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Editorial

Editorial for *Sustainable Social Development* (Volume 2, Issue 1)

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It is generally accepted that sustainable development encompasses three aspects: the environmental, social, and economic [1]. It is not merely the same as ecologicalization or environmental protection [1]. The environmental and social issues regarding sustainable development are the main focus of this issue, which also offers readers an engaging analysis of the factors influencing those problems. The content in this issue could inspire readers to pay close attention to various social phenomena and how they relate to sustainable development.

Sustainable development places a strong emphasis on environmental protection. Since there are a growing number of environmental problems to deal with these days, achieving sustainable environmental development has come to be an important concern for people. The current social problems must be resolved as they have a significant impact on environmental sustainable development. According to Sergio et al. [2], the fact that 13 million Brazilian residences used firewood for cooking in 2022 presents serious questions about the various effects this will have on important development indices. Their analysis suggests that unequal distribution of energy could be a barrier to sustainable environmental development. Furthermore, paperless behavior is progressively gaining popularity due to the quick advancement of scientific technology, which is beneficial to the environment. Pre-service teachers need to adopt paperless behavior in accordance with institutional rules, technology advancements, and ecological concerns, according to Tusyanah et al. [3]. They examined how the digital competencies of aspiring teachers affected their paperless behavior and recommended raising students' digital competency to align students' paperless conduct with environmental concerns.

How to better meet people's various needs and achieve sustainable development in social aspects is another highlight of this issue. According to Yan and Lv [4], accurate urban travel demand prediction is crucial for promoting sustainable travel practices, maximizing business development opportunities, and optimizing transportation systems in light of the growing challenges presented by traffic congestion, environmental pollution, and a variety of travel needs. Their work adds to our knowledge of the changing field of intelligent transportation systems and anticipating urban travel demand, and it also offers insightful information for future studies and useful applications in adjacent domains [4]. By examining the micro-case study, Wang et al. [5] explored the integrated development path of the rural tourism industry, provided recommendations for the integration development path at two levels, and came to the conclusion that the four key components of the integrated development of the rural tourism industry are talents, capital, operations, resources, and operation.

All things considered, sustainable development affects everyone, and it is imperative that we focus more on a wide range of social problems and phenomena. This may be the future direction of sustainable development research.

Finally, we deeply appreciate the authors' permission to authorize us to share their insightful thoughts.

Conflict of interest: The author declares no conflict of interest.

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Article

Right to the city ownership transfer in the integral reurbanization process of Villa 20 City of Buenos Aires

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Abstract: This article describes and analyzes the approach to the ownership regularization process implemented in Villa 20. Located in the City of Buenos Aires, Villa 20 is a low-income neighborhood that has been developed by its residents over the last 70 years through a progressive and continuous habitat self-development process. Based on the knowledge provided by the technical managers responsible for the implementation and by the social organizations involved, the aim of this study is to present the complexity of the ownership regularization process. Moreover, it seeks to show the fundamental role that the participatory process played in developing new instruments and reaching agreements meant to gradually advance towards the issuance of title deeds. Special emphasis is placed on the lack of normative interventions designed to adapt the built construction to the current planning regulations and on the prominence given to the title deed as the only validated instrument for proving tenure security. The ownership regularization approach conducted in Villa 20 focuses on addressing issues not covered by regulations through gradual urban and ownership regulatory actions. By means of a series of technical, social, and institutional adaptations legitimated by the participatory process, the aim of these actions is to issue a variety of documents that certify possession in order to strengthen housing security, even though they do not grant full title deed status.

Keywords: informal settlements; upgrading program; participatory platform; land tenure; urban development

1. Introduction

This article describes and analyzes the approach to the ownership regularization process implemented in the reurbanization process of Villa 20, a slum located in the City of Buenos Aires. Based on the knowledge provided by the technical managers responsible for the implementation and by the social organizations leading the participatory process, the aim of this study is to show how complex it is to determine the appropriate course of action when approaching the regularization of Villa 20 and the challenges that it poses.

Ownership regularization is a process through which the residents of informal low-income neighborhoods are granted certificates of possession or title deeds. In the case of Villa 20, this process is performed through a participatory approach in which social organizations, public servants, scholars, and neighborhood residents have been actively involved in the decision-making process.

Villa 20 originated 70 years ago under informal conditions and has been developed by its own residents through a progressive and continuous habitat self-building process. Over time, it has been the focus of various limited interventions until 2016, when the integral reurbanization process (still in force) began. A strong

participatory platform supports the reurbanization process and currently aids the collaborative action of the ownership regularization process. The strength of the participatory process in Villa 20 constitutes the platform for reaching a consensus on how to address each problematic situation and for defining strategies to move forward in each case. Due to the lack of normative interventions designed to adapt the built environment to the current planning regulations, the participatory process serves as a platform for fostering debate, creating new instruments, and reaching agreements. These, in turn, facilitate a gradual transition towards housing regularization and the acquisition of a title deed.

In recent years, the debate on land tenure has focused on having access to private property as the sole goal of secure tenure, overlooking the study of gradual instruments of urban regulation and social inclusion that guarantee rights and security. In Argentina, integral habitat-upgrading programs implemented in recent decades aim to achieve tenure legal recognition through the issuance of title deeds, which is seen as the culmination of the social integration process. However, this is not always possible due to various reasons, such as deficient regulatory frameworks, urban standards that disregard the social reality of those most affected by urban informality, insufficient budget for the adaptation of existing housing to make it suitable for the issuance of title deeds, and fragmented administrative structures.

In Villa 20, as in the rest of the slums in the City of Buenos Aires, residents address their need for housing via mechanisms not contemplated within the formal market. Their trajectories rarely comply with current planning regulations, and subsequent adaptations take decades to materialize. In the meantime, what is legally incomplete becomes legitimized by both residents and the state.

The approach to ownership regularization in Villa 20 involves finding a solution for everything that was not built in accordance with planning regulations. This is achieved through the implementation of specific methods, operations, and actions that, while ensuring access to housing and urban rights, seek to adapt criteria and approaches in a participatory manner in order to conciliate current planning regulations with the built environment.

Villa 20 is a test case of the social and territorial complexity that the regularization process has to face in informal low-income neighborhoods within the cities, where numerous technical, social, and institutional adaptations converge. Legitimized by the participatory process, these adaptations result in the issuance of certificates of possession and the execution of title deeds, both of which substantially increase the residents' housing security.

2. Theoretical background

2.1. Urban informality

Urban development is controlled by a set of regulations that establish the characteristics of plots, housing, urban amenities, urban infrastructure, and zoning [1]. These regulations ensure that all city dwellers are granted the minimum life conditions. They also determine aspects related to ownership, such as real estate ownership and

registration, which include the owners' right to hold a public deed that certifies them as the rightful owners of the property in the view of society.

Anything developed outside of these regulatory frameworks is considered illegal, irregular, or informal. The existence of urban informality is a fact that bears legal significance; that is to say, it entails the classification of a specific urban area or a particular property in terms of non-compliance with legal regulations that control ownership relations or the development of urban areas applicable in each case [2]. Some authors argue that informality arises from the operations of a regulatory formal market, in which land supply, prices, and financing conditions make it impossible for a significant part of the urban population to have access to housing. This leaves them with no other option but to seek housing within the informal market [3].

Urban informality is a global phenomenon and can be seen in many metropolitan areas around the world, mainly in the Global South. Far from disappearing, this phenomenon is closely related to the expansion of urban development processes. In 2014, the percentage of the world's urban population living in informal conditions was 23%. Currently, it is estimated that one in every eight people worldwide has no access to drinking water, sewer systems, or electricity, among other deficiencies [4]. By 2030, the number is projected to reach 2 billion people, and by 2050, it is expected that 3 billion people will be living in deficient informal conditions [5].

In Latin America, at least 23% of the urban population lives in informal areas [6–8]. In Argentina, according to data from the 2010 Census conducted by the National Institute of Statistics and Censuses (INDEC), 14.2% of the country's population is in a situation of irregular land tenure and the survey of informal settlements conducted by the NGO Techo indicates that in the majority of the country's informal settlements, 84% of the cases do not possess a sales agreement [9]. Additionally, the National Registry of Low-income Neighborhoods (ReNaBaP) surveyed 5687 low-income neighborhoods and a total of 5,280,000 residents [10]. As much as 55% of the low-income neighborhoods registered had been established before the year 2000, and 26% were created between 2001 and 2010, a period marked by economic collapse in the country [11]. In the Autonomous City of Buenos Aires (CABA), the population living in informal areas known as "villas", grew by 50% between 2001 and 2010. According to the INDEC, the number currently amounts to approximately 200,000 people [12], whereas the city has a total of 3,120,612 inhabitants.

Numerous cities have areas that do not comply with planning regulations and are not part of the formal housing market. These areas lack adequate infrastructure and are exposed to greater climate-related risks. They often present deficiencies in the electrical service, lack of natural ventilation in houses, and are vulnerable to both heat waves and floods. Additionally, the residents in these areas are susceptible to diseases as a result of the overcrowded living conditions, the limited access to safe water, and the impacts of climate change.

The figure below (**Figure 1**) illustrates two scenarios for the case of Villa 20. The first one is **Figure 1(a)** the initial urban situation, a neighborhood self-built by its own residents over a period of more than 70 years, and the second one in **Figure 1(b)** the goal of the reurbanization process, a result of the participatory design agreed upon by all the parties involved, which guarantees that everyone will have access to urban

benefits. The adaptations necessary for Villa 20 to transition from urban informality **Figure 1(a)** to urban formality **Figure 1(b)** require adjustments in norms and regulations in order to progress.

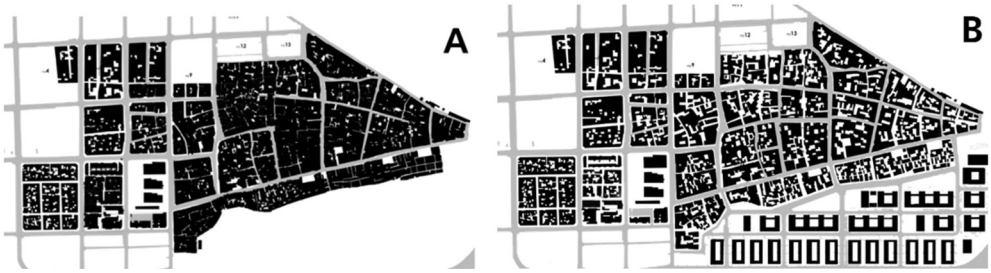

Figure 1. (a) Initial self-built situation; **(b)** Goal reurbanization plan.
Source: PIRU Villa 20 coordination team.

The residents of informal areas or slums lack full rights over the land where they have built their houses, as well as the financial resources necessary to access the administrative and judicial system. The extended absence of legal tenure recognition can hinder the provision of formal public services, access to urban infrastructure, and the general legal status of the urban residence [13]. Moreover, even though informal settlers do not have rights to the land, they do have the right to be fairly compensated for the buildings they have raised and the facilities they have installed, in case they were to be relocated.

2.2. The importance of title deeds and secure tenure

Conforming existing self-built developments to the current regulatory framework in order to achieve full ownership regularization entails a great level of difficulty. Many studies have concluded that title deeds are not really significant, and what actually matters is how residents perceive secure land tenure. It has been demonstrated that the perception of security through administrative processes encourages families to take ownership of their homes and improve them. Nonetheless, title deeds are important for residents since they protect them against evictions and occupations, reduce vulnerability to shifts in political power, and facilitate the resolution of neighbor, domestic, or inheritance disputes. Additionally, they provide access to credit, serve as a rental guarantee, and offer better job opportunities. Possessing a title deed is also advantageous for the city as a whole, as it helps stabilize land markets, leading to more rational and coordinated ways of public intervention. This includes, for instance, delineating the boundaries between private and public property, regularizing infrastructure operations and maintenance, and implementing parcel-based taxation.

In 1996, during the Second United Nations Conference on Human Settlements, known as Habitat II held in Istanbul, secure tenure was established as one of the two fundamental goals that governments worldwide should actively pursue. Security of tenure was described as an agreement between individuals or groups that grants them the right of access and use to land or residential property. This agreement must be governed and regulated by a legal and administrative framework and a person or household can be said to have secure tenure when they are protected against eviction

from their land or residence. It is usually believed that security of tenure entails the absolute individual ownership of a private property, however, it is just one of the many forms that security can adopt [14].

Title deeds or property titles are the result of a legal framework, whereas the administrative instruments that currently acknowledge land tenure are the result of social struggles and agreements with the governing administration. This incremental process requires organization and active participation and constitutes the steps of the ownership regularization process. Although the ideal goal is the registration of title deeds for each property, during this often lengthy period of time, each step of the ownership regularization process guarantees the security of the residents. The goal is not just the issuance of a title deed or tenure security, but a combined process of actions that, as they progress, seeks to reduce the risk of eviction or occupation.

Furthermore, it is important to underline that, while the legal recognition of individual title deeds can promote legal security for individuals, it does not guarantee social and urban integration. This can only happen when the process of issuing title deeds is integrated into a series of public policies that tackle the upgrading of urban, housing, sanitary, social, and economic conditions.

2.3. The ownership regularization processes in Latin America

In Latin America, different policies have been implemented to regularize urban informality, following two main paradigms:

1) Legalization of tenure through the issuance of title deeds, by means of a program or law with specific temporary scope. This paradigm posits that legalization acts as a catalyst for development, as it promotes access to financing, economic activity, and housing upgrading.
2) Integral regularization programs that combine the issuance of a title deed with the upgrading of public utilities, job creation, and the implementation of community support structures in specific locations.

Both paradigms have to face complex socioeconomic, urban, and environmental realities, and they deal with multiple legal aspects concerning land and property registration, in addition to financial and urban considerations. During the implementation process of both paradigms, various institutional and social actors interact as they collaborate in the same area or work. Due to the number of different situations in existence, there is no definite answer or universal solution. Evidence shows that successful regularization initiatives must be tailor-made for each informal sector, in particular, and for each country, in a broader sense.

The different approaches that aim to bring a solution to the low-income neighborhood situation in Latin America have been implemented for decades, and they have received various names, such as slums reurbanization or upgrading, regularization or titling, among others. We could name, for example, the programs implemented in Argentina, Colombia, and Peru, over the last twenty years.

These three countries have followed the major paradigm shifts in housing policies observed in Latin America—namely, the eradication, establishment, and integration of slums. However, they have adopted distinct approaches, addressing their own national contexts, which reflect the range of policies implemented in the region. Peru

was one of the first countries to grant title deeds on a large scale, while constantly overlooking housing upgrading policies for low-income neighborhoods. Colombia, on the other hand, focused on urban planning and urban renewal, implementing the issuance of title deeds as the culmination of major urban transformation processes. Notably, it was not until the year 2000 that a specific policy to grant title deeds took place. As for Argentina, the country takes a hybrid approach by combining upgrading strategies with the issuance of title deeds for both land plots and residencies. Only recently, Argentina introduced a new intermediate housing certification instrument for the purpose of overcoming the difficulties and delays the issuance of title deeds entails. In all cases, the completion of ownership regularization processes entails numerous challenges, leading to decades of insecure tenure for the most vulnerable parts of the population.

In the case of Peru, the large-scale state programs of title deed issuance—which had been extensively discussed since the 1990s—promoted the regulation of the administrative procedures for legalizing ownership. Nonetheless, these initiatives were not combined with an upgrade of the inhabitant's living conditions. Based on a study conducted in the low-income neighborhoods of Lima, Peru, Ramírez-Corzo & Riofrío show that a decade after the acquisition of title deeds, these documents have only served to validate ownership, failing to bring a solution to the housing problem. In the neighborhoods where title deeds were granted [15], the precarious housing situation and the lack of infrastructure persist, and, according to Calderón, the large-scale issuance of title deeds was carried out without taking into account urban, environmental, and social considerations [16,17].

As regards Colombia, Law 388 of 1997, the Territorial Development Law (Ley de Desarrollo Territorial, or LDT), introduced a "cascade system", starting with the Land Use Plan (Plan de Ordenamiento Territorial, or POT), as the main planning tool for territorial development. It established and defined the planning and urban actions to be implemented by cities in urban and urban expansion areas of the territory by means of partial and zonal plans. The LDT also introduced other planning, land management, and financial tools to execute the plan and improve the living conditions in low-income neighborhoods. As major cities increased their municipal autonomy, they also improved their fiscal strength—through property tax contributions—and their technical capacities for urban planning. This led to the creation of local plans, the strengthening of public utilities, more flexible planning regulations—for instance, allowing smaller land plot sizes—and a more efficient process of neighborhood regularization or legal recognition, a necessary step for subsequent interventions [18]. It was only in the 2010s, together with the development of neighborhood upgrading programs, that a program for the issuance of title deeds was implemented to address the issue of publicly-owned land plots occupied by social housing, accounting for approximately 21% of the cities' urban land.

In the 1990s, Argentina saw the implementation of a set hybrid of programs that combined the construction of traditional housing with new alternative policies. This period also witnessed the privatization of state-owned enterprises and services and the application of focused policies. Thus, there was a change of scenery in the way public policies addressed low-income neighborhoods, and local governments tackled the

problem via the implementation of various programs. These included the provision of urban infrastructure, serviced plots, self-built core housing and microfinancing, which were primarily carried out by NGOs throughout the country, with funding supplied by international cooperation. Progress was made in matters of ownership regularization and the issuance of title deeds for low-income neighborhoods located on state-owned lands. This was facilitated by the national program Arraigo and National Law 24374, which established the rules for the ownership regularization process in favor of the occupants and the expropriation laws administered by provincial governments.

The Arraigo Programe sought to facilitate the transfer of ownership from state-owned lands to their actual occupants. This initiative was accomplished through the organization of cooperatives, under the condition that the land would serve as their sole permanent residence. The program encompassed ownership regularization actions and environmental improvement. The National Law No. 24,374 of 1994, addressed the ownership regularization of private lands under occupation and established the possibility of legally granting the ownership to its occupants, as long as they could prove a public, peaceful, and continuous possession during a period of three years prior to 1 January 1992—this date was updated later on.

Moreover, provincial governments implemented measures of their own with the purpose of having more instruments available to address urban informality, although these measures were of limited scope and secondary importance. The province of Buenos Aires, in particular, implemented different programs, such as the Urban Reconstruction Program (Régimen de Reconstrucción Urbana), with the aim of regularizing informal settlements. This program involved their urban consolidation through initiatives focused on urban and ownership regulatory actions, environmental sanitation, and the elaboration of land-subdivision plans.

As the 2000s approached, new programs emerged, providing funding for integral neighborhood upgrading projects in low-income areas. These initiatives facilitated the investments in infrastructure that were required to regularize the resident's situation. One of these programs was the Settlement Upgrading Program (Programa de Mejoramiento de Barrios, PROMEBA), initiated in 1997 by the National Government of Argentina. Another one was Rosario Habitat, launched in 2000 in the province of Santa Fe, becoming the first program to be executed in the country by a local government.

As for the City of Buenos Aires, large-scale urban transformation processes have been in progress since 2015. They are the Integral Reurbanization Process (Proyecto Integral de Reurbanización—PIRU) by the City Housing Institute (IVC)—and implemented in Villa 20, Villa Rodrigo Bueno, and Villa Fraga; others carried out within the sphere of the Secretary of Urban and Social Integration in Villa 31.

Furthermore, at the national level, the Secretariat for Social and Urban Integration (SISU)—whose main precedent was the ReNaBap—introduced two significant advancements in the urban integration of these areas:

1) A new integral intervention model to be executed by worker cooperatives instead of only companies.
2) The introduction of the Digital Formalization Certificate (CeDIF) as an intermediate tool to progress in the formalization and urbanization of

neighborhoods. The CeDIF is an official registration certificate for housing units in the Electronic Document Management System, that guarantees secure tenure and grants access to public services until title deeds are issued.

While historical contexts, public policies, and government administrations may have different approaches, all countries aim to progress in the ex-post formalization of the built environment. This involves overcoming multiple barriers in order to turn possession into ownership, providing a solution to the dispute between those who actually reside in the dwelling and those who appear to be the owners on paper. Moreover, efforts are made to rectify existing situations that do not comply with urban regulations, regarding urban, construction, and hydraulic standards, among others.

Regularization policies are the most effective manner to navigate through institutional, social, regulatory, and legal barriers. By implementing measures and exceptions, they bridge the gap between reality and regulations.

3. Material and methods

3.1. Process-project and participation as a framework for ownership regularization

The ownership regularization of Villa 20 takes place within the framework of a participatory process that provides a platform for building consensus. This type of agreement is necessary to guarantee and facilitate progressive urban upgrading and ownership transfer to all the residents.

In Argentina, depending on the type of political or administrative agency, the responsible for the ownership regularization process are local or municipal governments and the City of Buenos Aires. In the case of Villa 20, the IVC (City Housing Institute) is the agency in charge of implementing the Integral Reurbanization Process (PIRU) regulated by Law 5705, which was passed in 2016 [19]. This law regulates the participatory process for the reurbanization of Villa 20, as well as the special regulatory aspects for its urban restructuring and regularization. Villa 20 has been the focus of various partial interventions by both national and local governments. In 2016, an integral reurbanization process (still in force) began, with a strong participatory platform that supports the reurbanization process. In 2016, there were 27,990 inhabitants, constituting 91,116 families that lived in 4559 residencies. The census conducted by the IVC in 2016 showed that 24% of the families were tenants, 63% were young people (under the age of 29), 70% of the households had ground floor and first floor, 90% had access to basic utilities under deficient conditions (illegal connections), and most of them were built using good quality materials [20].

This participatory process is based on a “process-project” planning model, in which the desired results of the intervention are not always fully defined from the beginning (**Box 1**). Instead, they represent a goal that guides all actions, allowing for modifications along the way in both the path taken and the strategies employed [16]. For this purpose, the process follows two main guidelines. Firstly, it recognizes the built environment created by the residents as the starting point for the reurbanization process and progressive upgrading. Secondly, it guarantees the exchange of knowledge to inform decision-making and to collaborate with PIRU (involving the

community, social organizations, government agencies, etc.) in the generation of structural changes at various levels (**Figure 2**). This model has an intersectoral, interdisciplinary, and collaborative approach, with the capacity to create a greater impact and modify deeply rooted practices.

Box 1. Villa 20 participatory platform.

Participation is instrumented through a set of devices that seek to strengthen the interaction among different social actors at various levels of complexity. These mechanisms are designed, modified, and adapted to:

a. Create a process of dialogue and decision-making that takes into account all the actors participating in the process, and

b. Guarantee the exercise of rights, transparency, and the sustainability of short, medium, and long-term processes. The set of devices developed is flexible and horizontal in nature; as it adapts to the process-project and does not constitute a hierarchical structure. Conversely, it seeks to promote different forms of participation, according to the nature of the issues addressed and the actors involved.

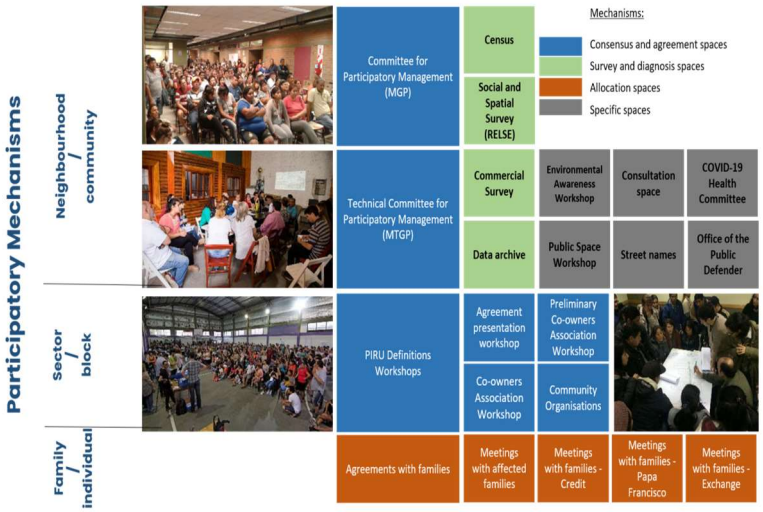

Figure 2. Principal participatory devices of the reurbanization process of Villa 20.
Source: PIRU Villa 20 coordination team.

These devices include both informative spaces and instances of joint management. Each device adapts to the different stages, steps and scales of the reurbanization process. The spaces of participation are designed to support the neighborhoods of Villa 20 throughout the 10-step process of social and urban integration and upgrading. The Participatory Management technical table (MTGP) serves as the central space for defining the ownership regularization process. It is integrated by representatives from different government agencies, and social leaders from various political groups present in the neighborhood. Periodically, members from the academic field and NGOs collaborate and provide their advice.

The participatory platform is the foundation for each of the stages of the intervention process in general and of the ownership regularization process in particular. This intervention begins with the opening of streets and alleys, the constitution of free areas to generate future "patios" or small yards, and the provision of infrastructure. In order to create openings and free space in each block, it is necessary to build new housing to ensure the relocation of those families that occupy the spaces to be freed. At the same time, as a result of collective construction, the ownership regularization operations are defined. This involves the registration of title

deeds and the issuance of certificates of possession, as well as the allocation criteria for homes within the historical neighborhood.

The reurbanization process supports the ownership regularization process and the gradual formalization progress through all of its stages: a). ownership, which must be registered by the legal responsible for the PIRU, b). block plan, once those streets and alleys have been created, c). subdivision of each block into individual plots and horizontal property, once those patios have been cleared and families have agreed to their formation and d). issuance of title deeds in favor of the residents.

New actors intervene in the ownership regularization process, such as the Cadastre Department, the Land and Property Registry, the Revenue Department, and surveyors. Typically, none of them takes place in the intervention of low-income neighborhoods, nor in the rationale behind the participatory process project.

3.2. Methods for ownership regularization process of Villa 20

The aim of the ownership regularization process of Villa 20 is to gradually issue title deeds for every household in favor of the families living in the neighborhood. This implies a complex, multidisciplinary process that takes into account technical, legal, and social aspects. It also requires government entities and community members to work together in a cross-disciplinary way.

Although the regularization process is complex, it can be outlined in five major stages (**Figure 3**), for the purpose of presenting a clear description: a). ownership and cadastral regularization at a macro level, b). subdivision into blocks, c). parceling, d). survey plan for each housing unit in the horizontal property (PH) where applicable, and e. issuance of title deeds. The first and second stages involve surveying the polygons that constitute the neighborhood, drafting the corresponding plans, and transferring ownership to the entity responsible for implementation. In the subsequent stages, progress depends, to a large extent, on the execution of a set of technical and social actions in the area.

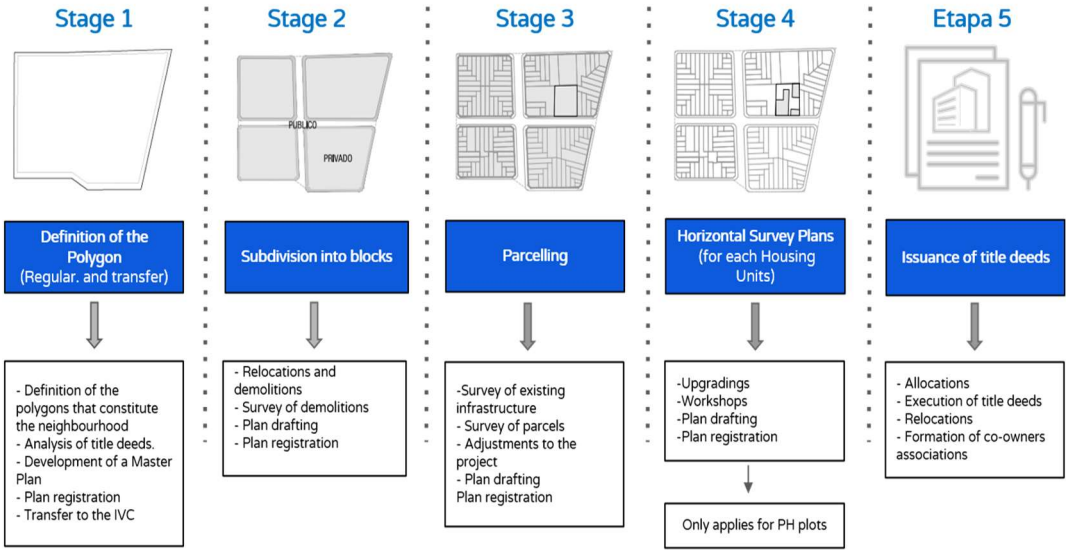

Figure 3. Stages of the regularization process of Villa 20.

Source: PIRU Villa 20 coordination team.

It is important to consider the technical and social work that takes place prior to the issuance of title deeds for each household, as this is not always reflected in the plans, programs, and budgets addressing the regularization processes in low-income neighborhoods. The final issuance of title deeds for existing housing units entails not only surveys and physical adjustments, but mainly social agreements and consensus-building for the process to progress. These can only be achieved based on accessing the information on each family, transferring knowledge, and trust-building in the reurbanization process. In this sense, the participatory platform provides the support for these agreements to advance.

The sectors of Villa 20 (**Figure 4**) to be regularized have different characteristics: a). cooperative sector, comprising 9 blocks owned by Cooperative 25 of Marzo, b). consolidated sector, encompassing 5 blocks which, through different government administrations, reached development regularization (opening of streets and infrastructure), c). historical neighborhood sector, comprising 16 blocks with no planned development interventions by the state until 2016 [21].

Figure 4. Urban-ownership sectors in Villa 20.
Source: PIRU Villa 20 coordination team.

The social and territorial approach to the ownership regularization process in Villa 20 entails interacting with the 9200 resident families at different scales (individual, per condominium or horizontal property, per block and at a neighborhood level). Each of the actions is strictly related to the advancement of the urban planning developed within the PIRU. **Table 1** shows a detailed description of the actions that make up each of the stages and their interrelation with the advancement in the physical transformation of the neighborhood.

Table 1. Stages of the ownership regularization process.

