.000	1.820	Supported
User's environmental attitude -> user's low-carbon behaviour	0.273	5.244	0.000	1.820	Supported
user's low-carbon behaviour -> user's carbon neutral lifestyle	0.660	27.732	0.000	1.000	Supported

With regards to Q5, the majority of the 20 respondents (18 individuals) stated that they engage in proactively taking low-carbon actions in order to generate additional energy points within the app. The five activities that were mentioned most frequently were Offline and Online Payment, Walking, Public Transport, Shared Bikes, and Online Movie Tickets. These were identified as

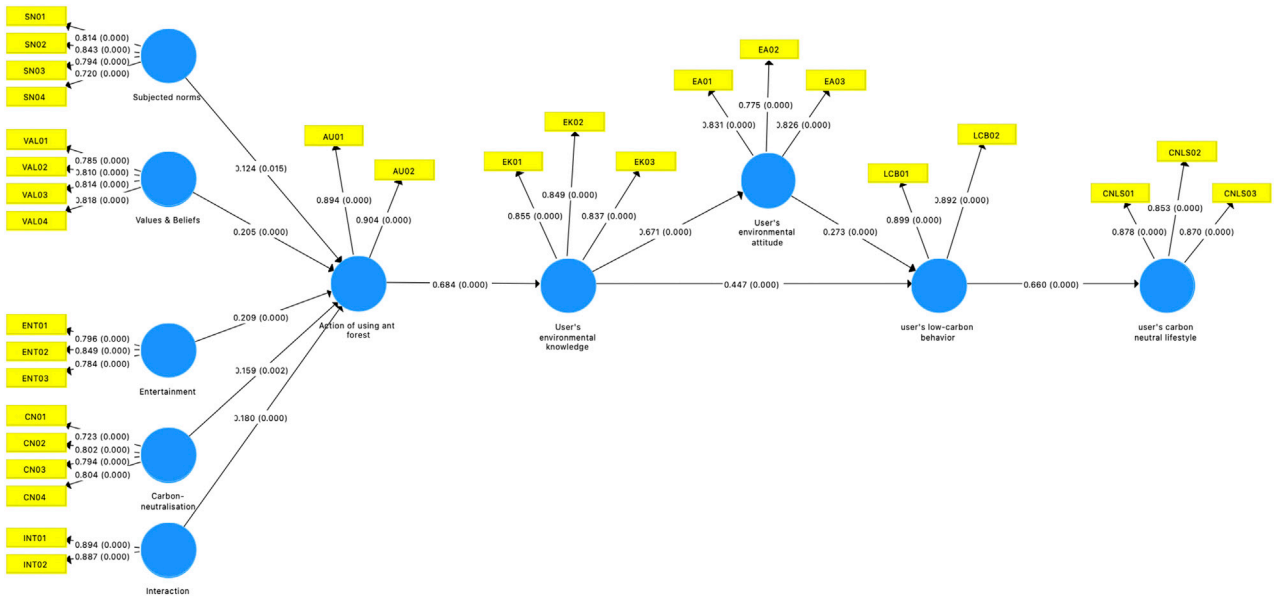

FIGURE 4
Results of structural equation path test.

the primary methods that participants employed to acquire additional green energy points. Additionally, 2 respondents acknowledged that they intentionally access friends' accounts in order to gain additional energy points. Furthermore, a majority of participants reported that they make a conscious effort to conduct daily transactions and purchase movie tickets online, and utilize Ali Pay over WeChat Pay for both online and offline payments in an effort to acquire more energy points within the app.

In response to Q6, a majority of the surveyed population demonstrated a fundamental comprehension of the concepts of green behaviour and low-carbon living. The majority of the respondents indicated that green behaviour encompasses the utilization of minimal non-recyclable materials, as well as a greater reliance on public transportation and the implementation of not wasting food. One doctoral candidate from Shandong province offered the following insight into their understanding of green behaviour and low-carbon living: "*. . . any action taken within one's capacity to make the planet more sustainable, no matter how small, can be considered a green behaviour. This includes . . . the use of public transportation, carrying reusable bags when shopping... When such actions become ingrained as a daily habit, it can be said to constitute a low-carbon lifestyle.*"

In response to Q7, a consensus emerged among the surveyed population that there had been changes in their behaviours. The majority of respondents identified modifications in their transportation habits and adoption of recycling practices when sending mail as the primary areas of change. One international student from Shanghai offered the following insight: "*. . . I had previously relied on public transportation solely as a cost-saving measure. However, with Ant Forest, I have developed a deeper understanding of the concept of sustainable travel, and will now actively choose to utilize public transportation, even in situations where taking a taxi is relatively inexpensive.*"

TABLE 7 Semi-structured interview question list.