Stages	Technical and social actions
Stage 1: Title and cadastral clearance (macro level) and ownership transfer to the sector in charge of the reurbanization process	
• Define the ownership polygons that form the neighborhood. • Survey the polygon and the existing paths. • Carry out the analysis of titles and record gathering. • Draft the polygon's plan project. • Register and record the polygon's plan. • Decree of transfer to the relevant organization. • Organization's Minutes of the Meeting of the Board including the acceptance of transfer. • Plans record and title transfer.	
Stage 2: Subdivision into blocks	
• Once the design for public space has been freed through relocations and demolitions, draft the block plan project. • Draft the block plan. • Register and record the block plan.	• Construction of new housing. • Social and spatial survey of every housing unit and resident family. • Participatory resolution of the transformation of each block (opening of streets, passageways, and patios). • Resolution, in participatory workshops, of which families are to be relocated into the new housing units. • Relocations. • Demolitions for the opening of streets, passageways, and patios.
Stage 3: Parceling	
• Update the technical verification of the existing structures. • Adjust the parcel plan project considering existing structures. • Carry out the works for the adaptation of functionality to the plots or housing units. • Survey the parcels. • Draft the parcel plan. • Register and record parcel plans.	• Training and sensitization of the resident families on the topic of ownership regularization. • Update the social survey of each of the recipient families. • Update the spatial survey of each of the existing housing units. • Physical adaptation of the housing units to prepare them for subdivision (by means of improvements). • Definition and consensus on the plot and housing units' distribution with the resident families in the different sectors of the 30 blocks. • Settlement of conflicts arising from the clash of interests within families or between different families who co-own a horizontal property space. • Adjustment of the final subdivision survey plan.
Stage 4: Horizontal survey plan of each housing unit for horizontal property (PH by its initials in Spanish) plots	
• Devise the operation procedures and carry out preliminary co-owners' association workshops with PH residents. • Draft PH plans. • Register and record PH plans.	• Training and sensitization of the resident families on the topic of horizontal property subdivision. • Participatory consensus process for the regulation of the ownership regularization operation. • Agreements between families residing in housing units that share a PH plot. • Physical adaptation of the housing units to prepare them for subdivision (by means of improvements.) • Execution of PH agreements.
Stage 5: Issuance of title deeds (allocation per family)	
• Prepare and approve the title deed operation. • Gather data and documents necessary for the issuance of title deeds. • Execute title deeds.	• Training and sensitization of the resident families on the topic of issuance of title deeds. • Participatory consensus process for the regulation of the title deed operation. • One-on-one work with each recipient family with the aim of gathering documentation and solving intra-family interests. • Carry out the housing allocation. • Carry out the preliminary co-owners' associations workshops and define the PH condominiums.

Source: PIRU Villa 20 coordination team.

While these five stages are consecutive, they might be implemented differently in each of the neighborhood's sectors, depending on the history and degree of

consolidation, on the partial interventions carried out previously, and on the different ownership sources within the polygon. At the beginning of the reurbanization process (2016), a large percentage of the historical neighborhood lacked ownership, as it did not reflect the registration, cadastral and physical situation of the sector. Currently, out of the 30 blocks that comprise the neighborhood (**Figure 5**), 2 are in the process of being transferred to the IVC, 18 blocks belonging to the historical neighborhood have recently been incorporated into IVC, 8 blocks' subdivision into parcels have been approved, 3 blocks are in the process of being subdivided into parcels and 123 plots have a title deed. In addition, as mentioned above, 9 of the blocks belong to the Cooperative sector, 7 of which are in the last stages of the block and parcel subdivision. The approach in this sector is different, considering that the transfer of ownership happens between Cooperative 25 of Marzo and its members.

Once the ownership regularization process is completed, the 30 blocks will be subdivided into 83 sub-blocks, with the opening of pertinent streets and alleys. The figure below shows the current stage of the ownership regularization process.

Figure 5. Ownership diagnosis plan, 2023.

Source: PIRU Villa 20 coordination team.

The plot divisions to be performed were decided in the per-block project design participatory workshops, in previous stages of the reurbanization process. In these workshops, the intervention projects for each block were developed collectively; they involved the opening of alleys and inner-block patios, as well as the design of the plot diagram (**Figure 6**).

Figure 6. Survey and agreed-upon reurbanization project for block n°16.

Source: PIRU Villa 20 coordination team.

The plot subdivision of blocks is carried out in two manners, according to the following criteria:

1) Housing units whose net floor area meets the minimum required by Law 5750 (Villa 20), and whose open floor area amounts to 30% of the total floor area, can be issued a title deed for a whole plot;
2) Housing units whose net floor area is smaller than the minimum required and whose open floor area does not add up to 30% of the total area, can group with one another to be issued a title deed for a shared plot or PH.

In each of the neighborhood's sectors, there are housing units and parcels with deficiencies in terms of consolidation, which also invade public space or a neighboring plot, or are waiting for patios to be freed, etc. These plots, not fit for title issuance, will have to wait for the necessary adaptations to be carried out, so as to comply with current regulations. In these cases, a certificate of possession is issued as a provisional title that secures tenure until the issuance of the title deed. In order to diagnose the current conditions of the housing units, the MTGP created a "traffic lights" matrix whereby green parcels are fit for title issuance, yellow parcels require minor interventions to achieve title issuance status, and red parcels require major interventions.

The approach to ownership regularization comprises five specificity areas:

1) Land surveying, consisting of the preparation of survey plans (block plan, parcel plan, and PH) for the neighborhood's sectors already intervened by the opening of streets and passageways.
2) Socio-territorial, pertaining to sensibilization and awareness-raising about the community's ownership regularization, and micro-scale monitoring of every block and plot with the aims of parcel consolidation, forming of PH plots, settlement of conflicts, and articulation and interdisciplinary approach to address such situations as gender violence, migratory issues, etc.
3) Technical-territorial: adaptation of housing units and plots in order to enable the subdivision into parcels.
4) Communication through different channels aiming at conveying knowledge about the regularization process and the rights and obligations of the title-issuance process.
5) Legal, pertaining to the transfer of ownership and the issuance of titles.

The 10 components that structure the ownership regularization process are:

1) Operation for the transfer of ownership of the historical neighborhood's established housing units: it is a fundamental regulatory instrument in order to move forward in the definition of criteria and in the ownership regularization processes, which consists of the regulation of two specific devices: title deed and certificate of possession. The operations were designed in the MTGP.
2) Participatory workshops per block: block-level participatory workshops seek to provide information and address queries regarding the ownership regularization process. In the workshops, the PIRU progress in each block is presented, along with the following steps for ownership regularization and the building regulations in force.

3) Socio-territorial approach per housing unit: a territorial team formed by residents provides micro-scale socio-territorial support aimed towards parcel consolidation, with regular visits and in situ interviews with the families that are going to be granted title deeds. The teams provide advice about building regulations and their compliance, recognize the plot's private and common spaces, and answer particular queries. In horizontal property plots—which share common spaces—the teams and the families devise the rules for coexistence.
4) Technical assistance for plot adaptation: a technical team, formed by architects, supports and advises neighbors regarding the adaptation of structures to the building regulations in force. In addition, a draft of adaptation to regulations is devised.
5) Communication piece: a booklet that explains, in a clear and didactic way, the information concerning the ownership regularization process. It is distributed to every family in the per-block workshops and in the socio-territorial accompanying process.
6) Parcel diagnosis: not all parcels are in the same condition to be regularized. Based on technical and social diagnoses, different variables are analyzed: the need for interventions in the parcel in order to constitute the PH, infrastructure connections, habitability conditions, and the invasion of public space.
7) Allocation of patios: inner-block areas that have been freed are used to generate patios that can be allotted to individual plots or to several housing units. The technical and social team, in consensus with the families, officializes the handover of patios. This is a key step in the definition of the plots to be regularized since it enables correct ventilation of the housing units and compliance with urban regulations.
8) Block and parcel diagrams: based on the survey, openings, creation of patios, and definitions at a parcel level, the preparation and record of land surveys comprising subdivision is performed, along with the cession of thoroughfare for each block. The land-survey plan is a fundamental milestone in the advancement of the ownership regularization process. In order to take the measurements, both for the parcel and the PH plans, the land surveyor needs to enter the housing units. This requires coordination in advance with the family and the social team. Once the plans are finished, the administrative procedure for their record and registers begins. This stage requires the intervention of the General Office for the Record of Works and Cadaster (Dirección General de Registro de Obras y Catastro—DGROC), the General Office General Notary Public (Dirección General Escribanía General-DGEG), and the Land and Property Registry (Registro de la Propiedad Inmueble—RPI).
9) Placement of plates for parcel numbering: in order to assign the street number plates, a preliminary territorial survey is carried out, with cadastral validation of the georeferenced plan of doors and numbering proposal.
10) Issuance of title deeds: work moves forward in those plots legally fit for title issuance; required administrative documents are gathered.

The set of components is implemented in different stages in each of the neighborhood's 30 blocks, depending on the level of progress of multiple factors, such

as the opening of streets and alleys, the development of urban infrastructure, the creation of patios, the agreements on individual and PH plots, the habitability state of the housing units, the intra-family agreements, etc. It can be noticed that a number of organizations and institutional areas take part in different stages of the process; not all of them are acquainted with socio-territorial work.

4. Results and discussions

Barriers and benefits of the ownership regularization process in Villa 20

The participatory platform and the involvement of all the actors ensure the progress of the ownership regularization process in Villa 20. The multiplicity of factors that have a bearing on this progress shows the complexity of achieving the aim of title issuance for all the housing units. The process faces barriers of diverse natures, such as political, legal, institutional, technical, and social. It is important to take these into account in order to advance in overcoming them. The barriers summarized below were identified by the different actors involved in the participatory process of Villa 20.

All the actors that were consulted perform different roles within the MTGP (territorial, legal, or technical management, or as members of the different social organizations), which allows them to have complementary views regarding the benefits and obstacles of the ownership regularization process. At the time of the interview, all the actors were working on defining the operations for the transfer of ownership—title deeds and certificates—, instruments that rule the criteria for allocation. The main points that were discussed concern the pertinence of issuing property titles for housing units that do not meet the building standards or that invade neighboring plots and/or public space, as well as the definition of the criteria to be eligible as a recipient taking into account register situations in the 2016 census, certificate of current residence, inheritance, among others.

As regards the objectives sought by the ownership regularization process in Villa 20, the actors provide complementary perspectives, stressing the recognition of rights, the formalization of possession, and the integration into the city's urban infrastructure:

> *To formalise the residents' habitat, acknowledge their history in the neighborhood, and give them the opportunity to formalise. The biggest step is the title deed, but achieving formalisation of the block plan is also key. Regularization is the final step of the reurbanization process. We ask for the State to acknowledge residents as legal persons who have the right to adequate housing and for people to be informed about this.* Territorial approach team—IVC.
>
> *The goal is to bring urban formalisation to the neighborhoods, to be able to have streets, basic services, and door numbers. To be a part of the city. Regularization is yet another layer of urban formalisation. For the residents, to have a title deed means a big change, they stop being occupiers and become owners, and to become an owner in Argentina you need possession and a title deed.* Director of Ownership Notarial and Condominium Regularization from IVC.
>
> *The title deed is the final step of the reurbanization process. It does not come before homes are liveable and all public services are ensured. After leading a life*

in which most of your rights have been abused, the title deed needs to guarantee a liveable home. We are deeply affected by the process, we have a specific posture, and every one of us is going to bring what affects them or what they know. Social referent taking part in the Technical Committee.

A cultural change of mindset makes it possible to establish what is public and what is private. You can pay municipal tax and have access to water and sewers, transportation, firemen, ambulances, and police. To be able to have an address. In my opinion, the final step is the title deed, which states: this is public, this is private. It is indisputable, both for the state, which needs a register of all the real estate and for each family. Land Surveyor—IVC.

It is clearly stated in the law, what could be done in Villa 20, even if fellow residents may have different opinions, this is our land, and, beyond ideology, we have a goal. The title deed is essential because it dignifies the families. And if something happens to the father, the mother feels safe because she knows she cannot be invaded, because that is her habitat, her home. It is a guarantee that your home is yours. Social referent taking part in the Technical Committee.

It is all about adding value to tenure that residents have held informally for so many years, from which they have suffered evictions. Residents themselves have developed the places in which they live, and the last stage is to regularise the land. Land has an owner, it belongs to someone. Ownership is the ultimate right in rem. Why regularization? Because we are regulating that which belongs to residents, but not just now because we give them title deeds; it already belonged to the residents because they had been regularising their neighborhoods and making adaptations to inhabit them. They developed, built their homes, lived, and now need titles that state that they are the owners and make them feel safe. Social referent taking part in the Technical Committee.

The main obstacles identified by the inquired actors can be organized into categories as follows in **Table 2**: information, social aspects, management aspects, technical limitations, and political limitations. However, it is information, and lack thereof, the category which underlies every obstacle:

Table 2. Obstacles in the ownership regularization process in Villa 20.

Obstacles	Description
Information	• Mistrust as a result of the lack of information. Regularization is a long process, entailing diverse measurements inside the housing units in different stages. The lack of knowledge about the different stages of the ownership regularization process leads to mistrust. • Lack of information may lead to situations such as a resident signing a wrongful title deed and becoming a potential victim of a real estate deal; or someone coming and offering him very little money and him accepting, intending to buy someplace cheaper in the province of Buenos Aires. But in reality, he will not be able to afford anything or if he does, it will be something without a title deed and whose legal conditions will be unknown to him.
Social	• Intra-family conflicts regarding inheritance rights or the designation of title holders, which are not settled among the family members. • Lack of gender perspective; address of gender violence issues. For instance, a man living in the front house within a PH plot blocked the way to his female neighbors who lived at the back; he built a wall, he closed the door with a key.
Management	• Lack of human resources; difficulty in finding land surveyors willing to work in low-income neighborhoods. There are not many land surveyors, they are generally in high demand by the private sector, and it is not usual for them to be acquainted with the work in low-income neighborhoods. • Simultaneity of processes: overlapping of different actions of the reurbanization process. Different stages occur simultaneously: relocations, building of new housing units, creation of patios, improvement of housing units, and measurements for the preparation of the block plans. Measurements may progress while moves or yard creation are pending. The simultaneity of processes along with regularization may produce confusion and resistance among families.
Technical	• Lack of knowledge about the technical differences between forming individual plots and horizontal property plots—horizontal property, in turn, is confused with a kind of condominium that limits the independence of each owner, of which there have been experiences in Villa 20. • There are obstacles in entering the housing units in order to take measurements to draft the subdivision plans and the horizontal property plot plans. Families often refuse to let surveyors inside. They do not know them, since they are new actors in the process. In order for them to be able to enter and take measurements, a lot of people have to have talked to the families beforehand.
Political	• The political dynamics are an obstacle; there are voices that produce fear and mistrust. Complex words are quick to produce confusion. There is a need to simplify the technical concepts and when other voices get involved they produce fear and insecurity. It is not easy to debunk myths. There is a constant need to prove that what is being done is for the neighborhood's sake and is a step forward, and there always arise voices that push backward. This produces frustration in the work teams as well.

Source: Developed in-house based on interviews with members and participants of the process.

Information and limitations imposed by technical language in the regularization process are barriers when trying to communicate the steps to follow. Political leaders highlight it as follows:

> *Before this process, I had no idea of what ownership regularization meant, it is hard to understand. Now if you speak of title deeds it is different; you know you are the owner of your house when you have the title deed; I only learned it when I had my house—2 or 3 years ago—, before that I had no idea.*
>
> *Neither had I. No one living in the neighborhood's informality knows about that. I have lived in Villa 20 my whole life; I am 40 years old and I have never had any paper that certifies that the house is my house; that worries me. In this place, there is squatting and justice does not support you. It took my dad many years to build the house.*
>
> *Consider yourself lucky if, after a meeting, 4 people have understood what horizontal property is, or what a plot is; it is very complicated. And it is us that first need to understand it to be able to bring it to our neighbours who are not as much into the topic.*
>
> *They understand its purpose—I am not an owner unless I have a title deed. They kind of know that the slum is informal, that they own their houses and that there*

is a legal issue that they solve by having a title deed, but of all the technicalities, they have no idea. They do not understand what a plot is, what horizontal property is, or what a subdivision is. It takes a lot of work.

The obstacles bring to the fore the complexity of the process, especially the socio-territorial complexity. In every account, there is an emphasis on the scarcity of knowledge regarding all the steps needed to reach the goal of the title deed. In a way, the obstacles also offer an explanation as to why steps take so long to be completed: multiple surveys, street openings, adjustment of plots and housing units, information required to make decisions, family conflicts, etc. However, it is important to note that not one obstacle poses the impossibility of reaching the goal of the issuance of title deeds. This becomes even clearer when contrasted with the benefits identified by the inquired actors in **Table 3**, who chiefly highlight that ownership regularization represents a big step forward in terms of social integration and tenure security.

Table 3. Benefits of the ownership regularization process in Villa 20.

Benefits	**Description**
Social integration	• To have an address, associated with finding employment. To name the street and be able to identify the address in Google Maps. • Expansion of rights, and security for the family and their descendants. Also, holding property changes the way of taking care. There arises a social responsibility. A father can be the guarantor of his son's rental. • The fact that it is called a slum is stigmatizing, even if you can show that you are an owner, who pays taxes, votes, and takes care of the city just like every other citizen. But we are expected to be constantly proving that we are capable. • Squatters know that they are, but now you can resort to justice because you have rights, you have a paper which is the title deed. • Inclusion is for everyone to have access to utilities and a title deed. The possibility to stop being an outcast. • When laying a brick, one is thinking of tomorrow, and the title deed allows you to say "This is mine", I have a paper that proves it and no one can do improper things inside my house. That entitles us to the same rights as every other citizen. Without that, anyone could bring your door down.
Legal	• The State has a better register of things concerning ownership and cadaster, and there is progress in formalizing what is being physically transformed in the neighborhood. If formalization falls behind, that is sure to entail future obstacles. • In the cooperative, we have been working with the residents for years. Everyone knows it is the main goal and no member is afraid of losing their home. For instance, there is a member of the cooperative whose house has been occupied, and she is waiting to have the title deed so as to take legal action against the squatter. Members become title holders, even if they are not currently living in their houses because they have been occupied.
Security	• Granting people security over land rights is essential. It is not just the little piece of soil in which their house is built, but also a right to the land, to habitat, and to the city. Residents need to be included in the city's general plan. Right to the bus, to security, etc. • Law enforcement agencies feel free to do as they please because it is a slum. Most cases of trigger-happy behaviors take place in slums, and that is also a consequence of informality. • Families are vulnerable, to not having papers as required by the law. There are forceful entries in which they break everything, and if afterward, they find out they were mistaken, they pay for nothing. Outside the slum, if they break your stuff upon a wrong order by a judge, they compensate you for what gets broken. Here nobody makes reparations. Outside, you can have a lawyer and they will have to pay. That helps you become less vulnerable. And you live without worries; having a title you are safeguarded. • The title deed is essential because it dignifies the families. And if something happens to the father, the mother feels safe because she knows she cannot be invaded, because that is her habitat, her home. It is a guarantee that your home is yours.

Table 3. (*Continued*).

Benefits	Description
Economic	• To have assets. When you ask for a loan or anything they ask for an electricity bill, and this and that, and if you do not have those things, you are out, you do not have tools. Your children want to rent and there is nothing you can do. Formalization helps you to have more rights because you can show that you contribute. We contribute in a different way, through unappreciated work; everything falls under the umbrella of informality. But when you make a contribution, you exist and you can demand that your rights be recognized. • If you made a great effort and managed to build a nice house in a slum, it is like having a stolen car, because it may be very nice but it has no papers. And the house you built with great effort, one brick at a time, does not have value as it would if it were anywhere else in the city. It is made with the same exact bricks and the same exact plaster, but the value is lost because it is built on land that is not yours. But time makes me the owner too, because I have been there for 30 years, I am 63 now and do not have the title yet.
Formalization	• When chaos gives way to a sort of orderly state, it is beneficial for the people living there. To be able to open streets for vehicles, water, and sewers—everything tends to improve your situation. As for coexistence issues, it is going to take time, it will not change in 1 or 2 years—to change people's mindset, to create regulations, and for the State to help the people coexist on better terms, and to have a record of the works that are carried out. • There is a huge divide between the formal and the informal city. If you are in the city and want to upgrade your house, you set the sign and the dumper truck and that is it, and the State has means to detect clandestine constructions. In informality contexts, the State has been renounced entirely. • The fundamental change in the State's position today is saying "ok, this has to be done in a participatory committee". For all its difficulties, it is better than the State making unilateral decisions as it was before, which was the reason for things not to move forward. Processes take longer but are more sustainable in time, and people have to give their opinions. This way, changes are more institutional and less exposed to the decisions of a specific government administration. Now, administrations may change but the committee remains the same.

Source: Developed in-house based on interviews with members and participants of the process.

The identified benefits mainly refer to the impact of formalization as it entails the recognition of rights, the inclusion into the scheme of urban benefits, and security in terms of legal rights that enable residents to defend against the threat posed by occupation or home destruction. No detriments were identified in the advancement of the regularization process. In this regard, ownership regularization is identified as one of the stages of the reurbanization process, intrinsically connected with it:

> *The opening of streets is fundamental for the development of infrastructure, but it is so too to draft the block plan. They tend to be seen as segmented actions, but they share a common goal.*
>
> *You cannot think of regularization without considering the associated reurbanization process. They go hand in hand, formalising the physical transformations of the neighborhood—the block, the parcel, and the housing unit. To regularise is to go from irregular to regular, and if you consolidate that which is extremely irregular, I am not sure whether you are regularising.*
>
> *The reurbanization process consists of adapting the housing unit in the best possible way for it to conform to the building regulations and be formalised. Before, it was not possible to register plots located in slums; it is a change of mindset as well. The ordinance by Cadastre did not change, but it was superseded by more up-to-date regulations which are the slums-reurbanization laws, and now Cadastre understands the situation in a different light, and the plots, now protected by law, can be registered.*

5. Conclusion

The paper presents the general outlines of the ownership regularization processes carried out in Argentina and the rest of Latin America which, in a way, serve as frameworks for the process in Villa 20. The main obstacles to achieving ownership regularization are highlighted; after 40 years, most of these obstacles still play a role in hindering the efforts made along the lengthy road towards regularization of the existing informal habitat, despite the fact that it has been long discussed by academia and that most politicians support it, as they consider urban informality to be a barrier to cities' development.

The adaptations required by Villa 20 to achieve urban formality—as is the case with many other informal areas in the cities—call for physical and regulatory transformations, together with the availability of resources that enable steady progress in the regularization process. The proper mechanism consists of having a set of tools specifically suited to the socio-territorial dynamics of Villa 20 within the current regulatory framework, which can progressively ensure tenure and title issuance.

Ownership regularization begins with the opening of streets and alleys, the building of new housing units for the relocation of families, the freeing up of space to form individual and horizontal property plots, the provision of infrastructure, etc. The intermediate steps, such as the record of block plans and subdivision plans, represent a huge progress towards regularization considered beyond individual security as a large-scale social and urban integration process. Both the understanding of the complementary nature of the different stages and their different advancement status in each of the neighborhood's sectors and the work towards reaching agreements in all of the 30 blocks are fundamental to the advancement of the process.

As described in the article, the advancement in the regularization process is greatly dependent upon a set of technical and social actions to be developed in the territory, which are not always properly visualized. These are not only surveys and physical adaptations, but also, and mainly, social agreements and work toward consensus. The family's access to information, the transfer of knowledge, and the building of legitimacy of the regularization process are the main challenges.

The information issue, along with the multiple simultaneous urban adaptations required by the complex regularization process, constitute a barrier that can only be faced with active participation by all the actors who have a say, so as to steadily build the coherence and consistency needed to legitimize the process. It is collective decision spaces that progressively build a shared view and enable the advancement of the regularization process, from the gathering of data (population census), survey of the existing infrastructure, and social survey of each of the resident families, to decisions regarding operations and the criteria for title allotment.

The participatory platform gives support to the advancement of the regularization process, building a shared view of its goals—recognition of rights, tenure formalization, and integration into the city's urban infrastructure—and enabling the search for tools able to overcome the socio-territorial obstacles it faces—mistrust, intra-family conflicts, surveys—with a focus on the lack of knowledge regarding the steps required to reach the issuance of title deeds.

Not one obstacle poses the impossibility of reaching the goal of the issuance of title deeds. Conversely, the identified benefits reveal the positive impact of formalization understood as recognition of rights, inclusion into the scheme of urban benefits, and security in terms of legal rights that make it possible for residents to defend against the threats of occupation and home destruction.

Ownership regularization is identified as one of the stages of the reurbanization process, intrinsically connected to it, tailored to the socio-territorial and institutional context, conjoined with the progress in the neighborhood's urban planning and with the sum of the specific types of knowledge provided by each of the actors involved in decision-making. Villa 20 shows that the challenge resides in devising the design of an urban formalization process based on demand, supported by appropriate legal instruments, and incorporating participatory urban management devices.

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Article

Energy poverty in Brazil: A systematic analysis

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Abstract: The utilization of firewood for cooking in approximately 13 million Brazilian households in 2022 raises pressing concerns regarding its multifaceted impact on key development indicators. This impact stems from the profound connection between access to modern energy sources and fundamental rights, including education, health, housing, and leisure. Despite Brazil's remarkable diversity in its energy matrix, the equitable distribution of this essential resource remains a persistent and significant challenge. To construct the present work undertaking a systematic review of the technical literature, uncovering a stark disparity in energy access closely correlated with income levels. This inequality in energy access underscores the urgent need for comprehensive analysis and intervention. The present work endeavors to delve deeper into this complex issue, aiming to illuminate the profound implications of both broad energy access and the consequences of energy deprivation on individual well-being and broader socio-economic dynamics. Also, this work aims to provide a holistic understanding of the challenges faced by communities with limited access to modern energy sources and, concurrently, the opportunities and improvements that can be brought about through enhanced energy accessibility. In addition, this study seeks to identify and evaluate potential solutions to address this critical issue. This work is driven by the recognition that equitable energy distribution is not only a matter of environmental sustainability but also a fundamental human right, pivotal to social and economic progress.

Keywords: energy; energy poverty; energy matrix; inclusion; rent inequality

1. Introduction

The concept of energy poverty is broad and involves different dimensions. ECLAC (Economic Commission for Latin America and the Caribbean) considers energy poverty when a household does not have equitable access to adequate, reliable, efficient, and safe energy services to cover its basic needs, which can support human and economic life, develop its members, and whose energy bill payment does not exceed 10% of their income [1]. The European Commission considers that energy poverty occurs when a household must reduce its energy consumption to a level that has a negative impact on the health and well-being of its inhabitants [2]. Among many other definitions, in this work we adopted the definition of the International Energy Agency [3], which characterizes the situation of energy poverty as the lack of access to modern energy sources, such as electricity, condemning the population to dependence on energy. that is available in its surroundings, generally firewood, with its limitations in energy efficiency and use, with economic, environmental, and health consequences.

Data from the recent demographic census show that 99.7% of Brazilian households have access to electricity [4], in a population of more than 203 million inhabitants.

Brazil has historically had a very unequal income distribution, and, according to the United Nations Development Program (UNDP), until 2020, Brazil ranked seventh among the 10 most unequal countries in the world, with an index of 0.533.

Therefore, there is a distinction between the availability of the service and its consumption, between having electricity available and being able to buy it. And this also applies to the consumption of gas that replaces firewood or traditional biomass in cooking food. Therefore, the fact that 99.7% of Brazilian households have access to electricity does not mean that all these consumers can pay for the service in a country with a GDP per capita of just US$1183 which is still unevenly distributed.

The annual per capita consumption profile of residential electricity reflects this inequality, ranging from 371 kWh for the lowest-income group (consumption equivalent to that of Morocco) to 2221 kWh for the highest-income group, consumption equivalent to that of Japan [5].

According to the Brazilian Institute of Geography and Statistics (IBGE), 11 million households in Brazil used firewood or charcoal for food preparation in 2016. This number rose to 13 million households in 2022 [6], which may characterize a condition of energy poverty [1], with repercussions on other development indicators, such as education, hygiene and health, housing, and leisure.

According to the 2017 World Energy Outlook report, the provision of modern, safe, and affordable energy for all citizens contributes to economic growth and poverty reduction in such a way that historically, economic advancement has been, to a large extent, the result of the change from an agrarian-based economy to an industrial one, changing energy patterns and consumption [7], so that it is possible to affirm that there is a direct relationship between access to and use of modern energy sources and economic and social development [8].

It is important to remember that the United Nations—UN—and its 193 member states agreed on a plan to achieve, by 2030, 17 Sustainable Development Goals (SDGs) for the world, aiming for societies without poverty and hunger, with quality of life and social inclusion, without burdening the planet. SDG number 7 concerns ensuring access to reliable, sustainable, and modern energy sources for all [9].

The present work aims to analyze the current scenario of energy distribution among the population of Brazil, pointing out the negative impacts on health, education, the economy, and the environment due to the lack of access to modern energy sources, mainly electricity.

2. Materials and methods

This work used data collection and analysis as a methodology based on a bibliographical review of available technical literature and access to statistical databases from institutions such as the Brazilian Institute of Geography and Statistics (IBGE), Brazilian Energy Research Company (EPE), and United Nations Development Program (UNDP). Economic and social aspects of access to energy and reflection on Brazil's energy scenario were considered, analyzing concepts of energy matrix, income distribution, energy poverty, and energy distribution planning in the country, in addition to the impacts caused on social well-being.

The methodology employed in this work draws from a rigorous and comprehensive approach encompassing data collection, analysis, and the synthesis of

existing knowledge. A multi-faceted methodology was devised, leveraging the following key elements:

Systematic Review: A systematic review of technical literature was conducted to compile a comprehensive understanding of the subject matter. This involved synthesizing and critically evaluating a wide range of scholarly sources, reports, and publications relevant to energy access and its socio-economic implications in Brazil.

Brazilian Institute of Geography and Statistics (IBGE): Primary demographic and economic data were sourced from IBGE, providing a foundational basis for understanding the population and economic conditions.

Brazilian Energy Research Company (EPE): EPE data was instrumental in gathering insights into Brazil's energy landscape, including energy production, consumption, and distribution patterns.

United Nations Development Program (UNDP): Data from UNDP, especially in the context of human development indices, contributed to a nuanced understanding of the socio-economic aspects related to energy access and its impact on well-being.

Analytical Framework: The research incorporated a comprehensive analytical framework that assessed various dimensions of the energy sector. This included the examination of energy matrix diversification, income distribution, energy poverty metrics, and energy distribution planning strategies in Brazil. The integration of these elements allowed for a holistic understanding of the complex interplay between energy access and its socio-economic ramifications.