Q1	The demographic information such as gender, age and place of residence
Q2	Is your occupation related to low-carbon and environmental protection?
Q3	How long have you been using the "Ant Forest" app?
Q4	How many virtual trees have you planted since using "Ant Forest"?
Q5	After using "Ant Forest", have you taken any low-carbon actions in order to create more energy points? If so, what actions have you taken? Please give examples of how your behaviour has changed.
Q6	Can you briefly talk about your understanding of green behaviour and low-carbon lifestyle?
Q7	Has your understanding of green and low-carbon lifestyles deepened and changed since using "Ant Forest"? If so, please give examples.
Q8	After using "Ant Forest", have you promoted low-carbon lifestyles to your family and friends? If so, please give examples.
Q9	If you no longer had access to "Ant Forest", would you continue to maintain your current low-carbon lifestyle?

In regards to Q8, the majority of the surveyed population reported that their family and friends had adopted the usage of Ant Forest, with a minority indicating that they would recommend it to their peers. One participant from Henan province noted that without actively promoting the use of Ant Forest, they had inadvertently influenced their household members to adopt sustainable habits such as selecting meals to be delivered without disposable tableware, as well as sorting household waste. Additionally, one participant from Chongqing pointed out that through the use of Ant Forest, they were made aware of the benefits of donating clothes and the positive impact it has on the environment. They described how they had taken this information and actively arranged with friends to donate old clothes to children living in impoverished mountainous areas, which not only promotes recycling, but also serves as an act of charity.

In response to Q9, the surveyed population expressed a uniformly positive sentiment towards the influence of Ant Forest on their behaviours. One participant from Guangdong province stated that the existence of Ant Forest facilitated the integration of low-carbon behaviours into daily habits. They noted that even when incentives such as green energy points were removed, their behaviours would remain unchanged. Another participant from Henan province highlighted that Ant Forest served as a source of knowledge and education on environmental protection, allowing them to have a greater understanding of the importance of low-carbon behaviours in addressing the environmental and climate crisis, and the ultimate benefit it brings to the society as a whole. The respondent also stated that even without the use of Ant Forest, they would still strive to make a positive impact to the environment.

6 Discussion

In line with the diffusion of innovation theory (DIT) and theory of reasoned action (TRA), our findings indicate that normative and value-belief factors, entertainment, carbon neutralization, and interaction all have a positive impact on user decisions to use Ant Forest. The largest regression weight was associated with value-belief factors, which is in line with the TRA's assertion that an individual's attitudes towards an object or behaviour are determined by their values or beliefs. This supports the findings of Yan et al. (2020), who posited that in the context of an increasingly severe climate crisis, personal environmental values and beliefs drive individuals to use Ant Forest as a means of contributing to environmental protection. Entertainment was the second most influential factor, with 62.8% of respondents using Ant Forest for recreational purposes and 40.2% of respondents first encountering the app as a game. It should be noted that game-based incentives, such as those used in Ant Forest, have been shown to be effective in promoting environmentally friendly behaviour (Ashfaq et al., 2022). The study also found that Ant Forest's innovative game design, which combines virtual and real-world elements, such as stealing energy and earning certificates for planting trees, attracted many users. Additionally, the platform's popularity, built on the Alipay platform and the appeal of human-computer interaction, not only attracted users with the fun of virtual tree planting, but also increased public interest in index afforestation and environmental protection (He, 2020). Interaction was the third most influential factor, with 36.2% of respondents engaging in monthly energy interactions with friends, and 22% engaging in weekly interactions. This satisfied people's daily social needs and made up for the shortcomings of current public welfare mini-programs in China. Subjected Norms had no significant effect, which is consistent with the findings of Zhang and Zhang (2022). The reason may be that for "Internet + tree planting" behaviour, the public's feeling is that of individual enjoyment, and not a shared enjoyment. The study also found that social media and government promotion of Ant Forest was inadequate, with only 25.6% of respondents learning about Ant Forest from government green development promotion, which easily leads to the public's misunderstanding and non-participation in the project. The above two aspects of the lack of participation are why subjected norm did not play its role.