Social Well-being Assessment: A critical focus of this study involved evaluating the impacts of energy access, or lack thereof, on social well-being. This encompassed an in-depth analysis of how disparities in energy access affect education, healthcare, housing, and overall quality of life.

The utilization of these methodological components ensured a robust foundation for this work, enabling a comprehensive examination of the energy landscape in Brazil and its implications on the broader socio-economic context. Through the synthesis of data from reputable sources and the application of a multi-dimensional analytical framework, this work advances the understanding of the intricate relationship between energy access and societal well-being in Brazil.

3. Results and discussion

3.1. Access and consumption of electric power

The Brazilian Energy Research Company (EPE) is a federal public company linked to the Ministry of Mines and Energy (MME) and carries out studies and research aimed at supporting the planning of the energy sector, covering electricity, oil, natural gas, its derivatives, and biofuels. A recent study published by EPE, called Residential Electricity Consumption by Income Classes [5], shows inequality in residential access to electricity by income classes in the country, which has intensified over the last few years.

The study indicates that the population group with the highest purchasing power consumes six times more energy per capita than the group with the lowest purchasing power, reflecting growing inequality throughout the second half of the 2010s.

Using a coefficient called the "Electrical Gini Index", the study related income

profiles to the corresponding annual per capita consumption of electrical energy. As shown in **Figure 1**, the Electric Gini Index decreased between 2005 and 2014 but increased from 2015 to 2019. **Figure 2** shows the consumption by salary range.

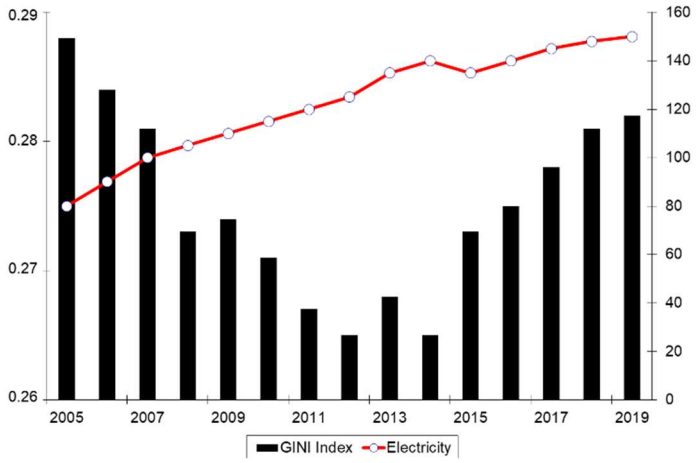

Figure 1. Electric Gini index.

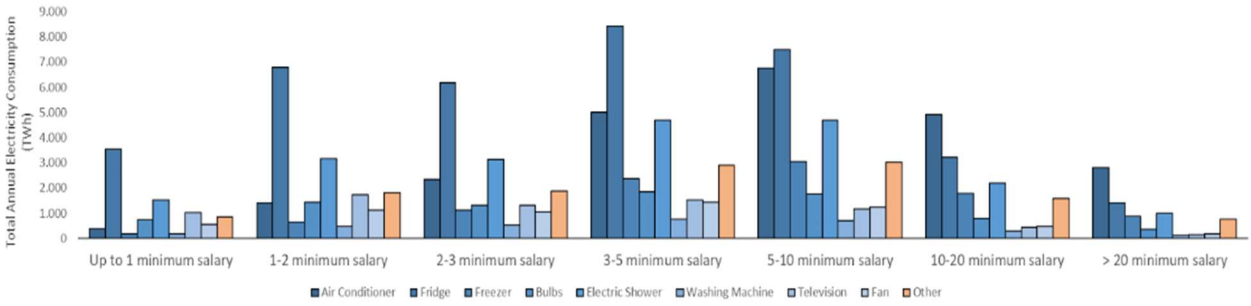

Figure 2. Consumption by salary range.

3.2. Access and consumption of gas for cooking food

According to González-Eguino [10], there are few options for energy sources in poorer areas, with traditional biomass being used more, which can characterize a situation of energy poverty. In turn, Giannini Pereira et al. [8] verify that the lack of access to modern energy sources can limit income generation opportunities and further worsen the poverty situation, particularly in rural areas where opportunities are limited. scarce, making these households powerless in the face of their social exclusion and having difficulty escaping poverty in future periods.

According to the International Energy Agency [7], a significant portion of the world's population uses traditional biomass as a source of energy to prepare their meals.

In Brazil, the use of traditional biomass in rural areas is high, reaching 59% of families in 2016, according to data released by the Continuous National Household Sample Survey (PNAD) carried out by the Brazilian Institute of Geography and Statistics [6].

Faced with the scarcity and vulnerability faced by families in relation to energy shortages and aiming to reduce this impact, the government implemented public policy programs with the aim of allowing people in extreme poverty to have access to and enjoy modern energy services. To this end, in 2001, the Ministry of Health and the

Ministry of Mines and Energy jointly launched the Bolsa Alimentação and Auxílio Gás aimed at improving the food and nutrition of Brazilians [11]. The Gas Aid consisted of providing R$7.50 (US$1.99) monthly to families, helping to purchase a 13-kg gas cylinder of Liquefied Petroleum Gas—LPG, also called "cooking gas".

The implementation of Vale Gás (VG) emerged in the context of the liberalization of oil derivative prices in Brazil, which began in the 1990s and culminated in the end of the LPG subsidy policy, which lasted from 1954 to 1995, and had the main objective is to help families purchase and replace gas cylinders, in addition to encouraging the replacement of firewood with LPG. According to Coelho et al. [12], programs focusing on replacing firewood with modern fuels, such as LPG, were implemented across the country, offering assistance to facilitate access to LPG for those most in need. The Vale Gás (VG) program was short-lived and in 2000 it became part of the broad social assistance program called Bolsa Família (BF).

Before the creation of the BF, in 2006, Brazil had 59 million people living in poverty and 25 million in extreme poverty in 2001 [13]. Although these numbers showed a slight drop during the 2000s, it was only after the implementation of the BF that a significant reduction occurred, reaching 14 million people in poverty and 5 million in extreme poverty in 2014 [13].

In this way, the BF has emerged as a valuable resource for low-income families, not only providing financial security but also guaranteeing food security and facilitating access to education. However, there are serious questions regarding the continued effectiveness of the BF in promoting access to energy for the most disadvantaged groups, especially regarding the lack of resources for cooking food. In effect, the inclusion of Vale Gás in Bolsa Família resulted in an indicative amount for the purchase of gas cylinders, but which was not linked to this acquisition. Thus, families were free to use the subsidy to purchase LPG to meet other needs, such as food or purchasing school materials, for example. In fact, research conducted in Amazonas demonstrates how the neediest families exchanged the subsidy for cooking gas for food and school materials [14].

According to Gioda [15], the use of firewood by the low-income population appears to be directly related to the price of LPG. **Figure 3** presents data from the Energy Research Company [16], in which residential firewood consumption decreased from 2007 to 2013, while there was a corresponding increase in LPG consumption. This corroborates the statement by Coelho et al. [12], that LPG subsidies contributed to a reduction in firewood consumption by families. On the other hand, it can be seen in the same figure that, from 2017 onwards, there was an increase in the consumption of residential firewood and, at the same time, a reduction in the consumption of LPG, suggesting its replacement with firewood in this period.

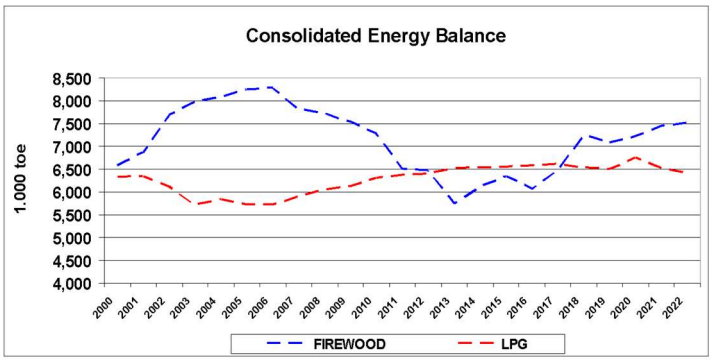

Figure 3. Firewood and LPG consumption in the Brazilian residential sector (2008–2019).
Font: EPE, 2023 [5].

The purchasing power of gas for cooking food and electricity can be analyzed based on the data in **Table 1**, which compares the value of gas, electricity, and the minimum salary in force in the country, from 2013 to 2022. The quantities are those usual for residential consumption.

Table 1. Comparative value of LPG, electricity, and minimum salary (2013–2022).

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Brazilian minimum salary (US$)	314	308	236	253	294	261	253	203	192	213
Liquefied Petroleum Gas—LPG (13 kg)	19	18	15	16	19	19	18	14	17	21
LPG (13 kg)/Brazilian minimum salary (%)	6	6	6	6	6	7	7	7	9	10
Residential electricity (100 kWh)	20	21	22	20	20	20	20	15	16	16
Residential electricity (100 kWh)/Brazilian minimum salary (%)	6	7	9	7	7	8	8	7	8	8

Font: EPE, 2023 [5].

In 2002, to achieve universal access to electricity in Brazil, electricity distributors were required to respond to new requests for residential electrical connection within three days in urban areas and within five days in rural areas, without charging fees. final consumer costs [16]. The Brazilian government provided financial assistance to energy distribution companies so that all new electrical connections could be installed free of charge for the end user. Based on these measures, Brazil launched the Luz para Todos Program in 2003, with the objective of providing access to electricity for the rural population still unserved, which corresponded to more than 2 million homes, according to IBGE [17], located in areas with a low Human Development Index (HDI) [17].

But access to electrical energy is only one part of access to energy, in its broadest sense, as shown by the Internal Electricity Supply (OIEE) and the Internal Energy Supply (OIE). According to the National Energy Balance 2023 [18], the residential sector consumed, in 2022, only 27% of the energy available by the OIEE and less than 11% of the energy available by the OIE. Still regarding the OIE, BEN 2023 highlights the growth in the share of firewood as a source of residential energy, from 24% in 2013 to 26% in 2022, a setback in social, environmental, and energy efficiency terms.

When a household does not have access to adequate, reliable, efficient, and safe energy services to cover its basic needs, which allow it to sustain human and economic

life, develop its members, and whose energy bill payment does not exceed 10% of their income, energy poverty occurs according to the Economic Commission for Latin America and the Caribbean—CEPAL [19].

The data presented allows us to verify that, in addition to the observed inequality in the country's income distribution, there is inequality in the consumption of electricity by different income classes, imposed by economic and social restrictions. The reality of the two extremes of the income distribution is very different and is evidenced by the figures for electricity consumption and the appliances with the greatest impact on this consumption [20–22]. In the lowest income brackets, with earnings of up to 10 minimum salary and which account for 80% of the population, the appliance with the greatest impact on consumption is the refrigerator. In the highest income brackets, with earnings above 10 and above 20 minimum salaries, which account for 20% of the population, the device is air conditioning [23–25].

Another relevant issue is the household use of firewood for cooking which, due to its low energy efficiency, can have negative effects on health and the possibility of accidents such as burns and fires.

Furthermore, energy poverty hinders individual access to formal education burdens those who provide basic services at home, most of them women, and, collectively, impedes social and economic advances [1].

4. Conclusions

Energy poverty, as demonstrated by the lack of secure and financially feasible access to modern energy sources, presents a significant challenge, particularly for low-income populations and those residing in remote areas far from urban centers. The repercussions of this energy deprivation reverberate throughout affected communities, directly impacting their quality of life and access to education. These groups often find themselves expending a considerable amount of time and resources on resolving energy-related issues, diverting a substantial portion of their monthly income to sustain an inefficient and unreliable energy service. These circumstances create a formidable barrier to social and economic advancement.

The present work has revealed that the mere availability of access to modern energy sources does not guarantee consumption, given the stark disparities in purchasing power within the population and the associated costs of these services, thus characterizing a state of energy poverty. Acknowledging the pivotal role of energy as a prerequisite for development and an enhancer of overall well-being, it is imperative to devise and enhance public policy initiatives that ensure every low-income family can access and afford electricity beyond basic subsistence levels.

Considering these findings, it becomes evident that a fundamental transformation in public energy distribution policies is imperative. Such policies must not only strive to enhance the continuity of energy access but also incorporate charging mechanisms that are grounded in socioeconomic assessments, thus ensuring that pricing structures are tailored to the income levels of the population. By doing so, it can work towards eliminating the stark disparities in energy access and consumption, fostering a more equitable and inclusive energy landscape that supports the socio-economic progression of all segments of society. The mission ahead is clear: to bridge the energy poverty gap and promote a more just and prosperous future for all.

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Article

Exploring the effect of pre-service teachers' digital competence on paperless behavior

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Abstract: Pre-service teachers must implement paperless behavior in line with institutional policies, technological developments, and environmentally friendly issues. Pre-service teacher candidates are expected to have digital competence in skills, abilities, and knowledge to successfully use computers, their related applications, and software in teaching and educational practice. It is predicted to affect their paperless behavior because digital activities reduce paper use. This study aimed to analyze the influence of prospective teachers' digital competencies on their paperless behavior. The research is based on the theory of planned behavior (TPB) using a quantitative approach and involved 372 pre-service teachers at the Faculty of Economics, Universitas Negeri Semarang (UNNES). Sampling was done by purposive sampling with specific criteria. The results of the study show that digital competence has an influence on paperless behavior by 43.1%. These findings add insight into the role of digital competence in an environmentally friendly learning process. This research suggests increasing students' digital competence so that students' paperless behavior rises in line with environmental issues.

Keywords: paperless behavior; digital competence; theory of planned behavior (TPB)

1. Introduction

The application of information and communication technology in various aspects of life is widely used because it is easy, practical, fast, and cost-effective [1]. This convenience unknowingly causes a positive impact, namely reducing paper use. The system is called paperless, which is currently widely applied by teachers or lecturers. One of its applications is using electronic portfolios in learning evaluation [2]. Paperless behavior is one of the efforts to decrease environmental destruction. Paperless behavior is essential to apply to teacher candidates in line with institutional policies, technological developments, and environmentally friendly issues. Paperless can support lectures by applying the optimization of information technology-based systems in assessment. Prospective teachers are expected to have digital competence in skills, abilities, and knowledge to successfully use computers, related applications, and software in teaching and educational practice. It is predicted to impact paperless behavior because digital activity reduces paper usage.

The application of information and communication technology can improve paperless behavior. With advances in existing technology, it can be easier for users to use technology such as computers. So prospective teachers are expected to have digital competence in the form of skills and abilities in using computers.

Paperless behavior at Universitas Negeri Semarang (UNNES) is still not optimal because many student assignments use paper. Ideally, student assignments

can be submitted via email or using other digital systems, which can reduce paper usage. Tusyanah et al. [3] recommended that UNNES students increase pro-environmental behavior through a paperless policy. In 2012, UNNES confirmed its intention to become an international conservation university. Conservation University is a university in the implementation of education, research, and community service that has a concept that refers to conservation principles such as protection, preservation, and sustainable use. One of the policies to become a conservation university is that UNNES enforces regulations paperless policy, which is stated in Regulation of the Chancellor of Universitas Negeri Semarang Number 27 of 2012 in the seven pillars of conservation.

Digital technology in the industrial era 4.0 has developed rapidly and has brought changes so that it dramatically affects various aspects of human life, including in the field of education, as stated by Tusyanah et al. [3]. So digital technology dramatically influences the digital aspect because technology has developed rapidly and is easy to use. Students are required to be able to use digital technology due to the rapid development of this technology. On the other hand, education will feel easy if it is related to technology, as we can access or search on "Google", everything is there. With that convenience, it needs to be utilized in terms of learning.

Previous research in this study was the implementation of the use of digital learning media during the COVID-19 pandemic, which explained that learning using technology needed to be used because, during COVID-19, students and teachers could not meet, as stated by Tusyanah et al. [3]. Research conducted by Reza et al. [4] with the title, "Based archive management training paperless office and making a monograph" explains that paperless in order to get used to processing and reading documents in digital form, in other words, reducing the use of paper as the primary material for document writing.

Behavioral research relies heavily on the theory of planned behavior (TPB) as the basis for looking for predictors of behavior derived from attitudes, subjective norms, and perceived behavioral control. These three things affect intention, which then influences behavior. Pro-environmental behavior is a practice that promotes resource protection and conservation practices and supports sustainable use of the natural environment, as stated by Lee and Kotler [5]. Conservation behavior is concrete action taken by conservative-minded humans to preserve the environment to maintain the use of natural resources (in this study, paper from trees) for present and future generations.

It can be interpreted that paperless behavior can be measured because it is done consciously by individuals and follows predictors, as stated by Ajzen [6]. Behavior is determined by a belief about whether a person has access to the necessary resources and opportunities to perform successful behavior, balanced by the perceived strength of each factor, as stated by Boar [7]. Behavior means response or reaction to stimuli. Behavior is an action or deed of an organism that can be observed and learned[8].

This study aims to analyze the effect of digital competence on paperless behavior among pre-service teachers. The aim of this study follows in the footsteps of previous research, which adopted a definition in which digital competence is focused on the skills and abilities of learners to perform certain tasks on or with

digital computers related to their specific tasks. content area domains Kletke et al., and Ballantine et al. [9,10]. Digital competence is defined and limited to having the skills, abilities, and knowledge to successfully use computers, their related applications, and software in teaching and educational practice.

2. Methods

It is quantitative research with descriptive statistics and simple regression with the Statistical Program for Social Science (SPSS). The following is an operational definition and indicators for making this research questionnaire. The questionnaires are distributed to the respondents. The questionnaires are made based on the definitions and indicators of variables as shown in **Table 1**.

Table 1. Definitions and indicators of the variables.

Variables	Definitions	Indicators	Sources
Paperless behavior	Paperless behavior is a natural action that can be observed and closely related to the management of paper use by humans in a sustainable manner for present and future generations [8].	1) Duration 2) Frequency	Kletke et al. [9], Ajzen [6]
Digital competence	It is skills, abilities, and knowledge to successfully use computers, their related applications, and software in teaching and educational practice.	1) General computer literacy Email/internet 2) Resentation software 3) Spreadsheets 4) Word-processing 5) Design graphic 6) Web 2.0 7) Database management 8) Technological Awareness	Evangelinos and Holley [11]

There are three study programs in the Faculty of Economics, UNNES. The respondents were taken from the population as shown in **Table 2**. Furthermore, the following is the population and sample in this study involving pre-service teachers.

Table 2. The population and samples [12].

The study programs	Students
Office administration education	106
Accounting education	159
Economics education	107
Total	**372**

The population in this study were all active students of Economics Education at UNNES in 2020, totaling 372 students. One hundred ninety-three samples were taken using a proportional random sampling technique based on this population. Data were collected by distributing questionnaires. The analytical method used is simple regression with SPSS.

As we understand it, digital competence refers to the ability to use digital technologies effectively and responsibly. When it comes to paperless behavior, digital competence plays a crucial role in shaping individuals' attitudes and actions. People with digital competence understand how to leverage technology for tasks that

traditionally involve paper. This understanding encourages them to adopt paperless solutions in their personal and professional lives. Hill et al. [13] stated that digital competence positively influences paperless behavior by fostering a deeper understanding of digital tools, encouraging environmental consciousness, improving efficiency, and facilitating effective education and awareness initiatives. As individuals become more digitally competent, they are likely to contribute to a broader cultural shift toward paperless practice (Hypothesis), as seen in **Figure 1**.

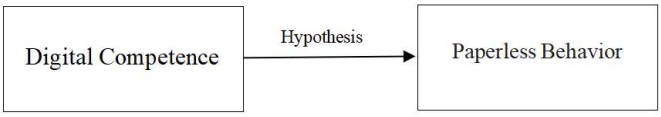

Figure 1. Research framework.

3. Results and discussion

3.1. Result

Before analyzing the regression model, we analyze descriptive statistics that allow us to approximate the reality of the sample of subjects being analyzed. The collected responses are based on indicators used to measure mental competence. The results show that the level of digital competence is determined by the average score based on a Likert scale of 1–4. The low-level indicator found in this study is the mastery of presentation software and spreadsheets, which deserves attention because it is the lowest of the seven indicators conceptualized. In contrast, the highest indicators are technology awareness and Web 2, the highest form of digital competency in research subjects. The best results were obtained for these two indicators, although the indicators still have not reached the ideal average value. The descriptive statistics can be seen in **Table 3**.

Table 3. Descriptive statistics analysis.

Indicators	*N*	Minimum	Maximum	Mean	Std. deviation
	Statistic	Statistic	Statistic	Statistic	Statistic
General_computer_literacy	372	9	20	16.44	2.138
e_mail_Internet	372	8	16	13.46	1.839
Presentation_software	372	4	12	10.57	1.564
Spreadsheets	372	4	16	11.24	2.471
Word_processing	372	8	16	13.53	1.788
Web_2.0	372	9	24	19.14	3.467
Video_maker	372	7	16	12.31	2.219
Databases	372	8	24	15.85	3.168
Technology_awareness	372	14	28	25.15	2.986
Design_graphic	372	7	16	12.35	2.279
Valid N (listwise)	372	-	-	-	-

Upon scrutinizing the results of descriptive statistics, it became evident that out of the nine digital competency indicators examined, four indicators registered low

proficiency levels. Specifically, proficiency in presentation software, spreadsheets, video makers, and graphic designs lagged behind, despite the increasing significance of these skills in future contexts. Recognizing the critical role these indicators play in contemporary and future digital landscapes, there is a clear imperative to enhance proficiency in these areas. Addressing the skills gap in these four indicators becomes essential to ensuring individuals are well-equipped to navigate and contribute effectively in an increasingly digital-centric environment. Consequently, efforts should be directed toward targeted improvement strategies and training programs to elevate proficiency levels in presentation software, spreadsheets, video makers, and graphic designs. This proactive approach will not only benefit individuals but also contribute to their readiness for evolving technological demands.

After tabulating the data, the subsequent step involves conducting regression analysis, the findings of which are detailed in **Table 4**. Regression analysis is employed to examine and quantify the relationships between variables, allowing for a comprehensive understanding of the patterns and trends within the dataset. In this context, regression serves as a statistical tool to model the connections between the variables under investigation, providing insights into the nature and strength of their associations.

Table 4. Simple regression equation test results.

Coefficients						
Model		**Unstandardized coefficients**		**Standardized coefficients**	***t***	**Sig.**
		B	**Std. error**	**Beta**		
1	(Constant)	3.487	0.605	-	5.766	0.000
	Digital_competence	0.400	0.024	0.656	16.737	0.000
a. Dependent variable: Paperless_behavior						

The SPSS coefficient output shows the partial effect of the independent variable on the dependent variable. In the digital competence perception variable, a calculated value of 16.737 is obtained, and sig. 0.000 is less than 0.05. This means digital competence has a positive and significant influence on paperless behavior. The following is a simple regression equation from this study:

$$Y(\text{PB}) = 3.487 + 0.400\text{DC} + \text{e}$$

From this equation, it can be interpreted that an increase follows every increase of one unit of digital competence towards paperless behavior of 0.400. Furthermore, to determine the percentage of *X*'s influence on *Y*1; then the *R*2 test was carried out, and the results are shown in **Table 5**.

Table 5. Model summary.

Model	***R***	***R* square**	**Adjusted *R* square**	**Std. error of the estimate**
1	0.656[a]	0.431	0.429	1.373
a. Predictors: (constant), digital_competence				

The SPSS output above shows the contribution of digital competence with an *R*-square value of 0.327. This means that digital competence can influence the

paperless behavior-dependent variable by 43.1%. Furthermore, 56.9% is influenced by other factors outside the regression model.

3.2. Discussion

Paperless behavior is an indicator of concern for the environment. This behavior needs to be improved because excessive paper use can damage the environment. There is environmental damage due to the uncontrolled logging of trees used as raw materials for making paper [14]. Data shows that 65–97 million trees were cut down to meet the needs of paper production [15].

In light of the critical need to safeguard our natural resources for both current and future generations, the adoption of conservation behavior becomes imperative. Equally important is the preservation of our cultural heritage, exemplified by a genuine appreciation for and commitment to the practices of our local culture. Conservation behavior, as defined by Retnoningsih et al. [8], encompasses tangible actions that are observable and scrutinizable, specifically in the context of the sustainable management of human use of natural resources.

Furthermore, pro-environmental behavior stands out as a proactive approach that advocates for the protection of resources, the implementation of conservation practices, and the promotion of sustainable use within our natural environment [5]. This involves a conscious effort to align individual actions with practices that contribute to the overall well-being of the environment.

In essence, the concept of conservation behavior reflects the tangible efforts made by environmentally conscious individuals who possess a conservationist mindset. Their actions are geared towards environmental preservation, with the overarching objective of ensuring the sustainable use of natural resources for both present and future generations. By recognizing the significance of these behaviors, we contribute to a collective effort to address environmental challenges and work towards a more sustainable and harmonious coexistence with our planet.

The sustainability of the Earth with thriving forests not only enhances human life by providing clean and oxygen-rich air but also plays a crucial role in supporting human existence as a whole. In this context, some individuals have proposed the concept of a paperless office. This concept not only reflects environmental consciousness but also holds the potential to reduce the negative impact of office activities on forests and other natural resources. By adopting this approach, we are not only nurturing the current quality of life but also investing in a sustainable future, fostering a balanced coexistence between humans and the environment. As for the benefits, there is a system called a paperless classroom; that is, it can save time, and resources, be environmentally friendly, save space, improve the organization, and ensure that documents are safe. Paperless is an effort to reduce the negative impact of environmental damage, as stated by Irawan [16].

Paperless is an environmentally friendly concept for a university/college. Some paperless components that must be applied are soft documents, online documents, and electronic documents. Human behavior is an activity that can be measured and can be planned. Someone will do something, starting with intention. Furthermore, this intention is influenced by the individual's attitude, knowledge, and competence.

The TPB, which was coined by Ajzen [6], states that "the TPB states that behavioral achievement depends on both motivation (intention) and ability (behavioral control). It distinguishes between three types of beliefs—behavioral, normative, and control."

As prospective teachers who realize the importance of maintaining a green environment, it is necessary to provide knowledge and competence to reduce the use of paper. Especially nowadays, along with the development of the Industrial Revolution 4.0 era and changes in human activities where almost all activities can be done online, digital competence needs to be improved, as stated by Prasetyo and Trisyanti [17].

A teacher must be able to use the Internet for teaching, as stated by Suharmanto [18]. The Internet can be used as a learning medium so that the teaching and learning process can be carried out effectively and efficiently. Using the Internet as a learning medium can make it easier for teachers to get or convey information related to messages or content and learning materials, making it easier for teachers to carry out the teaching and learning process for students. The teacher needs digital aspects for precise and accurate information supporting the learning process, as stated by Silvana et al. [19]. Digital competence in this study is digital competence in the form of skills, abilities, and knowledge to successfully use computers, their related applications, and software in teaching and educational practice. It is, of course, different from digital competence for prospective doctors, prospective judges, or other professions.

Digital competence in this study uses indicators that contribute to teaching, including general computer literacy, email/Internet, presentation software, spreadsheets, word processing, graphic design, Web 2.0, database management, and technological awareness. From the results of this study, it was found that digital competence had a positive and significant effect on paperless behavior. It is appropriate grand theory TPB, which states that behavior is influenced by one of the attitudes, and knowledge, skills, social conditions, and individual personality influence this attitude.

It is also following research from Astuti and Setiawan [20], entitled, "Fostering teachers' digital competencies and innovative work behavior in facing Merdeka Belajar policy: Digital informal learning as a mediator," which states that digital competence has a positive and significant effect on learning digital information and innovative work behavior.

Also, research from Umaima and Hutabarat [21] entitled, "Bekasi Regency workforce readiness to work in the paperless office" states that digital competency and digital usage behavior have a significant effect on the readiness of the workforce in Bekasi Regency to work paperless. Also, research from Ratnaningsih [22] states that personality influences behavioral intentions to use paperless information technology systems, personality variables consisting of agreeableness and extraversion are positively and significantly related to behavioral intention (intention).

It indicates that prospective teachers must also improve their digital competence to be paperless. Teachers have a strategic role in reducing the need for paper because they are role models for their students to maintain a green environment. One of the factors that can influence students to play a role in maintaining a green environment

is the teacher. The teacher plays a role in instilling the character of caring for the environment in students, which refers to every attitude and action taken at school, as stated by Rosela and Gunansyah [23].

4. Conclusion

This study concludes that digital competence positively and significantly affects paperless behavior. The better the digital competence, the better the paperless behavior because individuals reduce the use of paper and can utilize technology for the teaching needs of prospective teachers. It suggests that pre-service teachers should adapt and integrate technology into their learning, which in the end reduces the use of paper.

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Article

Rural tourism development path under the perspective of industrial integration—Case study of Tangwan township, Guixi City

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Abstract: With the improvement of people's economic income and the upgrading of tourism consumption demand, rural tourism is becoming more and more popular. Although the rural tourism industry is emerging all over the world, how to realize the high-quality development of the rural tourism industry is still a complex systemic issue. The integrated development of the industry is an important way to realize the high-quality development of the industry; therefore, this study tries to discuss the path of the integrated development of the rural tourism industry by analyzing the micro-case study. For the case study, the authors chose Tangwan Town, a rural tourism town in Guixi City, Jiangxi Province, China. We collected relevant qualitative and quantitative data through questionnaires, field research, and interviews, based on which we analyzed the SWOT and the obstacles to industrial development at the case site and gave suggestions on the path of integration development at two levels. Through the empirical study of the case study, we summarize the four priorities in the integrated development of the rural tourism industry, which are capital, operation, resources, and talents. This study further provides management implications for tourism management, visitor experience, and the further development of the rural tourism industry.

Keywords: rural tourism; industrial integration; tourism development path; Tangwan township; tourism management

1. Introduction

With the rapid development of urbanization, the pressure people face is increasing day by day, and tourism is becoming more and more indispensable. In order to escape from the hustle and bustle of the city, more and more people are keen to go to the countryside to relax or leisure during their vacation, and the strong market demand makes rural tourism flourish. Rural tourism originated in Europe and began to develop on a large scale in the 1880s. In many economically developed regions of the world, rural tourism has embarked on the path of large-scale and standardized development, but in many economically underdeveloped or even backward regions, rural tourism is still in the primary stage and is urgently in need of more experience and support. In many economically developed regions of the world, rural tourism has embarked on the development of scale and standardization, but in many economically underdeveloped or even backward regions, rural tourism is still in the primary stage, and there is an urgent need for scientific theories to guide it. In the past two decades, because of the implementation of national strategies such as poverty alleviation and rural revitalization, China's rural tourism has developed rapidly. The road of development is not smooth; China's rural tourism market's rapid development has also brought a lot of problems, highlighted by the homogenization of rural tourism

products, urbanization of the landscape, service quality that is not high, and so on. The rural tourism industry urgently needs to be transformed from high-speed growth to high-quality development.

High-quality development in tourism is accompanied by industrial integration, which, as an important strategy to promote industrial innovation and high-quality development, has now become an important way to promote the structural upgrading and adjustment of the tourism industry. In recent years, China has repeatedly proposed at the policy level that "the rural tourism industry should be integrated with the primary, secondary, and tertiary industries" so as to realize the development goals of expanding the development space of the tourism industry, innovating tourism products and services, and enhancing the competitiveness of the tourism industry through integration with other industries. However, China's rural tourism industry is basically promoted by the government, and there is insufficient understanding of the internal mechanisms of the integration and development of the rural tourism industry, and there is blindness in practice, so there is an urgent need for a systematic scientific theory to guide the integration and upgrading of the rural tourism industry.

Existing research on rural tourism mainly focuses on the connotation, impact, and products of rural tourism, and scholars have done less research on the development path of rural tourism. Meanwhile, existing research on tourism industry integration has gradually deepened from the initial analysis of the phenomenon of integration of tourism, agriculture, sports, and other industries to the exploration of the definition or connotation of tourism integration, as well as the motives, paths, mechanisms, modes, and evaluation of tourism integration. However, there is less literature exploring the high-quality development of rural tourism from the perspective of tourism industry integration.

China's rural tourism industry has entered a golden period of development and is also in a period of prominent contradictions. To promote the high-quality development of the rural tourism industry, the integrated development of the industry is one of the most important ways. How do we analyze the current situation and problems of industrial integration in rural tourism areas? What are the options for the path of integrated development of the rural tourism industry? What are the priorities for promoting the integrated development of the rural tourism industry? This paper intends to explore these issues through the empirical study of cases, which is of great theoretical and practical significance in guiding the high-quality development of rural tourism in China.

This paper is organized as follows: In section 2, we discuss the relevant literature and highlight our contributions in this regard. In section 3, we describe the study area and methodology of this paper and present a SWOT analysis of rural tourism at the case site. In section 4, we mainly use the questionnaire data to obtain five problems to be solved and propose two levels of solutions and concrete countermeasures. In section 5, we discuss and present our views on the direction of key work on integrated rural tourism development. In the final section 6, we summarize the full paper and reflect on the limitations of our study.

2. Literature review

2.1. Rural tourism

Rural tourism originated in Europe in the 19th century and has continued to grow. Many scholars have explored issues related to rural tourism from different perspectives, and existing research on rural tourism has focused on the definition, products, and impacts of rural tourism. Rural tourism is a multidimensional part of tourism, but there are some ambiguities in the definition of rural tourism, which often changes with the country, context of the time, and subject area, among other factors. Lane [1] defines rural tourism as a discrete activity with distinct characteristics. Chi [2] defines it as a comprehensive tourism product with multiple forms based on rural idylls, agricultural activities, farmers' experiences, and folk culture. Zhu [3] defines rural tourism as a complex system of multifaceted development objectives. Dai [4] defines it as a form of economic development, a form of small-scale tourism with the primary purpose of economic development. In conclusion, with the development of the times and the improvement of people's living standards, rural tourism is becoming more and more an important consumer product in people's cultural life and a new driving force for local or regional economic growth. Academic research on the subject of rural tourism products has gradually deepened, from a single tourism product to the development and integration of multiple products. These emerging tourism products often involve multiple industries, and their forms are characterized by diversity. For example, Tănase et al. [5] found that in Romania, grapes are an important basis for the local tourism product. Grape growing in agriculture, winemaking in industry, grape harvesting, and related cultural activities in the service industry are all integral parts of the local rural tourism industry [5]. Latorr et al. [6] studied mycotourism, a new type of tourism product, and found that wine tourism, religious tourism, and spa tourism were the tourism products most closely associated with my co-tourism, and that visits to truffle festivals, mycological parks, and hiring mycological guide were important manifestations of this product. Ritpanitchajchaval et al. [7] studied mountain trekking tourism as an experiential tourism product. The study found that the greatest marketing competitive advantage of such tourism activities lies in their ability to give tourists a greater sense of well-being, which is manifested in two main areas: improving health and experiencing unknown moments (adventure) [7].

The development of a large number of tourism products is bound to bring about a series of related impacts, which mainly occur in the areas where the tourism products are developed, and the focus can be divided into three aspects: ecological, economic, and socio-cultural. On the ecological front, the destruction of vegetation, shrinkage of biological habitats, and pollution from tourism waste are some of the most serious problems. Aziz et al. [8] found that most of the environmental problems in tourist destinations are due to the ignorant behavior of tourists and discussed how coastal tourism can be protected through the development of environmentally responsible behavior by tourists. The economic impacts of tourism include an increase in the income of local residents, diversification of industries, and foreign exchange balance. In his empirical study in Mauritius, Durbarry [9] found that rural tourism changed the local export structure from a traditional exporter of agricultural products to an exporter of non-traditional goods (textiles) and services (tourism), which significantly

increased local foreign exchange earnings. The socio-cultural impacts of tourism development are mainly reflected in the demonstration effects of tourism, policing and health challenges, and the over-commodification of culture. Teo [10] found both positive and negative social and cultural impacts of tourism in Singapore, the latter consisting mainly of the demonstration effect of tourism, changes in vernacular landscapes, and the commercialization of religious activities. It is not difficult to find that most of the studies focus on the impact of a certain one-sided impact on the place of tourism product development, and there are fewer, but not no, studies that address the multifaceted synthesis of the impact of tourism development. For example, Hassan et al. [11] analyzed the ecological, economic, and socio-cultural dimensions of the impacts of rural tourism on the Hassa region of Saudi Arabia, and also assessed the satisfaction of local residents with these impacts.

Despite the variety of studies related to rural tourism, how to effectively promote the development of rural tourism is both the starting and ending point of many studies. For example, Liu et al.'s study considered the government and the community as a community of interest and an integral part of the tourism product [12]. They conducted large-scale interviews and questionnaire surveys in China and came to the conclusion that the government plays a leading role in rural tourism development [12]. Du et al. [13] investigated the spatial mechanism of rural tourism development in China using geostatistical analysis and a random forest approach. They point out that the formation of rural tourism depends on the intrinsic characteristics of rural areas and favorable conditions for the development of tourism, and that the main factors affecting the development of rural tourism are cultural resources, tourism resources, and rural accessibility [13]. Wang et al. [14] explored the phenomenon of conflict in the development of rural tourism through a case study. They believe that this phenomenon mainly consists of three main conflicting parties and eight conflict issues and that if we want to effectively promote the development of the rural tourism industry, it is necessary to deal with the interests of the three conflicting parties and resolve these conflict issues [14]. The development of rural tourism includes economic, cultural, and environmental aspects, and economic development is the most important part, so the study of the rural tourism industry has both important theoretical significance and practical significance.

2.2. Rural tourism industry integration

The high-quality development of an industry is inseparable from the integration of industries, and this is especially true for tourism as a tertiary industry. With the development of tourism integration practice, the existing research on tourism industry integration has gradually deepened from the initial analysis of the phenomenon of integration of tourism, agriculture, recreation, and other industries to the exploration of theories such as the connotation of the definition of tourism integration, as well as practical aspects such as motives, paths, models and evaluation of tourism integration.

First of all, in the study of the rural tourism industry, exploring how to realize the integrated development of tourism and other industries is one of the important aspects. For example, Mitchell and Shannon [15] studied the rural tourism industry through the perspective of evolutionary (evolutionary) economic geographers and found that the spatial distribution characteristics of rural tourism resources are one of the important

factors affecting the integrated development of the tourism industry. However, Krogmann et al. [16] believe that tourism products are the core elements of the tourism industry, and as long as the products can be diversified, the tourism industry in the countryside can realize integrated development. Through a case study of the city of Nitra in Slovakia, they argued that local culture is the biggest driver of local tourism and that the development of cultural tourism products can well contribute to the integrated development of the local tourism industry [16].

Secondly, for the question of which industries the tourism industry can be integrated with, many researchers have given multiple answers from different aspects, which is also known as research on the path of integrated development of the tourism industry. For example, in the area of integrated development of agriculture and tourism. Pulina et al. [17] consider agritourism as a set of activities in which people combine tourism with agricultural production, services, and agricultural experiences that are beneficial to farmable yields and farm incomes. Wang et al. [18] found that the integrated development of both agriculture and rural tourism relies heavily on natural resources, especially agricultural resources, which may also contribute to the sustainability of agriculture. Using the Yangtze River Basin and the Yellow River Basin in China as case studies, the article examines not only the economic but also the ecological effects of agritourism integration, providing insights into the development of regional policies for integrating agriculture and tourism [18]. Santeramo et al. [19] analyze the synergistic relationship between domestic tourism and the wine industry in Italy and give their answer to the question of how to use the advantages of grapevine agriculture to promote the integration of the local tourism industry and give some policy recommendations for its development. In studies on the integration of industry and tourism development. Lin [20] explored tourists' demand for industrial tourism through an empirical study of Taiwan and concluded that the integrated development of industry and tourism is an important form of industrial transformation. At the same time, based on the IOA-NRM method, he also explored the sustainable development strategy of local industrial tourism and gave the corresponding countermeasures [20]. Byström [21] explores the question of whether there is a contradiction between the extractive resources sector and tourism, based on visitor data from local mining companies and interviews with respondents in three mining communities in northern Sweden. At the same time, relying on local mining tourism, a new regional tourism product, he studied the intrinsic connection between the industrial and tourism industries and the mechanism of mutual promotion [21].

The above examples of industry and agriculture are all about the integration and development between large industrial scales, while in tourism, as a kind of tertiary industry, the integration between various subsectors within the industry is also an important way to promote the high-quality development of the tourism industry. The cross-fertilization of various service industries under the tertiary industry has become the trend of the times, such as "beauty service + tourism", "sports + tourism", "health care + tourism", etc. Specific cases are as follows: Kim [22] discusses some of the views on the beauty-tourism-agriculture fusion industry. Her article surveys the perceptions of people in the Jeju Special Autonomous Region on the beauty-tourism-agriculture fusion industry, and based on this, she summarizes the problems of the fusion of the industry in the region and gives relevant recommendations [22]. Sports

tourism is considered part of the tourism industry created through the integration of sports and tourism. Taleghani et al. [23] collected and analyzed 112 questionnaires using KMO and confirmatory analysis with the aim of providing a management model for the development of sport-tourism integration and identifying disturbances in the sector. Similarly, industry integration plays an important role in the medical tourism services sector. Taking Bumrungrad International Hospital (BIH) in Thailand as an example, Wernz [24] used semi-structured interviews and archival data to analyze the BIH business model in depth, summarize the factors that drive the integration of tourism and healthcare and complete a successful empirical study.

In addition, with the continuous development of the times, the development of a variety of emerging cultures also makes the tourism industry produce many new forms. These innovative tourism products driven by unique cultural groups have gradually become a new economic growth point for the tourism industry, and have also promoted research in the area of innovative development of cultural and tourism industry integration. Examples include space tourism, heritage tourism, dark tourism, etc. Kim et al. [25] examined the perceived risks of space tourism in terms of both age and gender. Boyd [26] conducted a study of cultural and heritage tourism in Canada utilizing questionnaire distribution and interviews, specifically discussing the three areas of opportunities, principles, and challenges. Fabros et al. [27] explored the dark tourism indicators and tourist motivations and used them as the basis for creating a dark tourism spectrum for the Philippines.

In summary, research on rural tourism and how to realize the high-quality development of the rural tourism industry has been abundant, but there is less literature exploring the high-quality development of rural tourism from the perspective of multi-industry integration. This paper starts and ends with promoting the high-quality development of the rural tourism industry, seeks to explore the multi-industry integration path of rural tourism with micro-scale case studies, and at the same time summarizes and refines four key work directions in the integrated development of the rural tourism industry. It is hoped that our study will inspire the development and decision-makers of the rural tourism industry in the formulation of relevant working strategies and provide broader ideas for the creation of innovative products in rural tourism.

3. Materials and methods

3.1. Study area

Guixi City is located between longitude 117°24′–117°25′ and latitude 28°29′–28°17′ N. It belongs to the administrative jurisdiction of Yingtan City, Jiangxi Province, and Tangwan Town (TWT) is located in the southern section of Guixi City (**Figure 1**). The administrative area of TWT totals more than 180 km^2, with a population of more than 34,000 and 16 village (neighborhood) committees. Because of its long and splendid history and culture and prosperous trade economy, TWT has been awarded as the “National Key Town”, “National Beautiful and Livable Town”, “Provincial Famous Historical and Cultural Town”, “Top Ten Leisure and Tourism Towns in Jiangxi Province”, etc. At the same time, because it has a good location advantage and profound history and culture, and relies on the local characteristics of

rural tourism resources to vigorously develop the rural tourism industry, has become the center of economic and cultural rural tourism in the south of Guixi City. As of March 2022, there are 36 bed and breakfasts, 42 sightseeing and picking agricultural gardens, and 11 wineries above the scale level in TWT. Relying on economic activities such as fruit and vegetable picking, wholesale sales of agricultural products, and consumer services for travelers' lives, the annual per capita income of rural residents in TWT has significantly increased to a level of 15,000 yuan or more, and the number of tourists received in 2021 has exceeded 180,000 people. TWT represents the development of rural tourism in Jiangxi Province, China.

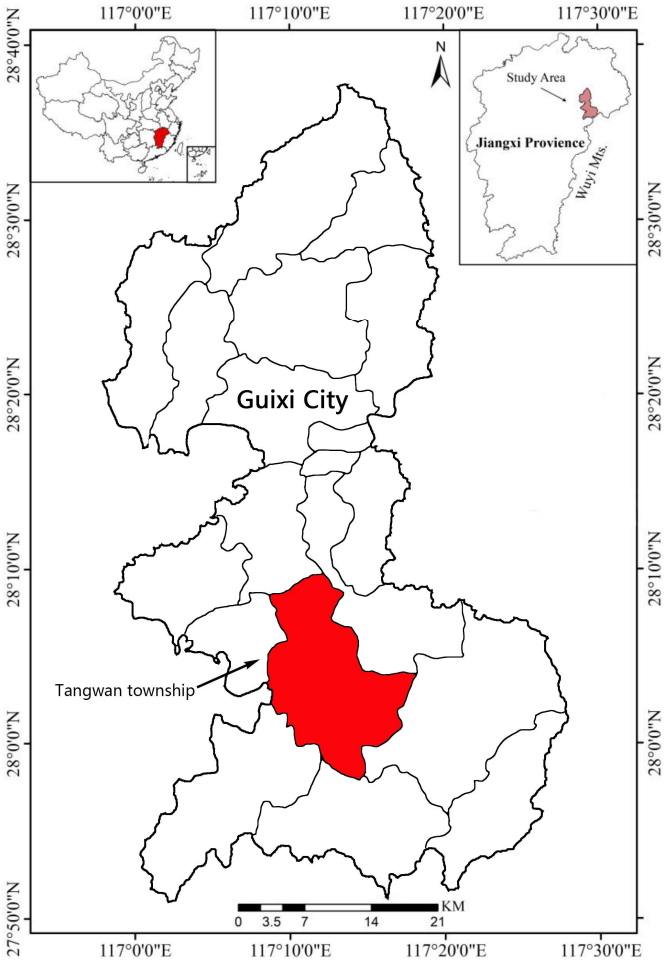

Figure 1. Location of Tangwan township in China.

3.2. Methods

3.2.1. SWOT analysis

SWOT analysis method, which is a highly theoretical form of situational analysis. It is to list the main internal strengths and weaknesses and external opportunities and threats closely related to the object of study through the survey, and then analyze them by matching the various factors with each other using the idea of system analysis, from which a series of corresponding conclusions can be drawn. By utilizing this method, it is possible to conduct a comprehensive, systematic, and accurate study of the scenario in which the subject of the study is situated, so as to formulate appropriate development paths, etc., based on the results of the study.

3.2.2. Questionnaire method and others

First of all, in order to collect necessary data from this field, the researcher designed a questionnaire, which was written in Chinese, as the research population was Chinese residents, and the translated questionnaire can be found in Appendix A. There are three main sections of the questionnaire, the first section is the basic information about the respondents and the second and third sections are the focus of the questionnaire. The second part of the questionnaire is about the tourists' experience of rural tourism in TWT, which contains six questions, such as the number of visits and means of transportation, the way of accommodation and dining during the tour, and so on. The third part is a thematic survey about tourists' feelings and satisfaction (Likert five-point scale). Eight questions were set up, and each question had five options with different levels of satisfaction for the respondents to choose from, and the selection mechanism was a single choice, and the statistical tables of the resultant data are shown in Appendix B. For these scale data, we will analyze the sample using descriptive statistics, and the reliability and validity of the questionnaire will be analyzed using the SPSS tool. This questionnaire survey was conducted in January 2022, and we selectively distributed paper questionnaires throughout the scenic area while waiting for the respondents to complete all of them before collecting them, and the selected targets were only limited to tourists visiting the town of Tongwan. We cumulatively distributed 200 questionnaires, and received 175 valid questionnaires, with a validity rate of 87.5%, except for the questionnaires that were lost and combed to remove those with logical problems. The analysis and application of the questionnaire data are mainly reflected in section 4.2 of the article.

Secondly, for stakeholders such as local residents, scenic area staff, and tourism-related practitioners, we conducted in-depth interviews with some representative figures. Each interview lasted approximately 20 min and a total of 10 men and 8 women from the local area participated in the study. The age of the respondents ranged from 19 to 60 years old, their occupations and family status (single, couples with/without children) varied, and their level of education ranged from primary education to a master's degree. The diversity of respondents allowed us to diversify our perspectives and obtain richer and more authentic information. Finally, in order to understand the real status quo of rural development of the tourism industry in TWT, and explore a scientific and feasible path of rural tourism development, we also reviewed a large number of related literature and data and went to the case site to conduct a field visit and investigation. We asked the local government and relevant organizations for some basic information about TWT, and they also introduced us to various aspects of the local development history and special culture. In the field visit session, we walked through almost every part of the town's core scenic area, and we visited some key landscape nodes several times. For this information of a qualitative nature from the visits and fieldwork, we mainly used it to shape the logical framework of most of the chapters throughout the text, and the focus can be seen in chapters five and six.

3.3. SWOT analysis of rural tourism industry integration development in TWT

3.3.1. Strength

Superior natural conditions: Tongwan's natural conditions such as climate, topography, and soil are very superior, the type of climate in Tongwan town is a subtropical monsoon climate, with both obvious four seasons, plenty of sunshine, moderate rainfall, fresh air, and other advantages. Both sides of the Xi stream are flat and open, with fertile soil suitable for growing rice and other subtropical cash crops. TWT is also rich in natural resources, with a total of 192,000 acres of forested land, of which bamboo forests are the mainstay, followed by cedar and wetland pines, etc. In addition, there are also large green tea plantations and oil tea plantations. The main mineral deposits in TWT include China clay, rare earth, granite, and uranium, forming a relatively complete industrial chain.

Comprehensive and diverse landscape resources: First of all, the beautiful natural ecological landscape, the town has both hilly plains and river valleys and other terrain, a long history of rice cultivation culture has given it a beautiful irrigated agricultural landscape, and abundant water resources have created the characteristic Jiangnan waterscape. Secondly, there are characteristic folk cultural landscapes, with opera culture as the main representative, such as local opera "Gan Opera", "Three-legged Class", "Hanging Opera (string puppetry)", "Tea-picking Opera", etc., in addition to the local festival customs and the characteristic folklore of the She ethnic group, and so on. Lastly, there are the characteristic humanistic landscapes, such as Tongwan Ancient Street, Tongwan Ancient Architectural Complex, Tongwan Reservoir, Shangzhu Minkeng Village, Easy Peak, Linlu Modern Agricultural Park, Tongwan Valley Wine Factory, Xia's Ancestral Hall, and so on.

Rich and unique cultural resources: One of them is the mellow flavor of grain wine culture because TWT is located in the monsoon climate zone of Jiangnan, so the town has a long history of rice cultivation, which has nurtured the culture of grain wine. The second is the time-honored "Academy Culture". Xiangshan Academy in Guixi City was one of the four major academies during the Southern Song Dynasty, and Tangwan Academy was a branch of Xiangshan Academy. The founder of Xiangshan Academy was Lu Jiuyuan, and the doctrines of Lu Jiuyuan and Wang Yangming were known as the "Lu and Wang Theory", which was a kind of doctrine to compete with the "Cheng and Zhu Theory" at that time. The third is the long history of religious culture, Guixi City is now China's Taoist culture, and the survival of one of the most complete areas, formed a multi-level regional religious culture system centered on Longhu Mountain. The fourth is the inspiring red culture. Shangzhu Minkeng Village under the jurisdiction of TWT was one of the important revolutionary bases in "Min-Zhe-Gan" at that time, and many revolutionary sites and memorial pavilions for martyrs have been preserved. This village was also the base of the Guixi Central County Committee and Guinan guerrilla, and now it has become an important red education base in our city.

3.3.2. Weakness

Inadequate public infrastructure: Differences in the geographic location of the various landscape points and the disproportionate size of the territory resulted in the

fragmentation and irrational distribution of public services. After field visits and surveys, we found that the problems are centered on three areas: First, seasonal differences in tourism lead to a mismatch between the supply of and demand for public infrastructure, such as the insufficient number of public transportation and public toilets during the summer peak season of tourism. Secondly, the infrastructure links between existing rural tourism projects and landscape sites under construction are not in place, and there is a lack of positive interaction between sightseeing agro-tourism sites and traditional tourist attractions; thirdly, the construction of most tourism projects lack an environmental quality impact assessment, and the planning of the projects focuses on the development and construction of landscapes, with a lack of post-scenic maintenance and management.

The extent of resource exploration is not deep enough: One of them is that the resource excavation is not sufficient, the resource development of the town is mainly based on tourism agriculture, and farmhouses, neglecting the utilization of the unique local human landscape and natural landscape. The second is the insufficient development of cultural products. The local area has many cultural resources such as academy culture, wine culture, bamboo culture, etc., but the development of related tourism cultural and creative products is lagging behind. Existing products are too industrialized and not innovative enough, leading to obvious homogeneous competition in the market.

Inadequate capacity for marketing operations: First, the publicity channels are traditional, mainly through tourists' recommendations and traditional commercial advertisements, which are inefficient; Secondly, the promotional materials are inconsistent or even missing, and the information on the basic introduction of the scenic spots, the roadmap of the tour, the tourism website and other materials are not well-informed; thirdly, there is a lack of network publicity channels, such as the new development of short-video self-media, tourism public number, network personal blogs and other new marketing methods that have not yet started, and there is a lack of benign interaction and exchange of problems between scenic spots and tourists.

Insufficient supporting talents and a low level of service: The tourism industry in the town is dominated by local part-time farmers and workers returning home. The lack of professional talents has led to the slow improvement of the quality of reception services in scenic spots. After entering the scenic area, tourists often simply take pictures and aimlessly take sightseeing tours, despite the lack of professionals to guide them to a deep understanding of the local characteristics of the culture and feel the town's rustic tradition of the vernacular human spirit.

3.3.3. Opportunity

Good development of the industry and strong support from national policies: Guixi is not only a national smart city pilot and 5G pilot city, but also a national urban-rural integration development pilot area approved by the National Development and Reform Commission. TWT is the demonstration zone of urban-rural integration in Guixi City, and the municipal government, with the goal of "urban-rural integration, industrial integration, and rural revitalization," has given a lot of preferential policies and financial support to TWT.

People's demand for rural tourism has increased and their enthusiasm continues to rise: With the rapid development of the economy and society and the change of the

main contradiction in society, people's material life has been greatly satisfied, and people's expenditures on improving the quality of spiritual life are also increasing day by day. Rural tourism has become an important choice for many people's vacation leisure and play, China's tourism market has great potential, and the industry's development prospects are worth looking forward to!

The industry has a deep foundation, which is conducive to the creation of high-quality rural tourism routes: In recent years, Guixi City, guided by the direction of "livable town + featured industries", selected Tangwan, Luohe, Zhoufang, and Tianlu as the construction pilot. In the southern part of Guixi City, a rural tourism demonstration belt in the south countryside area with TWT as the district center and Longhushan Town, Shangqing Town, Luohe Town, Wenfang Town, and other towns as the important parts. At the same time opened up a "modern agriculture and forestry culture tour", "patriotic red theme tour", "Jiangnan water town tour" and many other rural tourism lines with Guixi characteristics.

3.3.4. Threat

Fierce competition in industrial development and serious competition in product homogenization: First, in terms of rural tourism, Hunan, Guizhou, Zhejiang, and other neighboring provinces are also vigorously developing rural tourism industries. The latecomer Jiangxi in the geographical location, popularity, industrial scale, and other aspects of the gap are obvious. Secondly, in the development of rural tourism resources in Guixi City, the exchange with the governments of neighboring cities and counties is not deep enough, and many tourism products with strong homogeneity have been developed, which is easy to causes the phenomenon of uneconomical agglomeration.

Rapidly changing demand from tourists and frequent risk events in the industry: First, advances in transportation and ease of access to information have led to dramatic changes in tourism. People can quickly learn about tourist attractions and related peripheral information through cell phones, and through the major network platforms and third-party websites on scenic spot ratings and comparative choices, which makes tourists' travel needs change more quickly.

Secondly, unpredictable and significant risk events make the instability of the tourism industry's performance particularly pronounced. For example, in recent years, the new coronary pneumonia epidemic and major natural disasters have been devastating to some areas where the rural tourism industry is not on a particularly solid footing.

4. Results and responses

4.1 Compilation and analysis of questionnaire data

4.1.1. Socio-demographic characteristics of respondents

As shown in **Table 1**, more respondents in this sample were women (56%) than men (44%). In terms of age, most respondents were in the 18–38 year old age group (36%) and the 39–58 year old age group (44%).

Table 1. Demographic characteristics of respondents ($N = 175$).

Variable	Category	*N*	%
Gender	Male	77	44
	Female	98	56
Age group	18 and below	14	8
	18–38	63	36
	39–58	77	44
	59 and above	21	12
Educational level	Primary and below	14	8
	Junior high school	66	37.7
	Senior high school	46	26.3
	College	42	24
	Postgraduate and above	7	4
Marital status	Unmarried	72	41.1
	Married	103	58.9
Occupation	Public office or establishment	28	16
	A private firm	24	13.7
	Schoolchildren	46	26.3
	Company employees	63	36
	Others	14	8
Monthly income CNY	Less than 2000	42	24
	2001–5000	66	37.7
	5001–10000	53	30.3
	10000 or more	14	8

In terms of educational attainment, junior high school, and high school education accounted for more, with 37.7% and 26.3%, respectively, followed by 24% of respondents with a bachelor's degree, and a very small proportion of elementary school and post-graduate education, with a distribution of 8% and 4%. The respondents were predominantly married (58.9% were married). For occupation, business employees, students, and public officials accounted for 36%, 26.3%, and 16% of the respondents respectively. In terms of income levels, respondents were predominantly average (RMB 2000–10,000 per month), totaling 68% of the sample. At the same time, it was found that respondents with a monthly income of less than 2000 RMB were mostly students, accounting for 24% of the total, while those with a high income (10,000 or more) accounted for a relatively small proportion of the respondents.

4.1.2. Reliability analysis of the Likert 5-point scale

For the scale information collected on questions 14–21 of the questionnaire, we analyzed its reliability using SPSS 26.0. Firstly, Bartlett's test of sphericity and the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO test) were conducted to test the data's suitability for factor analysis. As shown in **Table 2**, the KMO value of the Feelings and Satisfaction Survey Scale is 0.921, and the significance of the

Bartlett's Sphericity Test result is 0.000, which indicates that this questionnaire has a high degree of validity and can be subjected to exploratory factor analysis.

Table 2. KMO and Bartlett's test values for the feelings and satisfaction survey scale.

Project	Perception and satisfaction survey scale	
KMO quantity of sample suitability	0.921	
Bartlett's test of sphericity	approximate chi-squared value	1702.192
	degrees of freedom	289
	significance	0.000

Then, based on principal component analysis, we conducted an exploratory factor analysis of the scale using SPSS 26.0, and the results of the analysis are shown in **Table 3**. As shown in the table, the factor loadings of each scale item are greater than 0.5, but the loadings are different, which means that there is a difference in the aggregation validity. Finally, we ran the software to obtain Cronbach's a value for the scale, which ranges from 0 to 1, with larger values indicating higher reliability. Academics believe that only questionnaires with a value of 0.8 or more have survey value, and a value of more than 0.9 can be regarded as the best questionnaire, and the Cronbach's a value of this scale is 0.864, which indicates that this questionnaire has a high degree of overall reliability.

Table 3. Factor loadings for each measurement question item of the scale.

Title number	Title information	Factor loading value
14	Infrastructure	0.568
15	Services	0.624
16	Overall layout	0.610
17	Creativity	0.534
18	Scenic views	0.775
19	Cultural atmosphere	0.816
20	Richness of the experience	0.682
21	Design of the route	0.737

4.2. Main problems of rural tourism industry integration development in TWT

4.2.1. Inadequate transportation facilities and services to be improved

Transportation problems to be solved. For the ninth question, "Do you think it's easy to get around here?", 175 questionnaires showed that 32% of the visitors thought it was easy and 68% thought it was inconvenient, so there is a lot of room for improvement in the town's transportation services. After the visit, it was found that the problem is mainly reflected in three aspects: first of all, the relevant traffic signs are not perfect, the absence of scenic guide signs results in self-driving travelers not accurately finding out the location of scenic spots as soon as possible; secondly, because most of the landscape points are located in hilly areas, the road for vehicles is relatively narrow, rugged and winding, and when two cars meet, the space is limited

and cannot be avoided in time, which is easy to lead to traffic jams. Finally, because the town of Tongwan has a number of mineral resources, mineral transportation vehicles make the scenic spot a number of highway road surfaces uneven, affecting the experience of tourists traveling through.