We examined the factors that influence user engagement in low-carbon behaviour through the use of Ant Forest. Results indicate that both knowledge and attitude have a positive impact on user engagement in low-carbon behaviour, with the influence of attitude on behaviour being greater than the influence of knowledge, which is supported by the knowledge-attitude-behaviour (KAB) theory. In particular, attitude serves as a bridge for users to participate in low-carbon behaviour, while knowledge serves as the driving force for users to engage in low-carbon behaviour. Ant Forest not only creates a virtual green environment, but also systematically disseminates environmental knowledge and presents specific low-carbon behaviours for users to choose from. As Yan et al. (2020) emphasized, the environment can indirectly affect people's cognition, behaviour, and habits. By conveying the severity of climate crisis and environmental degradation through text and animation videos, Ant Forest enhances users' environmental awareness and motivates them to take action to protect the environment. According to the survey results, almost all participants reported that using Ant Forest strengthened and changed their understanding of low-carbon lifestyles. One participant noted that before using Ant Forest, they were not aware that simple actions like switching to electronic receipts were also considered low-carbon behaviours and could contribute to the preservation of nature. As a result, they have not used paper receipts since. Additionally, the data shows that after using Ant Forest, users actively engage in low-carbon behaviours (e.g., declining disposable utensils when ordering takeout, using green transportation, sending green parcels) in order to acquire green energy points and accelerate tree planting. The KAB theory explains how Ant Forest bridges the virtual and the real, enabling users to make the transition from virtual experience to real-world action, which is suggested by the interview participants.

By testing the hypothesis based on Reinforcement Learning (RL) Theory, the empirical findings suggest that users' low-carbon behaviour had a significant impact on their carbon neutralization lifestyle, consistent with previous literature (Skinner, 1969; Gardner, 2014). In the case of Ant Forest, users engage in low-carbon behaviour in order to gain green energy points, which they can then use to plant virtual trees and unlock environmental certificates. The number of trees and certificates planted by an individual are also

automatically ranked and displayed on their friends' leaderboards, providing a sense of accomplishment that encourages continued engagement in low-carbon behaviour. Furthermore, our interview data revealed that 20 out of 20 participants reported that they would continue to maintain their low-carbon habits even if they were no longer using Ant Forest.

7 Conclusion and implications

This study integrates the four theoretical frameworks, namely,: the Theory of Reasoned Action (TRA), Diffusion of Innovation Theory (DIT), Knowledge-Attitude-Behaviour Theory (KAB), and Reinforcement Learning (RL) theory, to propose an integrated model to illustrate the mechanism of how the innovative mobile App is changing individual's behaviour and long-term lifestyle. We use Ant Forest as a case study and empirically tested 10 hypotheses by the survey and interview data. It is important to highlight that 1) both the features of mobile App (i.e., entertainment and social interaction): and the social environment (i.e., norms, value, beliefs, and awareness of carbon neutrality) are important for the decision-making of the use of Ant Forest, and 2) the formation of green lifestyle takes time and needs constant behavioural changes. The findings shed some light to the stakeholders, including technology companies, application developers, local authorities, on taking advantages of technology innovation products for the aim of carbon neutrality. Both the technology companies and the local authorities shall pay close attentions to utilise mobile Apps in low-carbon community building, and the mobile App developers shall make great efforts in transferring knowledge, virtualising outcome, quantifying impact through the application design to increase the users' loyalty.

This study has several limitations. The survey sample is not adequately diversified to represent the whole population, with most participants being young and well educated individuals living in urban areas in China, reflecting that the users of Ant Forest or other innovative mobile Apps are usually characterised as the similar group of individuals who are more open-minded to and quick-learners of the new concepts. This is not conducive to generalising the framework as well as the empirical findings. It will be interesting to see the framework being empirically studied with a sample that represents the whole population around the globe.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2023.1160986/full#supplementary-material

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