Service facilities such as public toilets and visitor service centers need to be improved. As shown in **Figure 2**, the data in question 14 of the questionnaire reflect that people's satisfaction with the infrastructure in the scenic spots is generally low, in which the options of "dissatisfied" and "very dissatisfied" together account for as high as 52%. More than half of the tourists had a bad experience in this area. After asking the respondents about the reasons as well as conducting field surveys, we found that the problems were concentrated in three areas. There are five public toilet facilities in one of the scenic spots, but they are scattered and inconvenient to use due to the increase in the number of tourists during the peak season. Secondly, there are two tourist service centers, one of which is a medical office, and there is a lack of services related to counseling and guided tours. Thirdly, the roadmap of scenic spots and landscape guide map is not placed in an obvious enough position, and there is a lack of publicity on the local characteristics of vernacular culture and anecdotes. In summary, due to the inadequacy of both transportation and basic service facilities in the scenic area, people's overall service evaluation of the scenic area is low. This conclusion can be inferred from the data on "Scenic Service" in the table, where only 33.2% of the respondents gave a positive answer. The largest number of tourists gave "generic" ratings, accounting for 29.7%, and the proportion of tourists who gave two negative ratings together was as high as 37.1%, exceeding the positive ratings, which is worthy of our deep thoughts.

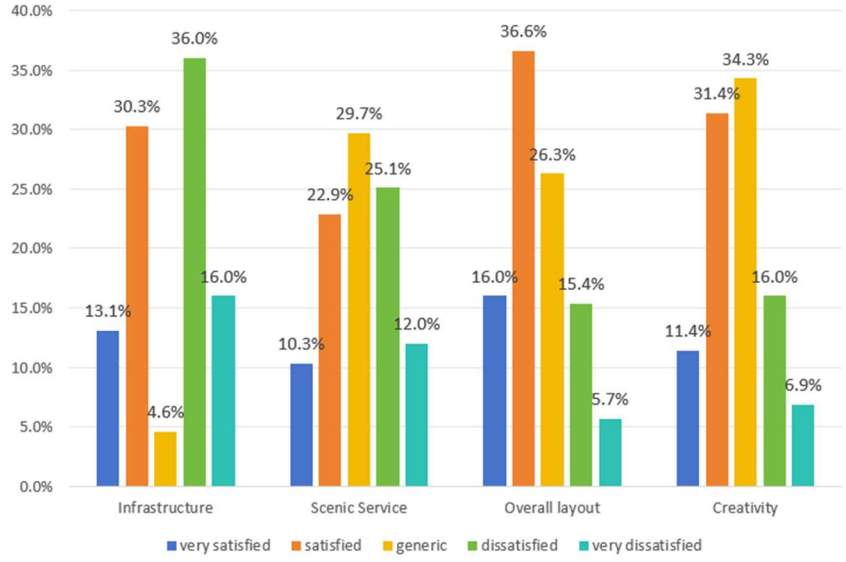

Figure 2. Perception and satisfaction survey 1.

4.2.2. Shallow excavation of cultural resources and low level of industrial products

TWT not only has a variety of natural ecological landscapes but also contains a wealth of characteristic folk cultural landscapes, local vernacular cultural landscapes,

etc., especially highlighted in the Valley Wine Culture, Shuyuan Culture, Religious Culture, Red Culture, and other aspects.

Whether the cultural resources of a tourist attraction are effectively utilized can be reflected in the feelings of tourists' scenic spots and satisfaction survey data. Because tourists are the most direct feeling group, they have a more relevant voice, and their attitude is also the most persuasive. Based on the reliability and validity analyses in the previous section (4.2.2.), we selected the four factors with the highest loadings to be represented, as these measure question items have better convergent validity. As can be seen from **Figure 3**, tourists' satisfaction with the landscape scenery in the scenic area is significantly higher, but their satisfaction with the cultural atmosphere, the richness of the tour feeling, and the reasonableness of the route are generally low. The data reflects that the town has deficiencies in the development of relevant tourism resources and the integration of local diversified industries, and has not carried out in-depth excavation and efficient utilization of cultural resources with local characteristics. In today's society with the trend toward diversified and personalized consumption, the town's surplus of low- and medium-end industries and insufficient supply of high-end innovative products have made it urgent to deepen its supply-side structural reform.

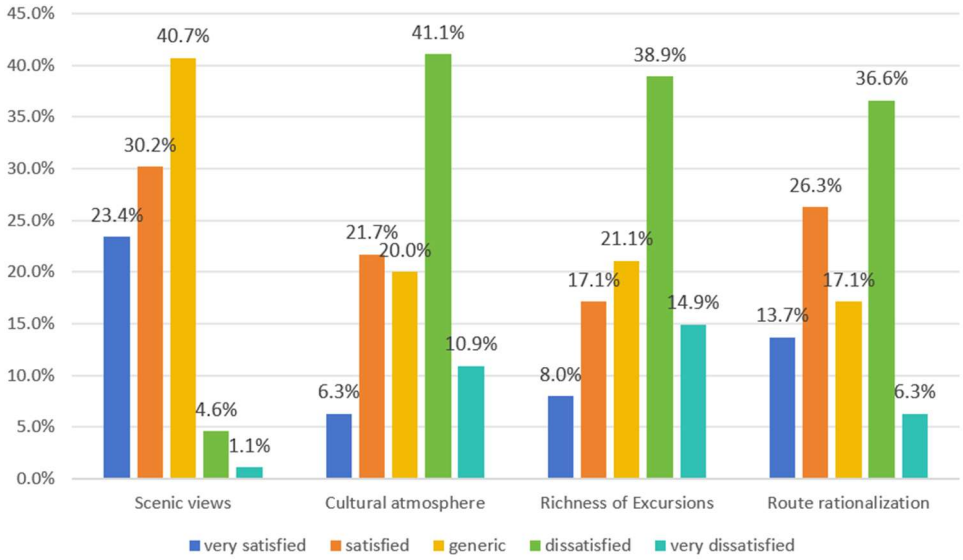

Figure 3. Perception and satisfaction survey 2.

4.2.3. More traditional methods of communication and insufficient features promoted

The rural tourism industry in TWT has highlighted problems in branding and market expansion, with traditional methods of publicity and insufficient investment in advertising funds. According to the questionnaire "How did you hear about here?", this question feedback data show that: 16% of the people through highway and bus and other transportation facilities such as advertising; 18% of the people through the network of third-party travel platforms and travel agencies to understand; the remaining 66% of the people through friends and relatives to inform acquaintances to know. This suggests that TWT's publicity and promotion methods are mostly based on referrals and recommendations from acquaintances, and especially lack the current

popularity of online publicity (short-video self-publishing, travel publics, online blogs, etc.).

Secondly, there is insufficient promotion of TWT's distinctive culture, and there is no deeper integration of processes between the same industries. The questionnaire data showed that 86% of the tourists came from Guixi City or neighboring cities and counties in Jiangxi Province, indicating that TWT has high visibility and a good reputation in the area, but market coverage is very limited.

There are three main reasons for this: First, there is a lack of integrated publicity for the town's cultural and spiritual core, local landscape features, and traditional historical lineage; second, the scenic spot lacks some related publicity materials, such as publicity brochures and audio guides, and the existing materials are not innovative enough; thirdly, the image positioning of some B&Bs and farmhouses is ambiguous, and there is no creative processing of their business characteristic projects, ignoring the theme image promotion.

4.2.4. Few types of tourist goods, cultural products to be explored

The results of the questionnaire show that nearly 90% of the tourists' knowledge of TWT's rural tourism products is limited to Tangwan Valley Wine and organic fruits and vegetables, which account for more than 80% of the direct-sale market, and they have little or no knowledge of other products. Extended processing products of related resources, such as agricultural processing products (dried fruits, bamboo shoots, medicinal herbs, etc.) and handmade products rich in local characteristics and cultural connotations (bamboo products, wooden products, etc.), their sales have not been effectively integrated with tourism activities.

TWT also has fewer cultural and creative products, such as Yuanbao baskets and oil-paper umbrellas, which are local specialties of bamboo culture, and hot stamping and calligraphy in literature and art.

4.2.5. Low number of high-end talents, service level to be improved

We counted the academic qualifications of employees in the rural tourism industry by means of distributing thematic questionnaires and interviews, such as managers of scenic spots, employees of lodging houses, operators of agricultural industrial parks, personnel in the sales industry of tourist commodities, and other related rural tourism industry employees. The sample data included a total of 122 individuals, and the specific distribution of educational qualifications is shown in **Figure 4**. Overall, the educational level of TWT's rural tourism employees is relatively low, of which the proportion of employees with junior high school and elementary school education is extremely large, totaling 62%, while only 12% of the highly educated talents with university education and above, and most of them are scenic spot-related public offices or staff in the organization.

The fundamental reason for this is that the local rural tourism industry has just started, and most of the employees are local villagers or workers returning to their hometowns. This situation of large span of the educational level of employees and lack of high-end talents directly leads to the low level of service at scenic spots, which indirectly affects the integrated development of the industry and the sustainability of rural tourism.

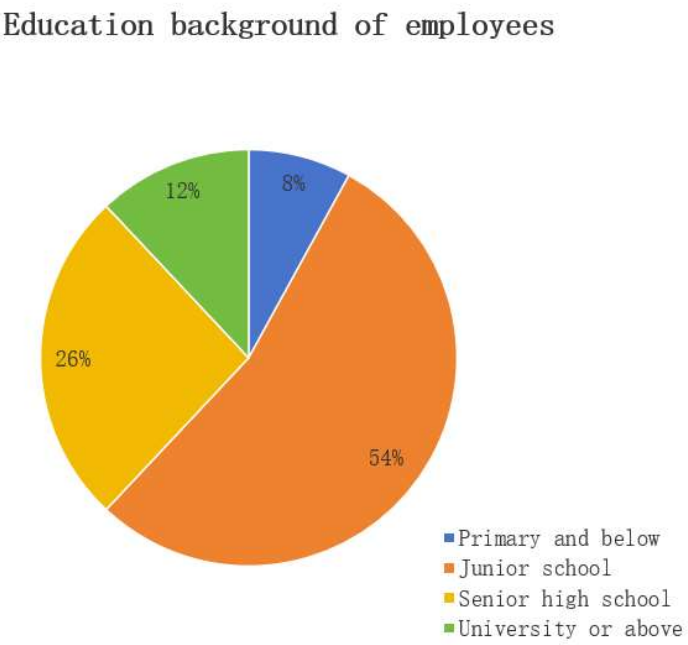

Figure 4. Education background of employees.

4.3. Industrial integration path at basic level

4.3.1. Agriculture + rural tourism

Based on the previous analysis, and with reference to the successful cases at home and abroad, we hereby give some suggestions to improve the quality of the industrial integration development of "agriculture + rural tourism". On the one hand, the management department can take the local farming culture as the core, and with the goal of publicizing modern agricultural science and technology and creating a cultural brand with local characteristics, develop a series of agricultural festivals such as the "Fruit Culture Festival" and the "Autumn Harvest Festival", and build some cultural practice places, such as the Farming Theme Museum, the Agricultural Science and Technology Park, and the Farming Academy, and so on. On the other hand, through the integration of local high-quality land resources, it promotes the production of advantageous crops on a large scale and in a mechanized manner. Taking the large-scale cultivation of rice and local branding as the focus point, expanding more and wider market share of agricultural products.

4.3.2. Industry + rural tourism

The integration of rural tourism and beverage manufacturing holds great promise for TWT, which can be categorized in two ways. On the one hand, we should make full use of the advantageous resources of valley wine culture, and play the "valley wine + tourism" card. The relevant departments should do the following: First, increase the investment of funds, and strive for more government funds and private funds to set up the Tangwan Valley Wine Chamber of Commerce; secondly, introduce and cultivate talents, relying on professional brewers, realizing the upgrading of equipment, the reform of crafts, and the combination of traditional crafts and modern technology; thirdly, relying on high-quality agricultural resources, we can develop a wide range of alcoholic products, such as fruit wines, rice wines, and herbal wines, so as to meet the needs of different consumer groups. On the other hand, in addition to

winemaking, the town can also make full use of the excellent spring water resources within the territory, the development of pure natural mineral water, fruit and vegetable juice, and other beverage products, to achieve efficient and comprehensive utilization of regional natural resources.

4.3.3. Bed and breakfast + rural tourism

After visiting and investigating the lodging industry in TWT, we found that there are problems of poor service quality and insufficient cultural connotation, and we would like to make the following suggestions: Firstly, in the planning and design of the B&B, it is necessary to pay attention to the display of regional culture and characteristics and maintain the original rural flavor and folk culture as much as possible, while also paying attention to the configuration of modern facilities to improve the living experience of travelers. Secondly, the B&B industry needs to focus on the improvement of service quality and make travelers feel at home by providing personalized and affectionate services. At the same time, there is also a need to strengthen staff training and improve their service awareness and skill level. Thirdly, there is a need to encourage the innovative development of the B&B industry, such as by launching special thematic activities and cultural and creative products, so as to attract more travelers to come for experience and consumption. Examples include the organization of special theatrical performances, and the development of special lodging products themed on religious culture, the culture of Jiangnan Water Town, and the culture of the academy.

4.4. Industrial integration path at elevated level

4.4.1. Cultural industry + rural tourism

One option is the integration of rural tourism with the local characteristics of rural culture. The Jiangnan Water Village culture and bamboo culture represent TWT's vernacular culture. In terms of Jiangnan water town culture, first of all, we can build some traditional Chinese buildings and decorative landscapes with ancient style and charm, shaping a simple and elegant cultural atmosphere. Secondly, we can learn from the experience of the film and television cultural tourism project in the Baihe Lake scenic area of the same city, and join hands with cultural media companies to create a film and television base. Finally, we can also rely on bamboo, water, gardens, and other landscape resources, the use of short videos, live broadcasts, public numbers, and other network media operations and dissemination, to create a "water town—ancient rhyme Tangwan" characteristic of the cultural tourism brand. In terms of bamboo culture, since TWT has abundant bamboo resources and a long history of bamboo product craftsmanship, the relevant authorities need to make full use of it and develop bamboo-related cultural and tourism products. The market value of bamboo culture can be deepened through the production of traditional bamboo industrial products such as Yuanbao baskets and oil paper umbrellas, the creation of bamboo toys, building materials, bamboo paper, and other modern life products, and the development of whole bamboo (bamboo shoots) banquets with bamboo shoots as the main ingredient.

Another option is the integration of rural tourism and red culture. TWT has a number of red cultural landscape sites, many of which are municipal youth patriotism

education bases and clean politics education bases. Here are a few suggestions for the development of red cultural tourism in TWT: First, the higher-level government needs to establish a scientific protection and utilization system to develop more red tourism resources, such as by building a number of new patriotic education bases, red tourism demonstration towns, and red tourism demonstration villages. Secondly, it is necessary to strengthen the cooperation of inter-regional red tourism scenic spots and launch multi-thematic red cultural boutique tourism routes with regional characteristics, so as to promote the clustered development of the red cultural industry. Thirdly, we will accelerate innovative development and promote the inheritance and utilization of red cultural resources by strengthening the combination of red culture with modern information technology, such as holographic projection, AR, and VR, and by developing publications, performing arts products, and souvenirs of red culture.

4.4.2. Education + rural tourism

TWT has a rich variety of flora and fauna, geological landscapes, and historical and cultural landscapes, which are high-quality science teaching resources. The local science study tourism has not yet started, so the development model of "education + rural tourism" has strong market potential. Firstly, natural resources can be utilized in-depth to develop mountainous and hilly landscapes, ecological forests, and bamboo forests, embedding educational and experiential elements to create study camps and practical training bases for teaching geography and biology, and launching tourism products for wilderness survival experiences and skills learning. Secondly, to create educational humanities theme scenes and develop experiential tour programs with students as the main consumers. For example, start tourism programs such as agricultural exploration classrooms, farming experience practices, and handicraft-making interest classes. It is also possible to shape landscape points such as a modern agricultural culture education base, a corridor for displaying the history and culture of nationalism, and a museum of agricultural development so that TWT can become a destination for organizing study tours for primary and secondary school students. Thirdly, we can deeply utilize the local cultural resources, design and build a number of landscape clusters with artistic connotations, and attract teachers and students from art colleges and universities to board at TWT, pick up winds, and write sketches with the beauty of the countryside.

4.4.3. Recreation and sports + rural tourism

TWT is bordered by the Wuyi Mountain Range to the east and also has many water features such as rivers, lakes, and reservoirs. Combined with the high forest coverage and green areas of the town, TWT's landscapes have been praised as a "natural oxygen bar", which makes it a high-quality destination for retirement and sports activities. In the part of "recreation + tourism", first of all, we should emphasize the concept of "ecology + modern agriculture + tourism", with the winery and modern farms as the core, which will lead to the co-development of related industries and the B&B industry. Secondly, we should highlight the culture of grain wine and health maintenance, and integrate food therapy and medication into the process of planting raw materials and manufacturing finished products. Finally, under the theme of "idyllic life, health, and well-being", tourism products can be developed to meet the diversified market needs of short-term, long-term, and migratory bird-type residences,

such as high-end retirement apartments, summer resort villas and special weekend B&Bs. In the "sports + tourism" component, on the one hand, a series of sports events, such as marathons and cycling races, can be developed by integrating and utilizing the resources of the Guitang Highway. On the other hand, we can make use of the natural geological resources of the hilly terrain, Danxia, and karst landscapes of the local area to develop and operate sports tourism products such as outdoor adventure, rock climbing hiking, and mountaineering.

5. Discussion

5.1. Integration of capital

Capital is an indispensable and important supporting element for industrial development, and the mobility of capital determines the sustainability of industrial development. In the face of the future development trend of rural tourism, and the integration of capital, we need to strengthen the government to guide and expand financing channels. The specific focus of the work includes:

Firstly, local governments need to introduce policies to encourage financial institutions to provide financing support to SMEs in the rural tourism industry, implement a loan risk compensation system, and gradually lower the threshold. Secondly, it is necessary to implement the emergency transfer of funds to activate the capital turnover rate, to enable business investment, specialized investment industrial chain investment, and other multi-pronged approaches to increase the role of the financial industry in the development of rural tourism boost. Thirdly, the reform and innovation of financial institutions should be implemented to increase the amount of private funds invested, and financing should be realized by using P2P platforms or developing crowdfunding and other financing methods, so as to gradually improve the market-oriented financing model. Finally, through the establishment of an effective fund management system, the rational planning and distribution of funds for rural tourism development can be realized. Examples include the establishment of an appropriate Industry Development Fund Committee and the utilization of idle funds for low-risk investments.

5.2. Integration of operations

In the era of information technology, the development of the industry is even more inseparable from efficient promotion and operation, which are important means for the industry to realize long-term stable development. Nowadays, people's lives are inseparable from the Internet, and the market image of a product on the network determines its brand value and market sales. In order to promote the high-quality integrated development of the rural tourism industry, in terms of operation and promotion, we can start with the following aspects:

First of all, make good use of all kinds of tourism network platforms to carry out online and offline publicity, create popularity, and improve the brand awareness of rural tourism. Secondly, it is necessary to pay attention to the ratings of each OTA (Online Travel Agency) or third-party website, and correctly deal with the cultural conflict that may arise between the daily "structural" behavior and the "anti-structural" behavior of tourists, with the goal of satisfying the tourists and forming a virtuous

cycle of interaction. Thirdly, local advantageous cultural resources can be utilized to lay communication channels and build dissemination platforms, focusing on displaying and recommending distinctive cultures to enhance their reputation and attractiveness. The government can take the lead in organizing all kinds of experts, scholars, and enthusiasts as the main members of the village protection and cultural heritage as the mission of non-profit public welfare social organizations, writing and finishing the village history, books, and convene the relevant academic forums, so as to enhance the cultural value and social value.

5.3. Integration of resources

In the consequences of modernity, Giles argues that when the social world develops to a certain point, along with the intersection of time and space, it will cause a return to tradition. By analyzing the theory of tourism motivation, it is found that tourists hold a high interest in novelty and the greater the cultural distance the stronger the attraction. However, as cultural distance increases, the sense of unfamiliarity with traveling also increases choices will also be relatively cautious. This shows that there is not a simple linear relationship between cultural distance and travel motivation.

Here, the following suggestions are given on how to regulate cultural distance and take advantage of resources in the development of rural tourism. The first step is to plan well, tell a good story, and make good use of local customs and handicrafts, such as the bamboo culture unique to TWT, the culture of the Jiangnan water town, and the performances of local operas. Secondly, from the perspective of industrial development, it is necessary to focus on the development of special agricultural products, tourism creative products, souvenirs, exhibitions and festivals, cultural theme lodging, and other areas, to expand the integration and overlap of the cultural and tourism industries, but based on the relative advantages of the resource characteristics, it is also necessary to follow the laws of the development of culture and tourism respectively. Finally, we should pay attention to the condensation and transformation of cultural resources, restore and present the intangible heritage and rural cultural resources in the form of stage scenes, and increase the value of cultural resources through commercial operation, so as to provide cultural support for high-quality rural tourism, which is also a kind of embodiment of cultural consciousness and cultural self-awareness.

5.4. Integration of talents

Entering the 21st century, the core of industrial competition has gradually evolved into the competition of talents, and professional talent resources have become the source of power for the sustainable development of an industry. To expand the talent resources of the rural tourism industry, it can be done in the following aspects:

First of all, to attract and gather external elite talents, the strategy of talent introduction can be implemented. This can be done by providing a good working environment and living conditions, and by supporting innovative talent programs to attract experienced and specialized talents to join the rural tourism industry.

Secondly, for the cultivation of internal talents, the means of university cooperation can be utilized. On the one hand, scenic spots and universities can establish cooperative relationships to introduce more college students into the rural

tourism industry through interns, volunteers, and other forms, and on the other hand, they can also utilize the teaching resources of colleges and universities to train and enhance the professional skills of rural tourism practitioners. Finally, it is necessary to encourage and support scientific research institutions, experts, and scholars to conduct in-depth research on rural tourism, to provide scientific and technological support and consulting services, to create a rural high-end development think tank for the countryside, or to provide intellectual support for rural tourism.

6. Conclusion and discussion

6.1. Conclusion and discussion

The focus in this article on a case study such as TWT is likely to mean that specific conditions of climate, topography, and infrastructure will be very different from those of other destinations, and for this reason, it is very important to bear in mind that one of the first requisites for successfully developing rural tourism in a destination is to identify and evaluate the specific conditions of that region. Likewise, it is also important to sort out local cultural resources, as this will affect the direction and focus of the development of the local rural tourism industry. Therefore, we can also further deepen the conclusion of the previous chapter that resources, especially cultural resources, are the most important foundation for the development of the rural tourism industry and the top priority of the work of tourism managers.

Based on the analysis throughout the text, we can draw the following conclusions: In the first instance, the integrated development of industry is the new driving force and development trend of rural tourism. There are two ways of thinking about the convergence and development of industries: one is the convergence between parallel industries, and the other is the convergence between sectors within industries. Secondly, micro-case studies have important theoretical and practical significance for the integrated development of the rural tourism industry, but the experience of successful cases cannot be applied mechanically. Advantageous resources are the foundation of rural tourism development, especially the local characteristics of culture, which should be deeply excavated and utilized. In the end, resources, capital, operation, and talent are the four most important elements of the integrated development system of the rural tourism industry. The development and management of rural tourist attractions can start with these four main aspects.

In conclusion, this paper is a micro case study of a rural tourism development path based on the perspective of industrial integration, characterized by a strong purpose and strong practical reference significance for the development and management of rural tourism. It is also mentioned in the literature review in Chapter 2 that there are more academic studies on the high-quality development of rural tourism, and there is a certain scale of inquiry on the path of tourism industry integration, but most of them are limited to the analysis of a single industry, and there is less literature exploring the high-quality development of rural tourism from the perspective of multi-industry integration. With the main line of promoting the high-quality development of rural tourism, this paper tries to explore the development path of multi-industry integration of rural tourism, facing up to the current situation of academia, where there are fewer research results and insufficient attention in this

specialized field, and expressing some of our efforts and expectations. The diversity of topics covered by the study and the practical application of the research content are the most important features that distinguish us from related and similar studies.

6.2. Limitations

Although this study provides many useful insights, like other empirical studies, it has limitations that provide opportunities for future research. For starters, because this study is a micro case study and was conducted only on Chinese residents, future scholars can delve into this issue from different research scales and countries. In the next place, this study is dominated by qualitative analysis, with less related quantitative evaluation work and more theoretical discussion than analysis of specific data, so future research can strengthen the quantitative aspects of the work. Lastly, there are many integrated development paths of the rural tourism industry proposed for the case in this paper, but all of them are only based on the summarization of the relevant theories and the advantageous resources and problems of the place, and there is no realistic feasibility analysis. The authors' purpose in doing so is to show more of the diversity of the integrated development paths of rural tourism and give readers a broader range of ideas. In future studies, researchers can conduct in-depth studies on certain key paths and strengthen the feasibility analysis of related programs.

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Appendix A

Rural Tourism Questionnaire for Tangwan Township

Hello! Welcome to be able to accept this interview and thank you for helping the research survey onintegrated rural tourism development! The purpose of this questionnaire is to understand thedevelopment of rural tourism in all aspects, and to provide high-quality tourism products and services for your rural leisure and excursions. Your personal information in the questionnaire will only be used for statistical analysis, and the whole process will be handled anonymously and confidentially, you can rest assured that you can fill in according to the actual situation, I apologize for the inconvenience caused, and thank you sincerely for your participation!

I. Basic information and survey of the situation

1. Your gender?
□ male
□ female
2. Your age?
□ 18 and below
□ 18–38
□ 39–58
□ 59 and above
3. Your education?
□ primary and below
□ junior high school
□ senior high school
□ college
□ postgraduate and above
4. Your marital status?
□ Unmarried
□ Married
5. Your occupation?
□ Public office or establishment
□ A private firm
□ Schoolchildren
□ Company employees
□ Others _____
6. Your monthly income? (CNY)
□ Less than 2,000
□ 2000–5000
□ 5001–10000
□ 10000 or more
7. Where are you from? (Please fill in)
□ Jiangxi Province ( ) city
□ ( )Province ( )city
□ Hong Kong, Macao, Taiwan
□ External
8. How did you get here?
□ passenger bus
□ train
□ self-driving car
□ tourist bus
□ helicopter
□ other _____
9. Do you think it's easy to get around here?
□ convenient
□ inconvenient
10. Is this your first time traveling here?
□yes
□no
11. How did you hear about here? [Multiple choice]
□ Friends or relatives to inform you
□ Online social media or third-party travel websites
□ Advertisements on highways or buses
□ Travel agency
12. Mode of accommodation?
□ hotel
□ guesthouse
□ farmyard
□ Family Wine Shop or Winery
13. What do you know about the tourism products in Tangwan? [Multiple choice]
□ Fresh fruits and vegetables
□ Agro-processed products (dried fruits and herbs, etc.)
□ Handicrafts made of bamboo and wood
□ Grain liquor
□ Others _____

II. Perception and satisfaction survey

14. Are you satisfied with the infrastructure in the townscape?
15. Are you satisfied with the services provided by townscape?
16. Are you satisfied with the overall layout of the townscape?
17. Are you satisfied with the creativity of the town's rural tourism?
18. Are you satisfied with the scenic views in the townscape?

19. Are you satisfied with the cultural atmosphere in the townscape?
20. Are you satisfied with the richness of the experience of visiting the town?
21. Are you satisfied with the design of the town's rural tourism routes?

Table A1. Perception and satisfaction survey.

Title number	Very satisfied	Satisfied	Generic	Dissatisfied	Very dissatisfied
14					
15					
16					
17					
18					
19					
20					
21					

If you have any comments or suggestions on the development of rural tourism in the town? Please write below.

_____

_____

Once again, thank you from the bottom of my heart!

Appendix B

Table B1. Statistical table of results of perception and satisfaction survey data.

Title number	Evaluation content	Number and percentage	Very satisfied	Satisfied	Generic	Dissatisfied	Very dissatisfied	Sum
14	Infrastructure	Number	23	53	8	63	28	175
		Percentage	13.1%	30.3%	4.6%	36.0%	16.0%	100%
15	Scenic service	Number	18	40	52	44	21	175
		Percentage	10.3%	22.9%	29.7%	25.1%	12.0%	100%
16	Overall layout	Number	28	64	46	27	10	175
		Percentage	16.0%	36.6%	26.3%	15.4%	5.7%	100%
17	Creativity	Number	20	55	60	28	12	175
		Percentage	11.4%	31.4%	34.3%	16.0%	6.9%	100%
18	Scenic views	Number	41	53	71	8	2	175
		Percentage	23.4%	30.2%	40.7%	4.6%	1.1%	100%
19	Cultural atmosphere	Number	11	38	35	72	19	175
		Percentage	6.3%	21.7%	20.0%	41.1%	10.9%	100%
20	Richness of excursions	Number	14	30	37	68	26	175
		Percentage	8.0%	17.1%	21.1%	38.9%	14.9%	100%
21	Route rationalization	Number	24	46	30	64	11	175
		Percentage	13.7%	26.3%	17.1%	36.6%	6.3%	100%

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Article

The role of sustainability and sustainable development in climate change mitigation and adaptation

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Abstract: Today, the best way to discern the interlinkages between climate change and sustainability and/or sustainable development is the United Nations (UN) Sustainable Development Goal (SDG) 13—Climate Action framework. The 2030 Agenda for Sustainable Development adopted in 2015 presents a shared blueprint for the peace and prosperity of humanity and the planet both now and in the future. At its core lie the 17 SDGs, which cover the 169 targets by constituting calls for urgent action in global partnership among developed and developing nations. Within this scope, countries acknowledge the imperative need to engage in strategies that simultaneously eradicate poverty and other deprivations, combat climate change, safeguard oceans, forests, and biodiversity, improve health and education, reduce inequality, and promote sustainable and climate-resilient economic growth. This article will briefly evaluate the various geographical, environmental, educational, and social dimensions of sustainable and climate-resilient socioeconomic development, considering the nexus between combating climate change and adaptation to climate change, as well as the adverse effects of climate change.

Keywords: climate change; mitigation emission reduction; sustainable development goals

1. Introduction

It has been over 35 years since the World Commission on Environment and Development (WCED), set up in 1983, published the well-known report entitled “Our Common Future” in 1987, which was also known as the “Brundtland Report” due to the Commission’s chairwoman, Gro Harlem Brundtland. This touchstone report developed the guiding principles of sustainable development as they are generally understood today [1]. The Brundtland Report stated that most global environmental problems were primarily the result of the enormous poverty of the Global South and the non-sustainable and non-equity patterns of consumption and production in the Global North. It developed a common strategy of “united development and the environment”, which is now described by the common term “sustainable development”. Sustainable development is defined in the report as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [2]. In 1989, the report was debated in the UN General Assembly (UNGA), and the UNGA decided to organize a UN Conference on Environment and Development, the first of which was held in June 1992 in the city of Rio de Janeiro, Brazil. Today, sustainability is discussed as a broader concept, including environmental and ecosystem health and protection, social justice, equity, economic and social vitality, etc. For instance, the University of California Los Angeles (UCLA) Sustainability Committee defined sustainability as the “integration

of environmental health, social equity, and economic vitality to create thriving, healthy, diverse, and resilient communities for this generation and generations to come. The practice of sustainability recognizes how these issues are interconnected and requires a systems approach and an acknowledgment of complexity" [3]. In this respect, sustainable practices support ecological, human, and economic health and vitality. Sustainability also recognizes that nature and resources are finite and should be used conservatively and wisely with a view to the long-term priorities and consequences of the ways in which resources are confidently made use of now and in the future for our children and our grandchildren, respectively, and for the living planet of the Earth.

2. Current situation and trends in terms of climate change and climate action

Various human activities are unequivocally understood to have caused global warming by elevating the global surface temperature by 1.1 ℃ above the pre-industrial levels of 1850–1900 from 2011 through 2020, primarily through the emission of greenhouse gases (mainly carbon dioxide—CO_2, methane—CH_4, and nitrous oxide—N_2O) into the atmosphere. Global emissions of greenhouse gases continue to rise due to unequal historical and ongoing contributions stemming from unsustainable energy use, land use changes, deforestation, and disparities in lifestyles, consumption, and production models across regions, nations, and individuals [4–6]. Observed variations and effects indicate widespread and rapid changes in the atmosphere, oceans, polar ice caps, and biosphere. Human-induced (anthropogenic) climate change is already affecting extreme weather and climate events and natural climate variability worldwide, leading to extensive adverse effects, associated losses, and significant harm to nature and humanity including climate and/or environmental migrations. On the other hand, it has been well-known that vulnerable communities and countries, historically contributing the least to the current climate change, are disproportionately affected.

When considering the existing progress, gaps, and challenges in adaptation, it becomes evident that adaptation planning and implementation have demonstrated advancement across all sectors and regions with documented benefits and evolving effectiveness. Nevertheless, despite the progress made, there persist gaps in adaptation processes, and these gaps are poised to further increase in current implementation rates. While in certain ecosystems and regions, soft and hard boundaries of adaptation have been reached, disparities in adaptation are experienced across regions and sectors. Global financial flows allocated for adaptation continue to limit the access of developing countries to such options on the grounds of limited adaptation options. When examining current progress, gaps, and challenges in climate change mitigation, it is discernible that policies and laws addressing climate change mitigation have consistently evolved over the past decade. However, the Nationally Determined Contributions (NDCs) submitted under the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement until October 2021 encompass global greenhouse gas emissions (mainly CO_2) in 2030 that could potentially exceed a 1.5 ℃ warming threshold, making it challenging to limit warming below 2 ℃ (the Paris

Agreement's global warming targets). Discrepancies exist between projected emissions from implemented policies and those outlined in the NDCs, while financial flows continue to fall below the required levels to meet climate goals across all sectors and regions [4,5,7,8].

The Sustainable Development Goals (SDGs) were adopted by the United Nations in 2015 as a universal declaration of action to end poverty, protect the Earth, and ensure that by 2030 all people have peace and prosperity [9]. The 17 SDGs are integrated—they recognize that action in one area will affect outcomes in others, and that development must balance social, economic, and environmental sustainability [10]. On the other hand, among others, in terms of having objective indicators of sustainable development, there are criticisms. For instance, Hák et al. [11] pointed out that indicators of varied quality have been proposed to assess sustainable development in various aspects, with respect to the fulfillment of certain criteria. Although there are plenty of theoretical works on quality standards for required indicators, in practice users cannot often be sure how the indicators really measure monitored phenomena [11].

SDG 13 aims to "take urgent action to mitigate climate change and its impacts" and recognizes the UNFCCC as the primary international and intergovernmental forum to discuss the global response to climate change. More specifically, the relevant targets of SDG 13 focus on integrating climate change measures into national policies, enhancing climate education, addressing mitigation or elimination of climate change, adaptation, reducing the impacts of climate change, creating awareness about early warnings, and focusing on institutional capacity building. The goals of SDG 13 also necessitate the implementation of commitments undertaken within the UNFCCC and support mechanisms that can enhance effective planning and management capacities related to climate change, especially in the least developed countries and developing Small Island Developing States [6].

The Future We Want, the outcome document of the Rio+20 Conference, underscores that climate change is an "inescapable and urgent global issue with long-term effects on sustainable development for all countries." Through this document, Member States express concerns regarding the continuous rise in greenhouse gas emissions and the vulnerability or susceptibility of all countries, particularly developing ones, to the adverse impacts of climate change. While present and persisting, these concerns have not been notably considered highly meaningful or serious in subsequent years. Member States have called for the widest collaboration and participation of all countries in an effective and appropriate international initiative against climate change [6,7].

The UN Sustainable Development Goal 13—Climate Action has been significantly considered in the Intergovernmental Panel on Climate Change (IPCC) Special Report on Global Warming of 1.5 °C [4]. This report broadly addresses the impacts of 1.5 °C global warming on the pathways of global greenhouse gas emissions related to natural and human systems. It encompasses the necessary reduction of global greenhouse gas emissions (response) required to address the threat of climate change within the context of sustainable development and efforts to eradicate poverty [6]. The report's more optimistic message lies in the synergy between sustainable development and limiting global warming to 1.5 °C. According to this perspective, many pathways

to achieve the 1.5 ℃ target would contribute to achieving the SDGs in critical areas such as energy access involving new technologies like decentralized renewable energy systems or improvements in public health [7].

3. Climate change mitigation, adaptation, and interactions with sustainable development

Climate change mitigation can be defined as "a set of human activities, initiatives, actions, measures and policies aimed at reducing greenhouse gas emissions in all human systems and improving and increasing sinks" [6]. It may be possible to define adaptation separately for human systems (socioeconomic sectors, activities, etc.) and natural systems (biomes, ecosystems, habitats, life communities, etc.). With this approach, adaptation in human systems can be defined as "the process of adaptation to the existing or expected climate and its effects to reduce losses and damages or to take advantage of beneficial opportunities," and adaptation in natural systems can be defined as "the process of adaptation to the current climate and its effects" [6,8]. Regular, rational, and planned human initiatives based on the values of nature, people, and ecosystems, considering science, can facilitate adaptation to the future climate and its effects. In fact, adaptation is a factor that should be considered at the very beginning and at every stage of a sustainable development process. By integrating this early into their policies and strategies, governments can accelerate robust economic development while reducing vulnerability to climate change. Adaptation approaches vary by geography, time, funding sources, levels of political support, and dozens of other factors [8]. There is no one-size-fits-all approach to adaptation. In this respect, however, adaptation examples can consist of taking engineering measures, such as raising special walls and levees on highly vulnerable coasts, to protect against, for example, more severe and frequent storms and storm surges that tend to occur higher and more frequently, or to protect water resources, basins, and wetlands, or to protect and restore steppe ecosystems, rainforests or coral reefs, or to provide early warning systems for wildfires and severe droughts.

Climate change mitigation and adaptation together can lead to long-term mutual interactions, synergies, and trade-offs with sustainable development. Accelerated and equitable action in mitigating climate change and adapting to it also provides benefits in avoiding damages caused by climate change and is critically important for achieving sustainable development goals overall [5,7]. Climate-resilient development pathways are progressively constrained with each incremental increase in further global warming. On the other hand, there is an increasingly narrowing window of opportunity to secure a liveable and sustainable future for everyone.

Climate change mitigation and adaptation options can also lead to synergies and mutual interactions with other aspects of sustainable development. Considering climate justice, these synergies and trade-offs depend on the pace and magnitude of changes, including inequalities, within the development context [5]. This is because as climate change intensifies, the potential or impact of certain adaptations and climate change mitigation options diminishes. For instance, transitioning to low-emission systems in the energy sector could yield numerous additional benefits, including

improvements in water, soil, and air quality, and health. Potential synergies exist between sustainable development, such as energy efficiency and renewable energies.

For agriculture, land, and food systems, numerous land management options and demand-side response options (such as dietary choices, reducing post-harvest losses, and reducing food waste and excess) can contribute to eliminating poverty and hunger, particularly in developing countries and impoverished communities, while enhancing health, well-being, access to clean water, sanitation, and sustaining life on Earth [12]. Conversely, certain adaptation options that encourage the intensification of production, such as irrigation methods not based on modern (e.g., drip irrigation, sprinkler systems, etc.) scientific techniques, may have adverse effects on sustainability (e.g., in terms of biological diversity, ecosystem services, depletion of groundwater, and water quality, etc.).

Carbon Dioxide Removal (CDR) represents a significant concept elucidating approaches aimed at removing carbon dioxide (CO_2) from the atmosphere. CDR encompasses a wide array of methodologies, including Direct Air Capture (DAC), coupled with permanent storage, soil carbon sequestration, bioenergy with carbon capture and storage (BECCS), enhanced mineralization, ocean-based CDR, afforestation/reforestation, among others. Importantly, CDR does not imply point-source carbon capture for fossil fuels or industrial sectors. Alongside the simultaneous deployment of greenhouse gas emission reduction measures and other carbon management practices, CDR serves as a comprehensive climate change mitigation tool addressing emissions stemming from some of the most challenging sectors (e.g., agriculture and transportation), ultimately mitigating 'past' CO_2 emissions from the atmosphere [8].

Within this context, reforestation and afforestation/forest restoration, improved forest management, soil carbon sequestration, peatland restoration, and coastal blue carbon management exemplify CDR techniques and application tools that, depending on the context, can enhance biodiversity, ecosystem functions, employment, and local livelihoods. However, the implementation of biomass production for CO_2 capture and storage or bioenergy through biochar or afforestation, especially on a large scale and in areas with insecure land tenure, could potentially result in adverse socio-economic and environmental impacts, including biodiversity loss, food and water insecurity, local livelihoods, and indigenous rights. Modeled pathways that assume more efficient resource utilization or shift global development towards sustainability entail fewer challenges, such as dependence on CDR and less pressure on land and biological diversity, thus presenting more prominent synergies for sustainable development [5].

Strengthening actions to combat climate change and mitigate its effects necessitates both faster transitions and higher upfront investments, while also providing benefits such as preventing damages caused by climate change and reducing the costs of adaptation. The collective impacts of climate change mitigation on the global Gross Domestic Product (GDP) (excluding damages from climate change and adaptation costs) are relatively small compared to projected global GDP growth. Predicted estimates regarding global total net economic losses and adaptation costs generally increase in tandem with the level of global warming [8].

Cost-benefit analysis is limited in its ability to represent all losses stemming from climate change, including non-monetary damages, or capture their heterogeneous

nature and the risk of catastrophic damage [5]. Many studies indicate that even without accounting for these factors or their co-benefits, the global benefits of limiting global warming to 2 ℃ surpass the costs of mitigation. This finding holds strong despite a wide range of assumptions regarding inequalities and social preferences. Therefore, steering global efforts towards limiting global warming to 1.5 ℃ rather than 2 ℃, in line with UN-guided climate actions (such as the UNFCCC Paris Agreement, UN SDGs—Climate Action, etc.), will increase mitigation costs [5,8]. However, it will also bring substantial benefits in terms of reduced impacts, associated risks, and decreased adaptation requirements.

Considering other dimensions of sustainable development, such as the potentially robust economic benefits derived from improving air quality for human and ecosystem health, could enhance the anticipated benefits of climate change mitigation. The economic impacts of strengthened mitigation actions vary across regions and countries, particularly depending on economic structure, regional emission reductions, policy design, and the level of international collaboration. Conversely, ambitious mitigation pathways imply significant and sometimes disruptive changes in the economic landscape, affecting short-term actions, fairness, sustainability, and finance. This holds especially true for developing and least-developed countries and impoverished communities, resembling the potentially more devastating social, economic, societal, and environmental consequences similar to maladaptation actions [8].

4. Some elements of comprehensive climate action for climate resilient development

A comprehensive and equitable approach integrating climate change mitigation, adaptation, and development should be thought of to advance sustainable development in the long term. Comprehensive responses within this scope can leverage synergies for sustainable development and reduce trade-offs [5]. Shifting development pathways toward sustainability and developing climate-resilient sustainable development is possible when governments, civil society, private sectors, and capital groups make community-centric development choices prioritizing risk reduction, fairness, and socio-economic-environmental justice and equity [7,8]. This is achievable when decision-making processes, financing, and actions are aligned across governance levels, sectors, and timeframes, emphasizing local knowledge and inclusive processes that include indigenous knowledge. However, opportunities for action may significantly differ among regions and within them due to historical and ongoing development models, a trend that is likely to persist in the future. Therefore, accelerated financial support for developing countries holds critical importance in enhancing climate change mitigation and adaptation actions.

Moreover, policies that shift from ‘traditional’ continuous production and industry-based growth paths to sustainability can expand the existing array of mitigation and adaptation efforts. Broader sectoral policies integrating approaches that encourage lifestyle or behavioral changes, combined with actions redirecting climate change mitigation towards development pathways such as financial regulations or macroeconomic policies, can overcome various barriers and create a wider range of

mitigation options [8]. Investments in integrated, inclusive planning and decision-making processes related to urban infrastructure can significantly enhance the adaptive capacity of both urban and rural settlements. The significant human habitation in the geomorphologically low coastal zones, coupled with the increasing and compounded climate risks faced by these populations, underscores the crucial role of coastal cities and settlements in advancing climate-resilient development, both within national economies and beyond [13].

The observed adverse effects of climate change, related losses and damages, anticipated risks, vulnerability trends, and adaptation limits indicate that the urgency for transformation toward sustainability and climate-resilient sustainable development is more pressing than previously assessed [7,12,14]. Furthermore, climate-resilient development integrates both adaptation and greenhouse gas reductions to advance sustainable development for all. Paths toward climate-resilient development have been gradually constrained by past developments, emissions, and particularly by each increment of warming above 1.5 ℃ due to climate change. Several studies, notably the latest reports from the Intergovernmental Panel on Climate Change (IPCC) offering the most significant global climate change assessments [15,16], suggest that in some regions and sub-regions, climate-resilient development may not be achievable if global warming surpasses 2 ℃. Protection of water resources, agricultural lands, biodiversity, and ecosystems among other aspects is essential for climate-resilient development. However, the capacity of biodiversity and ecosystem services to adapt to escalating levels of global warming is limited, increasingly complicating the achievement of climate-resilient development beyond the 1.5 ℃ global warming threshold [4,13,14].

Globally, every geographical and climatic region of the Earth is currently facing more frequent and severe compound and/or consecutive climate risks in the short term. Changes in these risks stem from alterations in the degree of danger or disaster, the exposed population, and the level of vulnerability of humans, living beings, biodiversity, and ecosystems [8]. Climate-related disasters can trigger chains of risks that spread across regions, affecting multiple sectors, and following intricate natural and societal connections (**Figure 1**). This initiates significant obstacles to the successful advancement and widespread implementation of adaptation and climate-resilient sustainable development. For instance, a severe compound heatwave and drought striking an agricultural region exemplify how interconnected risks lead to consecutive geographical, ecological, economic, and societal consequences, particularly impacting vulnerable groups like small-scale farmers, children, and pregnant women even in distant areas (for example, in **Figure 1**). Additionally, the figure might include various impacts of a prolonged and severe compound heatwave and hydrological-ecological drought on forest fires.

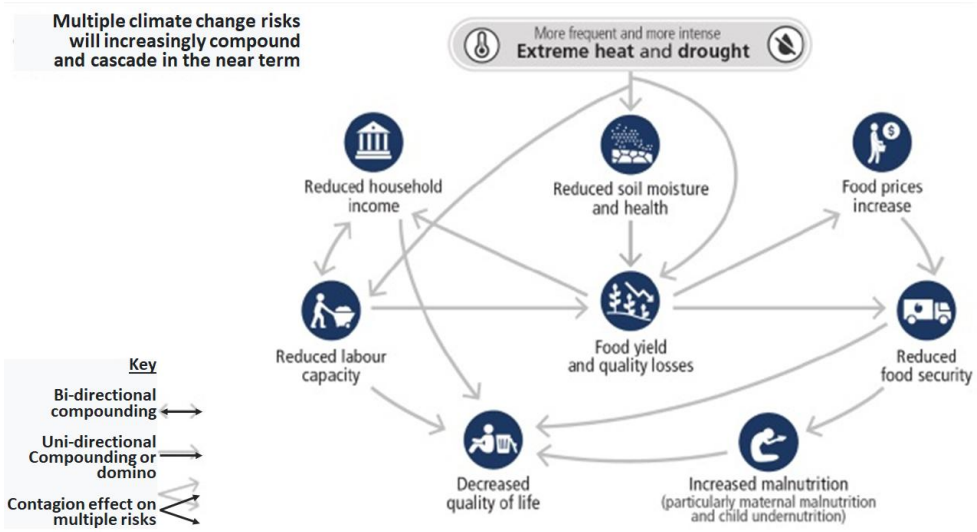

Figure 1. The compounding effects and various interactions of multiple climate change risks for smallholder farmers (re-arranged with some modifications from IPCC 2023). The figure displays the compounded impacts and interactions resulting from extreme high-temperature events and drought occurrences, such as record-high temperatures, prolonged and severe heatwaves, and agricultural-hydrological droughts. These factors lead to yield losses and quality reduction in agriculture.

Climate change poses a threat to both human well-being and the health of the planet. Therefore, any delays in coordinated and forward-looking global action concerning climate mitigation and adaptation carry characteristics that might lead to missing a rapidly closing window of opportunity to secure a liveable and sustainable future for everyone [8]. Removing or mitigating barriers to implementing and executing widespread climate mitigation and adaptation options will be necessary. Numerous limits on the feasibility or realization of these options, including economic, technological, institutional, social, environmental, and geographical barriers, could be overcome by addressing a range of obstacles [5]. The feasibility and effectiveness of these options increase through public, comprehensive, multisector solutions that differentiate responses to climate risk, interrupt between systems, and address social inequalities [8]. Strengthened short-term actions in cost-effective pathways modelling global warming to 2 ℃ or lower can better reduce the overall risk to the feasibility of system transitions compared to modelled pathways involving delayed or uncoordinated actions.

Various socio-economic and ecological development pathways and their associated outcomes indicate a rapidly narrowing window of opportunity to secure a liveable and sustainable future for everyone and all living beings. For instance, climate-resilient development represents the process of implementing greenhouse gas reduction and adaptation measures against the adverse impacts of climate change to support sustainable development [8]. Divergent pathways demonstrate how interactive choices and actions made by various government, private sector, and civil society actors can advance climate-resilient development, shift pathways towards sustainability, and facilitate lower emissions (high emission reductions) while adapting to climate change [5,13]. These various insights encompass diverse

knowledge and values, cultural perspectives, indigenous and local knowledge, and scientific information.

Droughts, storms, extreme rainfall, floods, or non-climatic events like epidemic diseases (e.g., COVID-19 pandemic, Ebola virus disease, etc.) can create more severe disruptions in pathways with lower climate resilience compared to those with higher climate resilience. In a 1.5 °C global warming scenario, there are limits to adaptation and adaptive capacity for some human and natural systems, and with each incremental increase (e.g., 0.1 °C) in warming, losses and damages will escalate [4,5,7,17]. The development pathways followed by countries throughout all stages of economic development influence the level or magnitude of greenhouse gas emissions, shaping the varying challenges and opportunities for mitigation across countries and regions. Action pathways and opportunities are shaped by past actions (or inactions and missed opportunities, etc.) as well as facilitative and constraining conditions, and they intersect within the context of climate risks, adaptation limits, and developmental gaps [5]. The longer emission reductions are postponed, the fewer effective opportunities will remain available for adaptation.

5. The role of science and education in achieving the sustainable development goals

In this section, a brief review of the current science and education policies and actions on climate change mitigation and adaptation has been performed. In the context it was discussed so far, answering the questions of how the national and global scientific community should support the implementation of the SDGs and strengthen its capacity, focusing, inter alia, on how educational institutions from primary and secondary education to universities and science academies can play their role in this system to improve the input of the SDGs into the national and global policy environment, etc. are all vital.

There are many scientific articles written about climate change education and the role of science and education in climate change mitigation and adaptation and disaster risk reduction, etc., many of which were prepared as a review or an assessment study [18–25]. It is recognized that the Climate Change Education for Sustainable Development is a comprehensive and multidisciplinary approach. “It asserts that it should not only include relevant knowledge on climate change, environmental and social issues, disaster risk reduction, and sustainable consumption and lifestyles, but also a focus on the institutional environment in which that content is learned to ensure that schools and education systems themselves are climate-proofed and resilient as well as sustainable and green” [19].

Education, which is linked to “SDG 4: Quality education”, and science is key to achieving all SDGs in Agenda 2030. The remaining 7 years to 2030 will be critical to revitalizing national and global efforts to transform education so that states and communities have the skills and knowledge to live together in harmony with our approximately 4.6-billion-year-old Living Planet of the Earth. However, aside from the effects of major global crises to date, it is observed that efforts to achieve the SDGs have slowed down not only in Turkey but also in many other countries, which have never been at the level they should be. In this context, one of the biggest obstacles to

progress has been the lack of scientific literacy, especially the understanding of sustainability, among the generations that will assume leadership. Therefore, there is an urgent need to find new ways of education that will serve our common needs and future. On the other hand, there are many strengths to take forward and many things that need to change. For example, a new social contract for education both in my country and other countries could provide both a vision and a solid and ambitious process for transforming education.

Science and education have always had to adapt to and respond to a changing world. Today, more than ever, education must help transform the world. In this context, first, it should be ensured that education is a lifelong human right. Unsustainable, undemocratic, and non-participatory economic and social development models endanger the future of humanity and the Earth. In this context, education is a part of the problem and the solution, and the education systems do support environmentally sustainable, democratic, and socially fair progress and development models [6,8]. Moreover, education is the best tool to optimize the relationship between democracy, diversity, social progress, prosperity, justice, and equity. However, currently, worldwide education is not suitable for these purposes. That is why a bold transformation in education is urgent and a priority.

For example, the SDG Academy, which supports UNESCO's 2030 Education for Sustainable Development (ESD) roadmap, was tasked with creating and curating the best educational content available on sustainable development and presenting it as a global public value [26]. Although the initial focus was on higher education institutions, the focus is now on ensuring the continuity of sustainable development education from pre-school to lifelong learning and implementation efforts. The core mission of the SDG Academy is to promote educational pathways that will help students acquire the tools, skills, and knowledge that will promote sustainable development at all stages of their lives.

Ideally, individuals at all stages of life should understand how they live together in harmony with other people, societies, and the Earth. In this context, all of us, in Turkey and in all countries of the world, must learn how to establish positive bonds with humans and nature in our daily activities and pursuits. This will not only secure a much-improved life support system for today's generations but also a sustainable future for future generations and societies.

Finally, it is useful to remind people that ESD is the key to achieving sustainable development through the following six SDG transformations [27]:

1) Education, gender, and inequality.
2) Health, welfare, and demography.
3) Decarbonization of energy and sustainable industry.
4) Sustainable food, soil, water, and oceans.
5) Sustainable cities and communities.
6) Digital revolution for sustainable development.

6. Concluding remarks

Each incremental increase in global warming will escalate losses and damages, making avoidance increasingly challenging, and the most vulnerable, impoverished

individuals, communities, and low-income working or unemployed labor classes in every country will experience intensified adverse effects. Global assessments indicate that overall adaptation cannot prevent all losses and damages effectively, even before reaching firm boundaries. As it has been learned from past discussions under the UNFCCC process and current negotiations within the Paris Agreement, losses and damages will highly likely be distributed unequally among social classes, regions, and sectors. Especially in highly vulnerable developing and least developed countries, which have high vulnerability, these losses and damages are unlikely to be comprehensively and fairly addressed by existing financial, governance, and institutional arrangements. "High levels of poverty, water, food, and energy insecurity, vulnerable urban areas, degraded ecosystems, rural environments, or biomes with limited resources face numerous non-climatic challenges exacerbated by climate change, hindering climate-resilient sustainable development" [13].

On the other hand, there should be a clear education agenda at the global, regional, and national levels in climate change adaptation and mitigation strategies, which require learning new knowledge and skills and changing behaviors to manage and overcome the risks of adverse climate change impacts by reducing the vulnerabilities of the human and natural systems. Consequently, not only investing in quality education for mitigating and adapting to climate change but also strengthening emergency preparedness through capacity-building in disaster risk reduction and climate change adaptation in the education sector are essential tools in achieving SDG transformations.

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Article

Geological and hydro-chemical characterisations of groundwater resources in the Wa municipal district

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Abstract: Few studies go beyond one or two parameters of groundwater characterisation at a time. This paper uses a multifaceted approach to describe the nature of groundwater beyond water quality, including the physical, environmental, and practical aspects of groundwater prospecting, the health effects, and how these conform to expected standards in global and national contexts. This was achieved by exploring the geological and hydrochemical characterisations of groundwater in the Wa municipality of Ghana. The main objective was to describe the spatial, hydro-geological, and hydro-chemical characteristics of groundwater in the rural areas of the Wa municipality. Using a sequential exploratory mixed research design and a digital elevation model, this study found that groundwater constitutes the main source of safe drinking water for rural and peri-urban communities, geologically dominated by granite and sandstone aquifers. The average transmissivity was 8.88 m^2/day, the average hydraulic conductivity was 0.18 m/day, the average aquifer thickness was 56.8 mbgl, and the average borehole water yield was 14.54 L/min. However, there were technological constraints on the ability to prospect water from confined aquifers at sites in the higher parts of the digital elevation model. Also, a lack of water quality tests for some boreholes results in the exposure of users to the effects of fluoride, causing dental fluorosis. The use of ultra-deep hand pump technologies, water quality testing of all boreholes, and artificial groundwater recharge methods for sustainable borehole water yield were recommended.

Keywords: characterisation; geology; groundwater; hydrology; Wa municipal; water quality

1. Background of the study

Groundwater is a resource hidden in the rocks of the earth's crust [1]. It is formed by natural and artificial means [2]. Naturally, rainwater infiltrates into the soil and surface water bodies such as rivers and lakes, and part of it is absorbed into underground water-bearing rocks, known as aquifers. In areas with inadequate surface water, the natural groundwater recharge cannot be balanced [3], so artificial recharge is used by spreading excess water on the surface of the earth or using recharge wells to increase infiltration to replenish an aquifer [4].

Groundwater is exploited from springs and wells, provides 30% to 50% of global water needs, and is consumed directly as safe drinking water [5]. In developing countries, groundwater accounts for 95% to 100% of potable water supplies [6]. Other important aspects of groundwater include provisioning services, by which groundwater is used for various human needs such as agriculture, industry, and domestic uses; regulatory services, involving the ability of aquifers to regulate the quantity and quality of groundwater systems; supporting services, through which the

needs of groundwater-dependent aquatic and terrestrial ecosystems are met; and cultural services, associated with the leisure, traditional, and spiritual properties of groundwater [7]. In areas where human activities pollute surface water to lose its quality for most domestic uses, the demand for groundwater is a necessity [8]. These are the reasons why characterisation of groundwater is imperative for the purpose of planning its effective use.

Several studies have been conducted on the characterisation of groundwater. For example, Gorai and Kumar [9] conducted a study on the characterisation of groundwater at Ranchi in India. However, they focused only on spatial distribution analysis of the groundwater quality index. Bodrud-Doza et al. [10] also conducted a study on groundwater in Bangladesh, but their study was narrowed to the characterisation of groundwater quality using various evaluation indices. In Ghana, Okofo et al. [11] and Manu et al. [12] concerned themselves with the hydrogeochemical characterisation of groundwater in the 'Tamnean' plutonic suite aquifers in the Garu-Tempane District of the Upper East Region and the Pra Basin, respectively. However, these studies were based on the rigorous geodesy of rocks and their chemical and water-holding properties.

From the above, apart from the spatial gap of non-coverage of the Wa municipality in the literature on groundwater, most studies on the characterisation of groundwater focus on the geology and water quality characteristics. But ordinarily, characterisation is about the description of the distinctive features of something [13]. Accordingly, this paper describes the nature of groundwater beyond water quality by incorporating the physical, environmental, and practical aspects of groundwater prospecting and how these conform to expected standards in global and national contexts.

Spatially, the focus is on features of the study phenomenon related to the geographic location or study area [14], that is, the Wa municipality. This study therefore investigated the groundwater situation in terms of its distinctive attributes in the study area. Geologically, groundwater is found in aquifers and sediments, and the more porous the rocks of an aquifer, the higher the capacity to store groundwater [15]. The nature of the bedrock and soil types and the relationship between these and groundwater were of interest in this study. For instance, in a study of the Qaidam Basin of Northwest China, Zhang et al. [16] found that areas with high groundwater holding capacities had sandstone, slates, coarse sand, and sandy clayey soils, with the water emanating from the fissures of their bedrocks. Kesse [17], cited in Asante-Annor and Ewusi [8], also found that in the Adansi mining area of Ghana, the Birimian and Tarkwaian bedrocks are common and have high water storage capacity, which may flow through the rock fractures and bedding patterns. However, these studies did not go beyond geological and hydrochemical characterisations to include issues of drilling success rates and operation outcomes associated with groundwater infrastructure.

Research findings on the characterisation of subsurface geological layers and their influence on groundwater supply are essential in planning for the promotion of water security [18]. In general, whereas mainstream literature is replete with information on the spatial, geological, and physicochemical aspects of groundwater, such findings are usually focused on some specific distinctive feature, such as geology or water quality. This leaves a research niche for multifaceted analysis of groundwater

prospecting and use, for a detailed understanding of the groundwater situation in a study area.

2. Objectives of the study

This paper describes:

- The study area: relevant characteristics of rural areas of the Wa municipality as the spatial unit of analysis;
- The hydro-geological and hydro-chemical characterisation of groundwater.

The paper is structured to achieve these objectives with a background statement, description of the hydrological cycle and groundwater formation, conceptual framework, research methods, discussion of results, and conclusions.

3. Hydrological cycle and groundwater formation

Groundwater formation is part of the hydrologic cycle, which explains the continuous movement of water above and below the surface of the earth [19]. **Figure 1** shows that radiation from the sun causes evapotranspiration from surface water bodies such as the sea, rivers, and lakes, as well as plants and animals. These rise into the atmosphere to cool, condense, and return to the land and surface water bodies as precipitation [2].

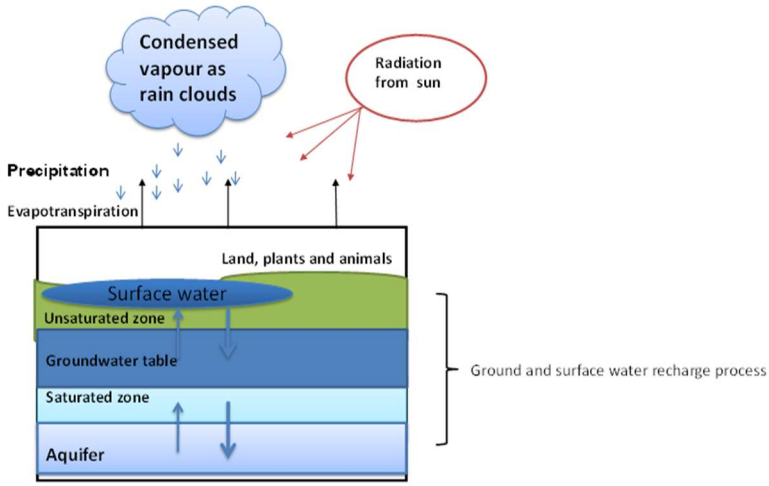

Figure 1. Hydrological cycle and groundwater formation process.
Source: Author's own construct.

Part of the water from precipitation permeates downward through soil pores and rock fractures to form aquifers underground [19]. Also, part of the surface runoff from precipitation and groundwater moves into the sea, rivers, and lakes to recharge them [20]. The water below the surface of the earth exists in layers. Beneath the topsoil is the unsaturated zone, containing water and air in the soil and rock pores [21]. This is followed by the groundwater table and the saturated zone, respectively. The saturated zone contains an excess amount of water and lies above the aquifer [2]. Both surface and groundwater sources recharge each other. Aquifers gain water through precipitation, surface runoff, and water bodies. Surface water bodies also gain water

from aquifers through capillary force, which pulls groundwater upward against gravity [22].

The above relationship has practical implications for how to address water insecurity issues in semi-arid and arid areas [4]. For example, the drying up of surface water bodies does not spell absolute water shortage, since part of it would have been stored in aquifers to be prospected as groundwater. Thus, while lamenting that Ghana's One-Village-One-Dam programme was a failure because the dams dried up, constructing boreholes at the spots where the dams were constructed could provide safe water from the aquifers near the dams. The dams in this regard, then serve as artificial methods of groundwater recharge [3].

4. Conceptual framework

Figure 2 illustrates the relationship between the spatial unit, hydro-geological and hydro-chemical characterisations of groundwater, each of which has been explained below.

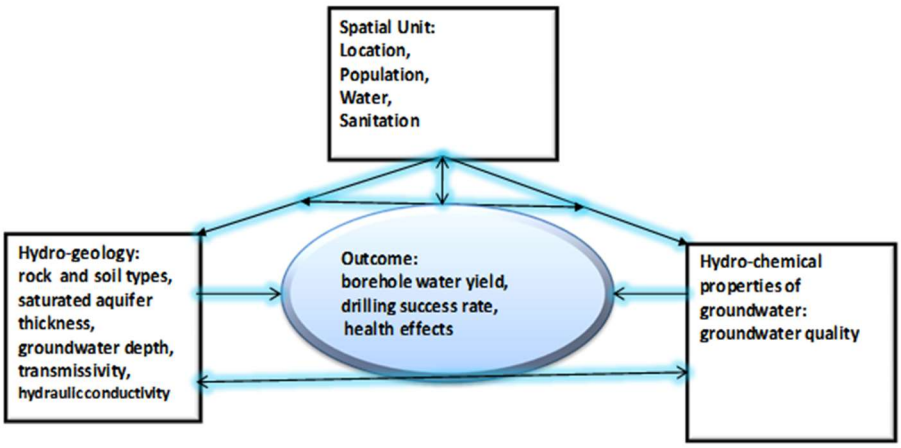

Figure 2. Conceptual framework of hydrogeological characterisation of groundwater.

4.1. Spatial unit

Spatial aspects in research relate to features of the study phenomena in the study area [14]. **Figure 2** shows the location, population, water, and sanitation as basic variables of interest in this study. The location in terms of region, district, community, and climatic belt has bearings on stratification by settlement types and hydrological significance, including surface and groundwater [23]. The Upper West Region in which the Wa municipal district is located is found in the tropical continental climatic belt of Ghana, which has a single maximum rainfall regime. This has implications for the amount of precipitation that recharges surface and groundwater [19,20]. Accordingly, changes in the rainy and dry seasons in the study communities linked to groundwater availability and use were ascertained.

Population as a spatial factor is measured as a variable in order to match groundwater infrastructure against population by planning standards, to see where

gaps exist in terms of adequacy or not. Water and sanitation, as well as all aspects of the spatial unit, have been looked at in the broader context of hydro-geo-chemical characterisations.

4.2. Hydrogeology

Hydrogeology, also referred to as geohydrology, deals with how groundwater interacts with the surrounding soils and rocks through the processes of recharge, as it flows from the surface and enters aquifers underground [24]. This study assessed the rock and soil types and their water-holding characteristics in terms of aquifer thickness, aquifer depth, and transmissivity.

The common soils of northern Ghana, in which the study area is located, are clay and sandy soils, with 80% of the soil being sandy clay [25]. Clay and sandy soils are weathered from mudstone and sandstone rocks, respectively [26]. Coarse-textured sandy soils have large pore spaces for easy infiltration of water to reach the water table [27]. However, clay soils are less porous, slowing down the permeability of water to the water table [28]. The types of rocks, soils, and their relationships with other groundwater characteristics as presented in **Table 1** have been examined in the specific contexts of the study communities.

Table 1. Types of aquifer rocks and their relationships with groundwater.

Aquifer rock type	Major form	Water holding characteristics	Hydraulic conductivity	Chemical properties and water quality concerns
Sedimentary rocks	Consolidated or unconsolidated	High primary porosity and the primary water-bearing and producing rock	Very high hydraulic conductivities	Arsenic (causes cancer, skin lesions, cardiovascular disease, diabetes); Chromium (causes lung, nasal, and sinus cancer)
Igneous and metamorphic rocks	Crystalline-rock and volcanic-rock	Igneous and metamorphic rocks are permeable only where they are fractured, and they generally yield only small amounts of water to wells. But when they extend over large areas they yield large volumes of groundwater	Wide range of hydraulic properties due to variations in rock type	Arsenic (causes cancer, skin lesions, cardiovascular disease, diabetes); Calcium (improves the nervous system, blood circulation, and muscle movement); Aluminum (causes kidney disease); Magnesium (essential cofactor of several enzymes, improves neuromuscular conduction); Iron (needed for body growth and development)
Limestone	The upper units of limestone aquifers may be crushed or weathered materials, whereas the lower units are generally unaltered or fractured hard materials	Fractured limestone aquifer is considered a highly productive aquifer	Very low hydraulic conductivity	Calcium carbonate (causes constipation, flatulence, and bloating); Magnesium carbonate (acts as an antacid by neutralizing the excess acid in the stomach), Calcium hydroxide (it neutralizes acidic pickling juices, which reduces their antibacterial properties); Magnesium hydroxide (causes gastrointestinal irritation, and watery diarrhea)
Sandstone	Consolidated rocks	When extended over a large area, sandstone aquifers can be highly productive and provide large volumes of water	The hydraulic conductivity of sandstone aquifers is low to moderate	Silicon dioxide (no evidence to suggest that silicon dioxide is dangerous to human health); Calcium carbonate (causes constipation, flatulence, and bloating)
Granite	Plutonic and crystalline	They have a medium to low permeability, and so contain aquifers with modest water resources	Coarse-grained granite aquifers have greater length and higher hydraulic conductivity	Potassium (lowers urinary calcium excretion and plays an important role in the management of and kidney stones); Feldspar (causes nausea, weakness, chest pain); Mica (abdominal pain, diarrhea, and vomiting)

Source: Akanbi [42]; El-Rawy and Smedt [43]; Sudheer et al. [41].

An aquifer is a body of porous or permeable unconsolidated sediments or fissured rocks containing groundwater, hydraulically continuous according to its size and from

which groundwater could be exploitable in useable quantities [23]. Of interest in this study was saturated aquifer thickness. Saturated aquifer thickness is the vertical thickness of the pore spaces of the rock forming the aquifer and filling it with water [29]. It was necessary to investigate aquifer thickness, especially for unconfined aquifers in this study because it influences aquifer storativity, which measures the volume of water dischargeable from an aquifer per unit area and per unit reduction in hydraulic head, independent of aquifer dimensions [30]. Unconfined aquifers were of interest because only boreholes related to them were studied. They are aquifers with groundwater in direct contact with the atmosphere through the open pore spaces of the overlying soil or rock, and atmospheric pressure could increase or decrease the groundwater in such aquifers [31].

Aquifer size is synonymous with a description of the size of a 'container' that stores groundwater. In other words, it is the volumetric storage capacity of an aquifer and is measured by the bulk volume of the aquifer rock times its mean specific yield [32]. However, the geology of some areas dominated by sandstone aquifers impedes the ability to assess the aquifer size homogenously. Although these extend over large areas and provide large amounts of water [33], the sandstone aquifers in the study area, or the Upper West Region of Ghana in general, are largely discontinuous, making it easier to estimate their thicknesses rather than sizes [34]. Hence, there was a need to investigate the average aquifer thickness and its implications on borehole water yield.

Aquifer depth as a geohydrological factor refers to the mean depth below the surface of the earth at which groundwater can be found for the purposes for which it is required [35]. Aquifer depth varies spatially and seasonally, with several studies reporting various results. For instance, Green et al. [36] found minimum and maximum aquifer depths of 15 mbgl to 90 mbgl at the Gwydir River catchment area in Australia. In the case of Ghana, Kyere et al. [37], in their study of groundwater prospecting in the Bawku West District, found aquifer depths ranging between 10 mbgl and 40 mbgl, and an average depth of 21.4 mbgl. According to Rural Water Supply Network [38], the standard aquifer depth for a borehole fitted with a hand pump is 50 mbgl or less. This study therefore ascertained the aquifer depths of boreholes fitted with hand pumps in the study area to determine their conformity to acceptable standards, which could inform water resource use planning.

Transmissivity describes the ability of the aquifer to transmit groundwater throughout its entire saturated thickness and is measured as the rate at which groundwater can flow through an aquifer section of unit width under a unit hydraulic gradient [39]. In simple terms, it is the ease with which groundwater flows below the surface of the ground in an aquifer. The commonest aquifer rocks in northern Ghana are granite and sandstone [40]. The transmissivity of granitic aquifers varies from 10.28 to 90.06 m^2/day with a mean of 33.6 m^2/day [41], and a water yield of 56.8–91.1 m^3/day [42]. Sandstone (basic aquifer rock) has a transmissivity average of about 400 m^2/day [43], and a water yield of between 138 and 1683 m^3/day [44]. Transmissivity was determined in this study for comparison to the expected standard. Related to this is hydraulic conductivity, a parameter that measures the ease of water flow through a permeable aquifer under the influence of other characteristics of the aquifer and the nature of groundwater, including density and viscosity [45]. This was also ascertained for the explanation of groundwater movement behaviour.

4.3. Hydro-chemical properties of rocks

Table 1 presents details of the hydro-chemical properties of some common aquifers by listing sedimentary rocks, igneous and metamorphic rocks, sandstone, limestone, and granite as examples. It also shows the forms in which the aquifer rocks occur, as well as their water holding and chemical properties, including the health effects of each chemical property, based on the findings of Akanbi [42], El-Rawy and Smedt [43], and Sudheer et al. [41].

4.4. Outcomes

Figure 2 presents 'outcomes' as the dependent variable. The independent variables (spatial unit, hydrogeology, and hydro-chemical properties) and their subcomponents together contribute to the outcomes. Key indicators of the outcomes include the effects of the independent variables on the performance of groundwater-related point source facilities, specifically boreholes with hand pumps. The outcomes component of the framework shows borehole water yield, drilling success rate, and health effects.

Borehole water yield is the volume of water that can be abstracted from a borehole. It is the rate at which water is abstracted from the borehole in terms of quantity per unit of time and can be expressed as L/s, m^3/hr, and m^3/d among others [46]. Knowledge of borehole water yield is important because it avoids over-pumping of the borehole in order not to induce saline intrusion and excess lowering of the water table and cause borehole failure [46]. Borehole drilling success rate refers to the chance of drilling a borehole to discover water [47]. This study measured the drilling success rate by assessing the number of boreholes drilled and the successful outcomes.

The health effects of groundwater use were also considered as an outcome because they emanate from the hydro-chemical and bacteriological properties of groundwater-bearing rocks, which also relate to the geohydrological (aquifer properties) and spatial units (human impacts, e.g., waste disposal practices) of the conceptual framework. For instance, calcium carbonate in sandstone aquifers causes constipation, mica in granite aquifers causes nausea and vomiting, while indiscriminate waste disposal and open defecation in a settlement as a spatial unit causes E. coli contamination, resulting in abdominal complications [41–43]. The outcomes guided the assessment of the effects of spatial, hydrogeological, and hydro-properties of groundwater on the performance of boreholes in terms of water yield and the health effects on the water users. Although the literature reveals the availability of information on aspects of the study in other spatial settings, the uniqueness of the results of this study lies in the integrated and multi-factorial nature of the exploration of groundwater characterisation.

5. Materials and methods

This section describes the methodological procedures used to achieve the research objectives.

5.1. Research design

The sequential exploratory mixed research design, comprising the sequential use of quantitative and qualitative methods and approaches, was used [48]. Quantitative

methods were used first, followed by qualitative. The quantitative approach involved the collection of both secondary and primary data expressed in quantitative forms, using numbers, percentages, tables, and graphs. This was followed by the qualitative approach, involving the collection of both secondary and primary data, expressed in words in the forms of quotations, narrations, descriptions, tables, maps, and pictures. Secondary data collection included desk reviews as presented in **Table 2**, involving sourcing data from relevant institutional reports, as well as published articles and other website information.

Table 2. Desk review strategy.

Area of review	Sources of information	Inclusivity criteria	Relevant institutions
Background of the study to diagnose the research problem	Articles, books, past project reports by other institutions, policy documents	Reviewed documents should not be much older than a decade; and relevant to the spatial, geological, and social contexts of the study	WaterAid Ghana, UN, Ghana Statistical Service, Center for Indigenous Knowledge and Organisatioonal Development
The study area (spatial unit): location, population, water sanitation	Municipal/District profile, population census reports, journal articles	Reviewed documents should not be much older than a decade; and relevant to the spatial contexts of the study	Wa Municipal Assembly, Ghana Statistical Service, WaterAid Ghana, UN,
Geology: rock and soil types, water-holding characteristics, hydraulic conductivity, transmissivity & water yield, physicochemical properties	Articles, books, past project reports by other institutions, policy documents, CWSA reports	Reviewed documents should not be much older than a decade; and relevant to the geological contexts of the study	Ministry of Sanitation and Water Resources, Environmental Protection Agency- Ghana, Community Water and Sanitation Agency, Water Resources Commission at Wa, CWSA, borehole engineers
Social domain: policy contexts, institutional framework and roles (management), infrastructure, accessibility, availability, affordability, human impacts, challenges and prospects	Ghana Water Policy, MGDs & SDGs, Africa Water Vision for 2025, Articles, books	Reviewed documents should be within the current policy duration period. Books and articles should not be older than a decade	Ministry of Sanitation and Water Resources, Environmental Protection Agency-Ghana, Community Water and Sanitation Agency (CWSA)

Structured household interview checklists, key informant interview guides, questionnaires, focus group discussion guides, and observation checklists were used for primary data collection. The data from such instruments was both quantitative and qualitative. In the first phase of the sequential method, any use of such instruments is aimed at quantitative data, followed by qualitative data in the second phase.

5.2. Sampling

A 2-phase multistage sampling technique was applied. Multistage sampling is used when the elements of the population are spread over a wide geographical region and it is not possible to obtain a representative sample with only one technique [49]. Groundwater studies have a number of characteristics that make it difficult to obtain a representative sample based on one sampling method. In phase one, purposive sampling was used to select five communities of the Wa municipal district, out of the 20 largest communities as listed by the Ghana Statistical Service [GSS] [50]. The study communities were overlaid on a Digital Elevation Model (DEM) with the

elevation classes (or heights) represented by the colours defined in the legend in **Figure 3**.

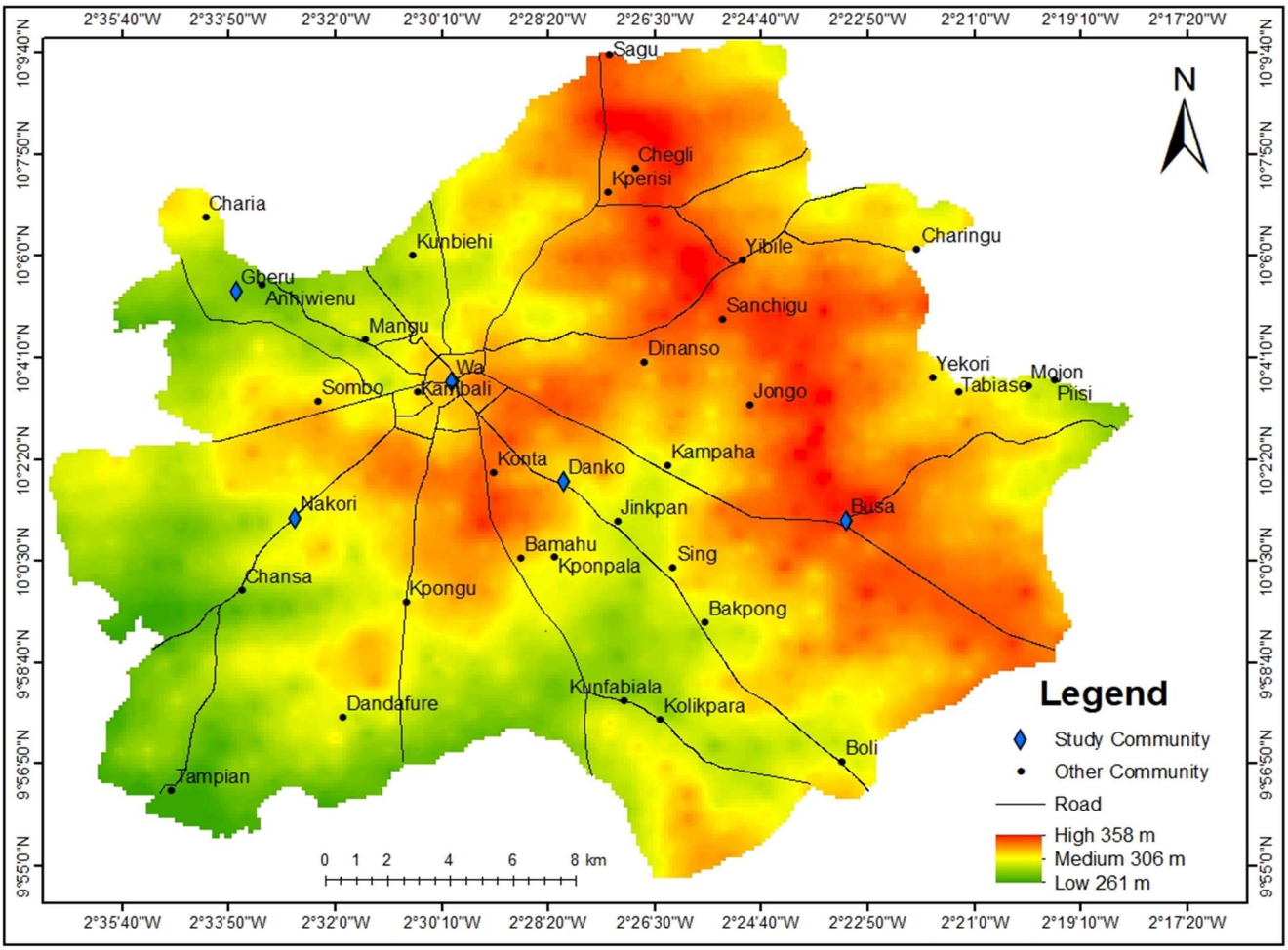

Figure 3. Sample communities within the context of a digital elevation model of the study area.

In phase two, five communities were purposively selected: two rural, one urban, and two peri-urban in Wa municipality. The purpose of the selection by stratification of settlement type is to facilitate a comparison of groundwater resource accessibility among them. Each of the five communities was selected in a different DEM class. The classification by DEM was to ascertain how differences in the slope of the land affect borehole construction success or water yield in the various seasons (rainy and dry). **Table 3** specifies the communities and their settlement status in each district, while **Table 4** summarises the sampling process and data collection methods.

Table 3. Selected study communities.

SN	Wa municipal	Settlement status
1	Wa (Konta)	Urban
2	Nakori	Peri-urban
3	Busa	Rural
4	Danko	Peri-urban
5	Gberu	Rural

Table 4. Target population, information sought, and methods of data collection.

Objective	Target	Specification	Number	Information required	Technique/tool of data collection and sampling method
Describe the relevant characteristics of the spatial unit (communities of the Wa municipal) of analysis	Communities	Any 18-year-old or older household member (other members of the same household could then participate) Community Water and Sanitation Management Board (CWSMB) members	400	Details of respondents, main sources of water, sanitation, seasonal variations in borehole water flow, observable aspects of water quality	Face-to-face interview/structure household interview checklist. Sampled by fishbowl and accidental methods
	Ghana Statistical Service	NA	NA	Location details, population, percentage access to water and sanitation infrastructure, climate, geology	District Analytical Profiles were obtained from the GSS website
	Wa Municipal Assembly	Community Development Officers	1		Self-administered questionnaires; observation checklist
		Works Department Officers	1		
Ascertain the hydro-geological and physicochemical characterisation of groundwater	CWSA	Hydrologist	1	Groundwater quality in terms of bacteriological and physicochemical properties of groundwater, number of boreholes constructed, groundwater management/governance, borehole water yield, aquifer thickness, transmissivity, borehole drilling success rate	Self-administered questionnaires
	Borehole construction companies	Borehole Engineer	1		Self-administered questionnaires
	Ghana Health Service	Municipal Health Officer	1	Impact of poor sanitation on groundwater and the health implications	Self-administered questionnaires

The actual locations of the communities in the district context are illustrated in **Figure 4**, which are compared to relative positions in **Figure 3** to identify the DEM.

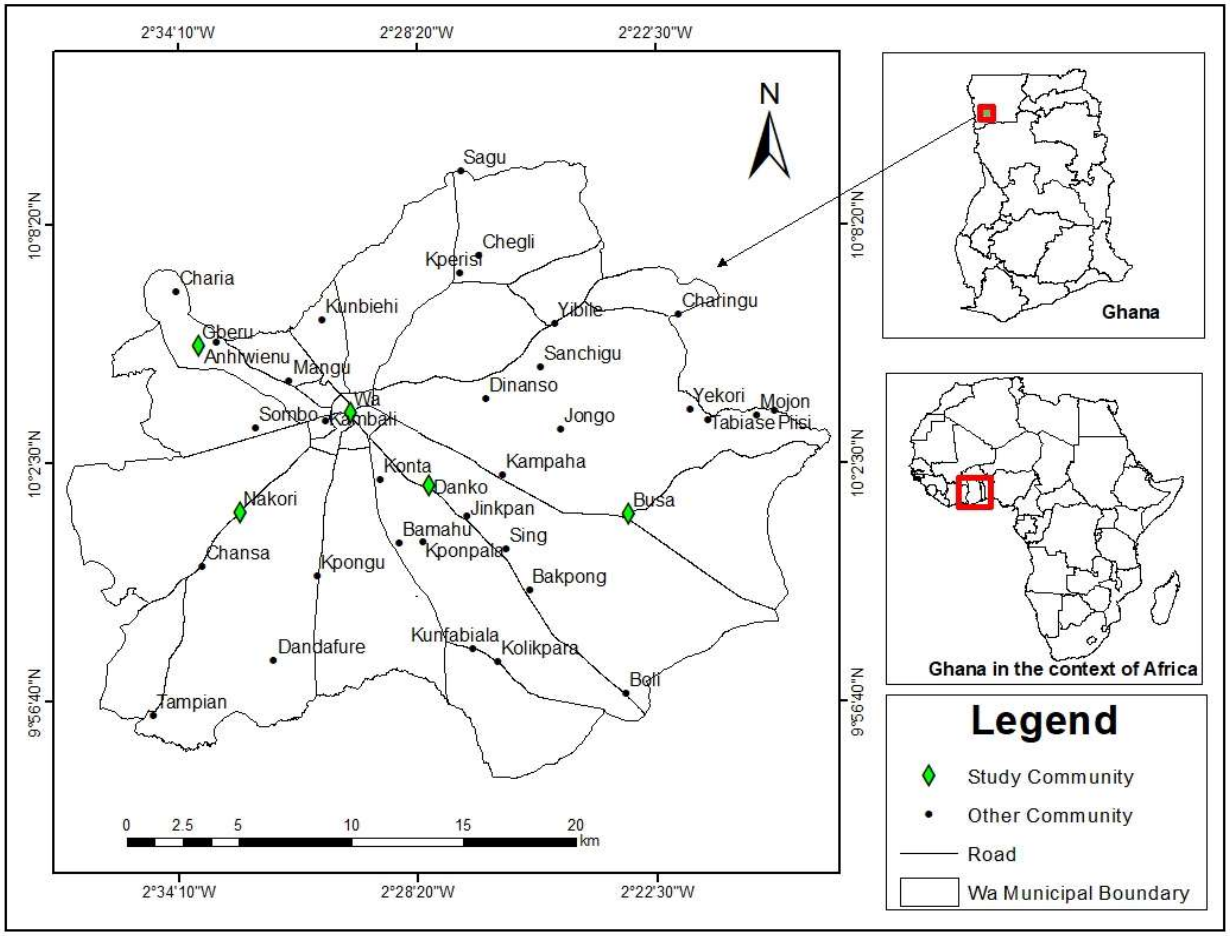

Figure 4. Study communities in the Wa municipal district context.

5.2.1. Sampling of respondents

5.2.1.1. Target population and sampling methods

The selection of houses was by the fish bowl or lottery method. Houses in each cross-section were enumerated, coded, and randomly selected using the lottery or fish-bowl method for the proportion of respondents calculated for each community from the sample size. Once in a house, the first household member to meet, who was 18 years and above was selected accidentally for interview based on informed consent, using a structured interview checklist with largely close-ended questions by face-to-face technique. This was preferred to questionnaires because the abilities of rural household respondents to read survey questions and write responses were uncertain.

Purposive sampling was used for focal groups and officials of government departments and private sector agencies listed in **Table 4**. It was preferred to use questionnaires for formal sector officials because they are literate. Questionnaires were issued in advance, to enable respondents to access and provide the right information, with a deadline of not more than three days. Designations and contact numbers of respondents were taken, to facilitate follow-up interviews and data cleaning if it became necessary. Community-level focal groups were engaged through discussions, using the focus group discussion guide, with a time frame of 30 min to 1 h per group.

5.2.1.2. Sample frame and sample size

The sample frame included the actual lists of sampled houses with households that are users of groundwater facilities. Members of the Community Water and Sanitation Management Boards were also targeted at the community level.

Sample size: The Wa municipality has numerous sub-sections without known population sizes because they sum up together to give the population of their capital city. As a result, we estimated a sample size for the study population in the five communities using Equation (1):

$$\text{Samplesize (n)} = \frac{\text{t}^2 \times \text{p}(1-\text{p})}{\text{m}^2} \quad (1)$$

where n = required sample size, t = Confidence level at 95% (standard value of 1.96), p = Estimated prevalence of people depending on groundwater for drinking (these are unknown, so the best decision is 50% or 0.5), m = Margin of error at 5% (standard value of 0.05). Therefore, $\text{n} = \frac{1.96^2 \times 0.5(1-0.5)}{0.05^2} = 384$.

The sample size of 384 was rounded off to 400, divided equally among the five study communities, giving 80 household respondents for each study community indicated in **Table 5**.

Table 5. Sample size of study communities per district.

SN	Wa municipal	Settlement status	Number of respondents
1	Wa (Konta)	Urban	80
2	Nakori	Peri-urban	80
3	Busa	Rural	80
4	Danko	Peri-urban	80
5	Gberu	Rural	80
		Total	400

5.3. Measurement procedures

(a). Measuring unconfined aquifer water yield

Equation (2), adopted from Michigan Technological University [51], is used for measuring the flow rate or borehole water yield of unconfined aquifers.

$$\text{Q} = \frac{\pi \text{k}(h_2^2 - h_1^2)}{\ln \frac{r^2}{r^1}} \quad (2)$$

where Q = flow rate of water from the borehole (cfs), k = coefficient of permeability of soil (fps), h_1 = height of water surface above the bottom of the aquifer at the perimeter of the well (ft), h_2 = height of water surface above the bottom of the aquifer at distance r^2 of a borehole well centreline (ft), r^1 = radius of a borehole well (ft), r^2 = radius of water surface whose height is h_2 above the bottom of the aquifer (ft), ln = natural logarithm

An unconfined aquifer is an aquifer with its water in direct contact with the atmosphere through the open pore spaces of the overlying soil or rock, and the groundwater could be increased or decreased by atmospheric pressure. On the other hand, confined aquifers are groundwater-bearing rocks overlain by relatively

impermeable rock or clay that limits groundwater movement into or out of the aquifer [31].

Alternatively, a specific yield (S_y) could be measured. "Specific yield is the percent ratio of the volume of water that an unconfined aquifer will yield by gravity to the unit volume of the unconfined aquifer" [52]. Given that confined aquifers were not of interest in this study, the S_y for unconfined aquifer is calculated by Equation (3):

$$S_y = \frac{\text{volume of water an unconfined aquifer will yield by gravity}}{\text{unit volume of the unconfined aquifer}} \quad (3)$$

This study involved only boreholes constructed on unconfined aquifers because all construction attempts on confined aquifers were unsuccessful in the study area due to technological constraints. This is why the focus on measurement is on unconfined aquifers. Measuring borehole water yield provides information for the regulation of the use of the borehole by preventing overpumping and borehole failure during seasonal variations in groundwater level.

(b). Measuring borehole water depth

A borehole/protected well depth gauge was used for the monitoring of groundwater depth/aquifer depth. The gauge is attached to a tape measure and inserted from the top through the tube of the borehole. The tape is uncoiled as the gauge goes down the borehole.

Upon getting into contact with water, the pedestal sends a sound, and the graduated tape measures the water level. Monitoring the level of groundwater was found to be of water security significance with livelihood implications because:

- It helps to know the level of groundwater with seasonal variations, such as in the rainy and dry seasons.
- The level of groundwater helps in the determination of rules of allocation of water from various sources in order to ensure that safe water for drinking and other domestic uses is judiciously used to avoid shortages in the dry season.
- The rules of allocation partly deal with which source of water is used for what livelihood activity based on the results of groundwater levels.

In most cases, Community Water and Sanitation Management Boards at the community level measure the aquifer depth, and wherever such information was available, the researchers took advantage of that.

(c). Measuring saturated aquifer thickness

The meaning of saturated aquifer thickness has already been provided in earlier sections of this paper. According to the Louisiana Department of Environmental Quality [52], data on saturated aquifer thickness should be available to the well/borehole drilling agency. The determination of saturated aquifer thickness of an existing borehole could therefore be done by obtaining the data from the published reference boring/well logs of the borehole/well driller or field data. The saturated aquifer thickness has the dimensions of length for unconfined aquifers, the saturated thickness of confined aquifers corresponds to the thickness of the aquifer (ibid.). This study therefore ascertained data on saturated aquifer thickness through interviews with CWSA officials, the Works Department of the Wa Municipal Assembly, and relevant borehole engineers.

(d). Measuring transmissivity

Transmissivity has also already been defined earlier in this paper (see Murray Water [39]). It is calculated by Equation (4), provided by the Louisiana Department of Environmental Quality [52]:

$$T = K \times b \tag{4}$$

where T = transmissivity (ft 2 /day), K = hydraulic conductivity (ft/day), b = saturated aquifer thickness (ft).

where different units of measurement were used, such as liters (L) and meters (m), they were specified. Transmissivity was determined in this study to assess the ease of groundwater prospection from boreholes and for the purpose of comparison to the expected standard.

5.4. Hydraulic conductivity

Hydraulic conductivity is a hydrogeological parameter that measures the ease of water flow through a permeable aquifer under the influence of other characteristics of the aquifer and the nature of groundwater, including density and viscosity [45]. It is expressed as Equation (5):

$$\mathrm{K} = \frac{\mathrm{T}}{\mathrm{b}} \tag{5}$$

where K = hydraulic conductivity, T = transmissivity, b = saturated aquifer thickness.

It was essential to determine K in order to ascertain the permeability of aquifers and how aquifer thickness and transmissivity affect groundwater movement to account for borehole water yield.

Groundwater quality test:

Groundwater quality tests help determine if specific contaminants (physical, chemical, and biological) have infected a body of water, and the test results help inform how contaminated water needs to be further treated. The tests could be classified into bacteria tests (e.g., for E. coli, due to fecal contamination), mineral tests (e.g., chlorine, chloride, nitrate and nitrite, lead, copper, iron, zinc, potassium, and sodium, which could emanate from the aquifer rock), pH test (which measures the concentration of hydrogen ions in the water), among others [53].

The first step in water quality testing is sampling the sources of water being tested, that is, boreholes in this regard. The selection process takes into consideration, sources that are most prone to contamination and the use of the water. Samples of borehole water are collected in sterile tubes following some guidelines to avoid contamination. Once the samples are collected they are transported to laboratories to be tested using specialized equipment for the various parameters identified in the types of tests discussed earlier (Perfect Pollucon Services, n.d.).

However, this study did not conduct a water quality test. It depended on available water quality test results on existing boreholes provided by the Hydrology Department of the CWSA in Wa, which is responsible for the management of rural and small-town water services. It was discovered, however, that most boreholes owned by private individuals and donor-funded did not go through water quality testing. The failure to conduct a water quality test under this study was recorded as a methodological challenge due to funding constraints.

5.5. Data sources and analysis

The sources of data were categorised into two: desk review of the literature and relevant institutional reports and policy documents (see **Table 2**) and primary sources, presented in **Table 4**, with target respondents, type of information sought, and data collection methods. Chronologically, the data collection process began in June 2019 and ended in August 2019. Data presentation and analysis also began in September 2019 and ended in November 2019. All data presented in this report, whether primary or secondary, are based on 2019 as the reference year. However, some sources of literature have been updated.

Both quantitative and qualitative approaches were used in data presentation and analysis. The quantitative methods were the presentation of data using descriptive statistics with the aid of Microsoft Office Excel, such as frequency tables and graphs, using absolute numbers (1, 2, 3, …), percentages (%), and relevant units of measurement, such as meters (m), kilometres (km), centimetres (cm), litres (L), seconds (s), hours (h), days (d) among others. The qualitative methods were narrations, direct quotations, pictures, and maps, among others. Quantitative and qualitative analyses of primary and secondary data were concurrently, supplemented by reviewed literature. The mixed methods used facilitated cross-triangulation and comparison to lay bear, the contribution of this study to new knowledge.

5.6. Challenges of the research

The challenges were mainly related to scheduling, methodological creep, and accessibility to data. In terms of methodological creep, the original research proposal sought to undertake water quality tests by using samples of water from boreholes in each of the study communities. It was also intended to involve geologists in a study of the rock compositions of the study districts with an emphasis on the detection of chemical contaminants, such as arsenic and fluoride, and water-holding properties. However, these aspects were constrained by budget limitations. Accordingly, researchers had to rely on available secondary data on hydrogeological and physico-chemical properties of groundwater and groundwater quality, related to specific wells in particular communities in the study districts.

Also, some formal sector institutional respondents could not be reached for their responses to questionnaires. However, through triangulation of questions and the availability of secondary data on their roles, the failure did not affect the findings significantly.

6. Results and discussion

6.1. The spatial unit

This section discusses the relevant features of the spatial unit or study area, pertaining to the first research objective. In line with the conceptual framework in **Figure 2**, the location, population, water, and sanitation issues have been discussed. **Figure 4** presented in the methods sections shows a map of the study area.

The Wa municipality is one of the districts of the Upper West Region (UWR) of Ghana and is located within longitudes 9º55′ W and 10º5′ W and latitudes 2º15′ N and

2º40′ N. It is bounded to the north and east by the Nadowli and Wa East Districts, respectively, and to the west and south by the Wa-West District. Wa, is the capital town of the UWR and central city of the Wa Municipality. It has a land area of approximately 579.86 km^2, a population of the municipality is 107,214 with a density of 185 persons/km^2 and forms 15.3% of the region's total population. About 35% of the population is under 15 years old. Over 34% (36,453) reside in rural areas [50]. The large population has implications for the demand for water by households. It is also located in the tropical continental climatic belt of Ghana, which has one rainy season between May and October, followed by a dry for another half of the year. The mean annual rainfall is between 1000 mm and 1150 mm, compared to the other climatic zones in Ghana, which all have double maxima rainfall regimes and mean annual rainfalls exceeding 1150 mm. The municipality therefore has semi-arid conditions. Programmes and policies on water, targeting the cheapest sources that rural people depend on, such as groundwater, therefore require prioritization.

Figure 5 presents details of the household respondents. It shows the age and sex distributions, as well as the settlement types respondents belonged to. The data reveal that the respondent population is youthful and female-dominated, as the age group 18–33 and females had the highest frequencies in both study districts. This is consistent with the analytical reports of GSS [50], that the Wa municipality has a higher female population of 50.6%, and that youthful age groups dominate in the municipality.

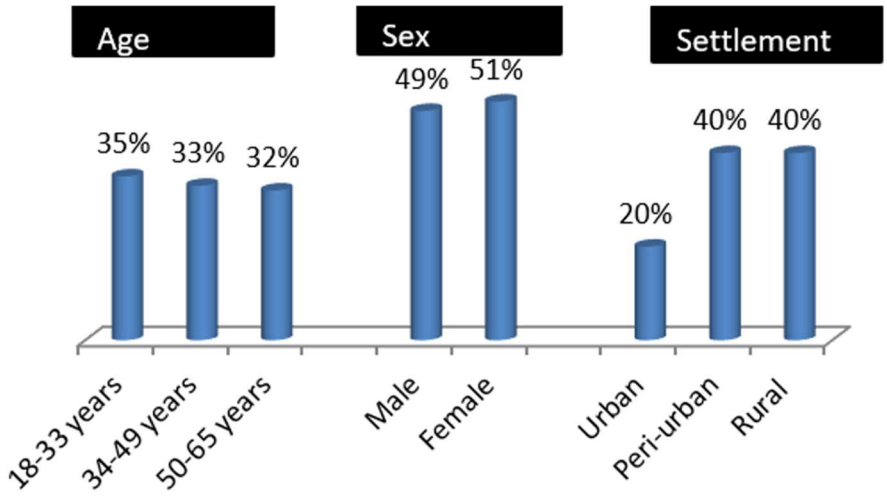

Figure 5. Age, sex, and settlement types of respondents.

The data shows that only 20% of respondents in the Wa municipality are urban. The largely rural nature of settlements is the reason why studies in groundwater characterisation and prospecting are essential since it constitutes the main source of safe water for rural communities in Ghana [47]. **Figure 6** shows that groundwater constitutes the major source of water for rural and peri-urban household respondents through the use of boreholes and wells.

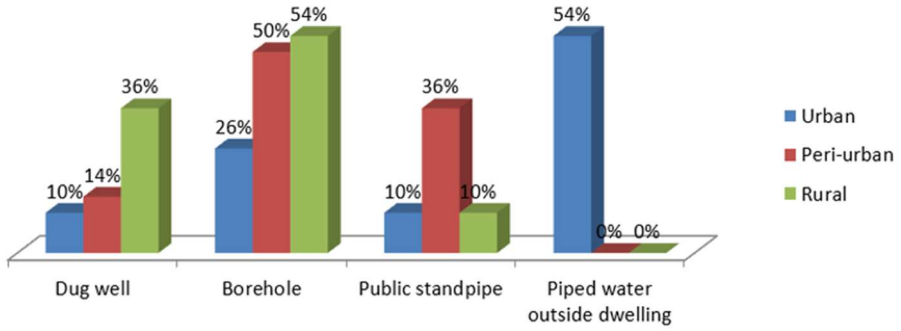

Figure 6. Evidence of dominance of groundwater infrastructure.

In terms of waste disposal, **Figure 7** shows that open dump sites and indiscriminate disposal methods are widely used by rural and peri-urban respondents. This increases the risk of contamination of surface water bodies as surface runoff and wind carry the waste into the water bodies to pollute them.

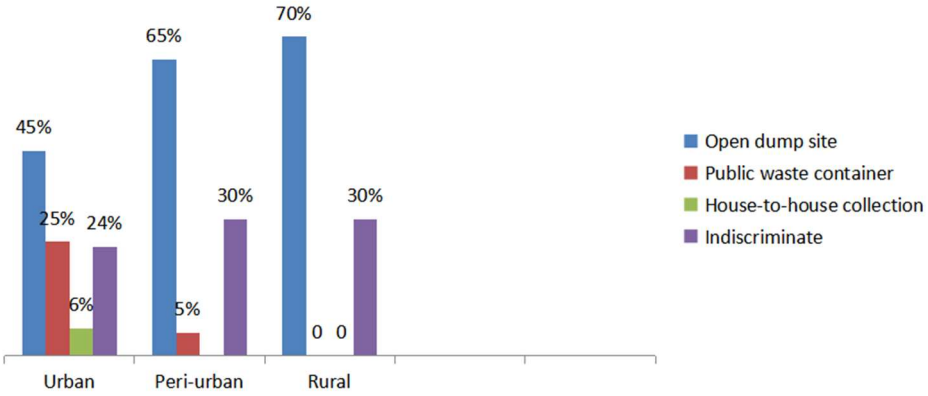

Figure 7. Means of waste disposal.

However, since surface water bodies also recharge groundwater aquifers, contaminated surface water also poses a threat to groundwater quality [3]. This calls for an examination of the hydro-chemical and bacteriological characterisation of groundwater to assess its quality and how it impacts health, as part of the outcome as a dependent variable in the conceptual framework of this study.

6.2. Hydro-geological and hydro-chemical characterisation of groundwater

This section addressed the second objective of this study, which aimed to ascertain the hydro-geological and hydro-chemical characterisation of groundwater. It explored the rock and soil types constituting the aquifers, transmissivity, aquifer thickness, water yield, and hydro-chemical and bacteriological properties of groundwater, as dictated by the conceptual framework. **Table 6** presents the data on the relationship between geology, soil, and groundwater as provided by the CWSA.

Table 6. Relationship between geology, soil, and groundwater

Aquifer rock type	Major form	Relationship between rock type and groundwater	Major soil type	Relationship between soil type and groundwater
Sandstone	Consolidated rocks	High transmissivity in the rainy season, but low transmissivity in the dry, may have silicon dioxide and calcium carbonate. When extended over a large area, sandstone aquifers can be highly productive and provide large volumes of water	Sandy soil, sandy clay, lateritic soil, lateritic soil	Highly porous and promotes quick groundwater recharge
Granite	Plutonic and crystalline	Groundwater assumes the chemical composition of granitic rocks, especially potassium, feldspar, and mica. Transmissivity values for groundwater in granitic terrains are minimal. They have a medium to low permeability, and so contain aquifers with modest water resources.	Clayey	Low percolation of surface runoff to recharge groundwater

Source: Hydrology Department of the CWSA, September 2019.

Responding to a question on the relationship between rock type and groundwater, an official of the CWSA at Wa, stated:

"The aquifers in the Wa municipality are mainly granite and sandstone. Granitic rocks and clayey soils have the attributes of causing minimal transmissivity and slow recharge rates of groundwater, while sandstone, associated with sandy soils, is more porous, promotes groundwater recharge quickly, and has high transmissivity. The average transmissivity in the municipality is 7.4 m^2/day, the average aquifer depth is 62 mbgl, and the average borehole water yield is 44.22 L/min."

It should be noted that in 62 mbgl, 'mbgl' means 'metres below ground level', hence mbgl is the same as meters (m). So mbgl is only used to distinguish values in metres associated with groundwater. Comparing the findings from the interview results above to the relationships between geology and groundwater in the mainstream literature, Sudheer et al. [41] report that the transmissivity of granitic aquifers varies from 10.28 to 90.06 m^2/day with a mean of 33.6 m^2/day, and a water yield of 56.8–91.1 m^3/day [42]. El-Rawy and Smedt [43] also assert that sandstone aquifer rock has a transmissivity average of about 400 m^2/day, while Al-Sudani [44] found water yield of between 138 and 1683 m^3/day to be associated with sandstone aquifers. **Table 7** presents data on the hydrological characteristics of selected boreholes and the corresponding digital elevations, derived from the DEM in **Figure 3** of this paper.

Table 7. Hydrological characteristics of selected boreholes.

SN	Wa municipal	Aquifer depth (mbgl)	Saturated aquifer thickness (mbgl)	Transmissivity (m^2/day)	Borehole water yield (L/min.)	Hydraulic conductivity (m/day)	DEM (m)
1	Wa (Konta)	67	42	8.49	14	0.20	358
2	Nakori	57	80	9.48	15	0.12	306
3	Busa	71	37	8.40	13.90	0.23	358
4	Danko	62	40	8.44	14.30	0.22	345
5	Gberu	54	85	9.61	15.49	0.11	212
6	Average	62.2	56.8	8.88	14.54	0.18	315.8
7	Expected	25-85	60	12.4	6.0- 18		

Source: This study, 2019.

The findings in **Table 7** show that the averages of aquifer depth and aquifer thickness are comparable to the average values of the Wa municipality as reported by the CWSA and the Wa Municipal Assembly's Works Department, as well as the expected standard values of 6 mbgl–120 mbgl for aquifer thickness in Ghana by the Food and Agricultural Organisation [FAO] [54]; water yield of 6–18 L/min for hand pump boreholes reported by Rural Water Supply Network [55], and an aquifer depth of 60 mbgl by Cobbing [47]. A groundwater depth of 50 mbgl or less is ideal for standard boreholes fitted with hand pumps. But transmissivity falls short of the 12.4 m^2/day requirement for both domestic and agricultural purposes [56], while the average water yield in **Table 7** (14.54 L/min) is below the reported value of 44.42 L/min by the CWSA, and the average transmissivity of 8.88 m^2/day is also higher than the reported 7.4 m^2/day. The data reported by the CWSA and Municipal Assembly were available before this 2019 study. Hence, changes in precipitation could cause changes in groundwater parameters [19].

The gap in the literature is, however, the inability to account for how other factors, such as digital elevation, affect geohydrological groundwater parameters. **Table 7** shows that boreholes located on the lower DEM have higher aquifer thickness, lower aquifer depths, and lower hydraulic conductivity. For instance, hydraulic conductivity, which measures the ease of water flow in an aquifer, is influenced by the nature of groundwater, including density or aquifer thickness [45]. Thus, given Equation (6) hydraulic conductivity (K) is expressed as:

$$K = \frac{T}{b} \quad (6)$$

With a larger aquifer thickness (b) of 85 m and a transmissivity (T) of 9.61 for the Gberu community borehole, hydraulic conductivity is:

$$K = \frac{9.61 msq/day}{85m} = 0.11 \text{ m/day}$$

This means the hydraulic conductivity is lower, compared to Busa, which is K = 0.23 with an aquifer thickness of 37 m and transmissivity of 8.40 m^2/day. Impliedly, as the density or aquifer thickness increases, groundwater flows slower in an aquifer. On the other hand, transmissivity, which describes the ability of the aquifer to transmit groundwater throughout its entire saturated aquifer thickness [39], is a product of hydraulic conductivity and aquifer thickness. So, an increase in any of the factors (K or b) or both increases T, because $T = K \times b$.

For instance, at Danko, where the hydraulic conductivity (K) is 0.22 m/day and aquifer thickness (b) is 40 m, $T = 0.22 \text{ m/day} \times 40 \text{ m} = 8.22 \text{ m}^2/\text{day}$.

Both transmissivity and conductivity are impacted by the porosity or permeability of the aquifer itself. Impermeable aquifers have lower K and b values. Linking transmissivity and conductivity as independent variables in the conceptual framework of this study (**Figure 2**), to the dependent variable of outcomes, especially water yield, Akinwumiju and Olorunfemi [57] assert that transmissivity is one of the factors affecting borehole water yield. This was confirmed by this study in **Table 7**, as communities with higher transmissivity values, equally have higher borehole water yields. For example, the transmissivity value of Gberu is 10 m^2/day the highest in **Table 7**, with a correspondingly highest water yield of 15.49 L/min at the lowest DEM

of 212 m. But according to Scherrer et al. [58], boreholes are often drilled where the needs are highest and not where hydrogeological conditions are most favourable.

In terms of aquifer thickness, this study found an average of 56.8 mbgl, which is higher than the range of 15–22 mbgl reported for the coastal regions of Lagos in Nigeria, where groundwater is also extensively used [59]. This information is therefore relevant for policy consideration for large-scale groundwater prospecting for purposes beyond domestic uses in the Wa municipal communities.

Also related to the outcomes is another dependent variable, namely borehole drilling success rate. According to Cobbing [47], the success of drilling a borehole to obtain water is dependent on how well-fractured the aquifers are, the aquifer depth, and whether it is confined or unconfined. **Table 8** presents evidence of actual boreholes drilled in the study districts between 2015 and 2017, obtained from the officials of the CWSA and the Works Department of the Wa Municipal Assembly.

Table 8. Drilling success rate.

Year	Districts	Total number of borehole drilling attempts	Number of successful drills	Number of unsuccessful drills
2015	Wa municipal	4	4 (100%)	0 (0%)
2016	Wa municipal	13	11 (85%)	2 (15%)
2017	Wa municipal	7	6 (86%)	1 (14%)

Source: CWSA and Wa Municipal Assembly, September 2019.

Borehole drilling could be described as shallow or unconfined well drilling when it does not go beyond the top layer of the saturated aquifer. From the data provided for 2015 and 2017, the chances of drilling a borehole to have an economically feasible amount of water were between 85% and 100%. The results confirm the report by Cobbing [47] that communities in the Upper West Region have a high borehole drilling success rate due to the well-fractured rocks.

However, there have been instances of unsuccessful well drills. In line with this, this research also investigated evidence of the relationship between digital elevation and the possible challenges of constructing boreholes to find groundwater in the study communities. **Table 9** presents the causes of failure in borehole drilling attempts and associated digital elevations (refer to **Figure 3**). The data show that four out of the seven cases shown in **Table 9** were in the high DEM, two in the medium, and one in the low DEM. This implies that most of the attempted borehole sites were either along hills or slopes with deep aquifers, for which reason surface runoff does not easily convey and permeate into the aquifers. This is supported by the findings of Janyani et al. [60] that the ideal location of boreholes is valleys or lowland areas, which also have nearby streams or springs.

Table 9. Challenges of borehole construction.

Wa municipal communities	Aspect of physical scarcity threat	Digital elevation (DEM)/ranking
Wa (New Market area and Konta areas)	Failed attempt to drill due to underground rock	368 m (high)
Busa	Failed attempt to drill due to underground rock (70)	358 m (high)
Danko	Failed attempt to drill due to underground rock (70 m)	345 m (high)
Gberu	Failed attempt to drill due to underground rock at the attempted site (60 m); at least, one borehole has a dry well	212 m (low)
Bamahu	Deep aquifer (more than 80 m), no groundwater at attempted site	360 m (High)
Charingu	Failed attempt to drill due to underground rock, inadequate groundwater at the attempted site (deep aquifer: more than 70 m)	306 m (high)
Nakori	Deep aquifer (more than 80 m), inadequate groundwater at attempted site	306 m (high)

Source: Field survey, 2019.

Rural Water Supply Network [38] aver that under circumstances such as those expressed in **Table 9**, ultra-deep hand pump technologies should be used, because standard hand pumps are unreliable for regularity of borehole water yield in such areas. Specifically, the PolDaw Ultra Deep Well is a PolDaw Designs (UK) Technology. This was a response to the need for pumping from aquifers with depths of 200 to 300 feet (60 to 90 m), in various countries. WaterAid runs pilot programmes using the PolDaw Ultra Deep Well technology in some water-scarce localities of African countries. WaterAid could therefore be resourceful for details of the technology and cost implications of its adoption if the Wa municipality expresses interest in the promotion of adequate groundwater access in the area.

Apart from the hydro-geological characteristics discussed above, during focus group discussions with the local Community Water and Sanitation Management Boards, respondents in the study communities expressed their indigenous knowledge of the detection of groundwater availability. At Busa in the Wa municipality, a participant in the FGD said that:

"The signs of groundwater availability are classified as physical and biological. The physical signs include the presence of sandy-clay soil, closeness to the foot of hills, heat, and ease of flooding. The biological signs include the presence of termite and ant hills, some identified tree species, areas with thick vegetation cover, tall trees with green leaves and tall grasses."

Figure 8 shows some successfully constructed boreholes and their proximities to biological indicators of groundwater availability based on the indigenous knowledge of community-level FGD participants. Ant hills can be spotted around a mechanised borehole in Busa, for small-town water supply, constructed by the CWSA.

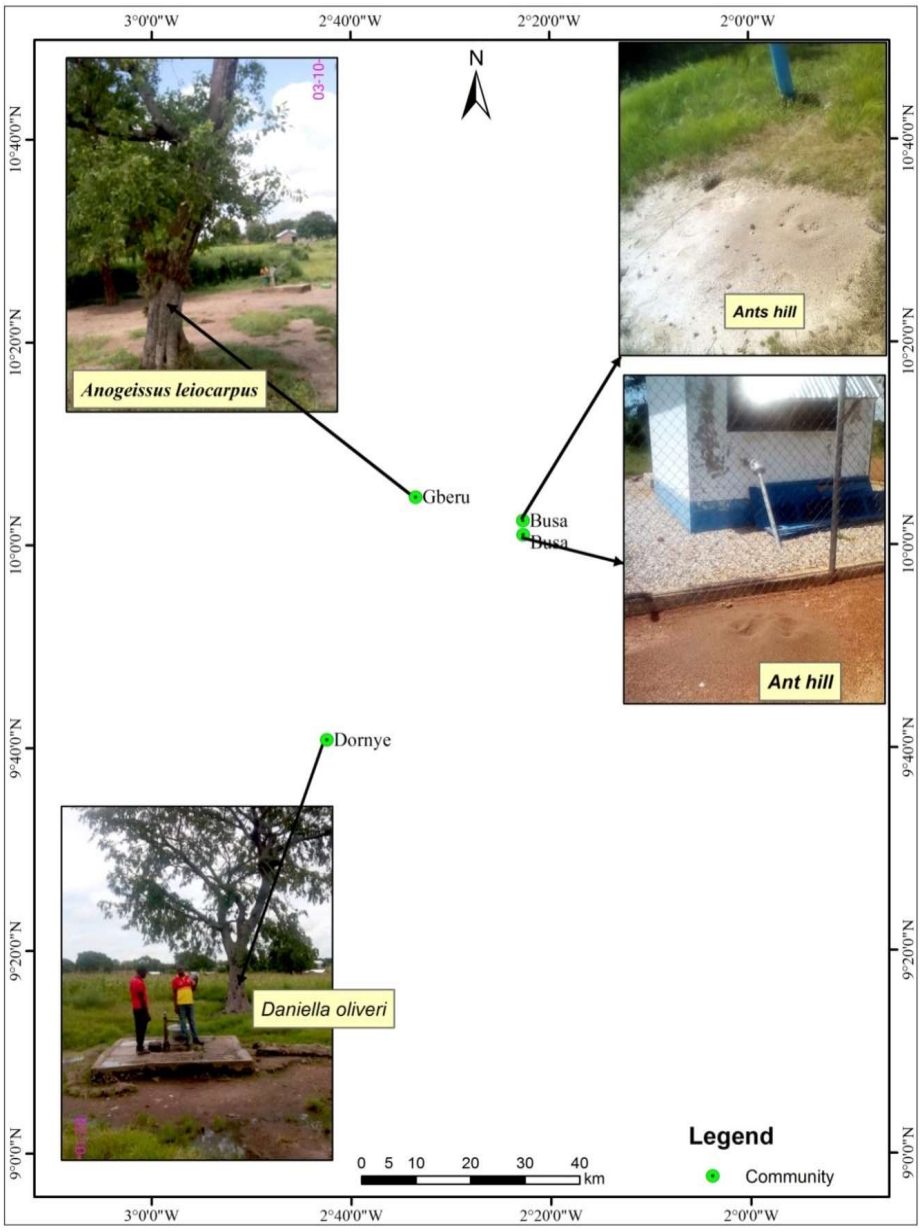

Figure 8. Signs of groundwater availability.

Source: Filed survey, September 2019.

Figure 8 further shows Dornye and Gberu communities with successfully constructed boreholes closer to the Anogiessusleiocarpus and Daniella Oliveri trees, respectively. The findings are consistent with those of Condon and Maxwell [61], that the availability of groundwater is influenced by the vegetation, soil, and rock types, the topography of the land, and the climate of the area.

6.3. Borehole water yield

Borehole water yield is a measure of the volume of water that can be abstracted by pumping a borehole per unit of time [62]. Reports on values of borehole water yield in the Wa municipality by the Hydrology Department of the CWSA-Wa and the Borehole Drilling Unit of the Works Department of the Wa Municipal Assembly revealed an average of 44.22 L/min, while this study found an average of 14.54 L/min. Hand pump boreholes should have a sufficient yield of around 0.1–0.3 L/sec (6.0–18

L/min.), but for a small-town water supply, the normal yield should be 2–10 L/sec or 120–600 L/min [55]. Thus, Wa municipality has good water yield records on average, for hand pump boreholes.

6.4. Seasonal variations in water yield

Table 10 also provides data from household respondents on user experiences of borehole water yield in the rainy and dry seasons, by using reduced water flow necessitating the need to pause for borehole water recharge as an indicator. The results reveal that it is only in the dry season that 34% of the respondents experienced reduced water yield in their boreholes, as most respondents in the high DEM communities reported cases of pausing for borehole recharge in the dry season. Gberu, the only study community on a lowland of 212 m reported no cases of pausing for borehole water recharge. This finding suggests that the use of DEM in groundwater projects is important for construction success, which is lacking in most groundwater-related research findings. In the rainy season, **Table 10** shows that all respondents in both study districts chose the 'No need to pause' option. This also substantiates the role of precipitation in groundwater recharge [19].

Table 10. Pausing for borehole recharge in the dry and rainy seasons.

District		Dry season			Rainy season		
	Community	**No need to pause**	**Need to pause**	**Total**	**No need to pause**	**Total**	**DEM**
Wa West	Busa	2.5% (10)	17.5% (70)	20% (80)	20% (80)	20% (80)	358 m (high)
	Danko	12.5% (50)	7.5% (30)	20% (80)	20% (80)	20% (80)	345 m (high)
Wa municipal	Gberu	20% (80)	0% (0)	20% (80)	20% (80)	20% (80)	312 m (low)
	Nakori	20% (80)	3.5% (14)	20% (80)	20% (80)	20% (80)	306 m (high)
	Wa	14.5% (51)	5.5% (29)	20% (80)	20% (80)	20% (80)	358 m (low)
	Total	66% (257)	34% (143)	100% (400)	100% (400)	100% (400)	

Source: Field survey, September 2019.

The fluctuation of borehole water yields breeds the need to explore alternative means of aquifer recharge in areas faced with dry wells in the dry season. Following the assertion of Wang et al. [22] that surface and groundwater systems recharge each other, deliberately increasing dugouts to serve as surface water buffer stocks in the rainy season for the regulation of aquifer recharge throughout the year is a gap in the practice of groundwater resource management in Ghana.

6.5. Hydro-chemical and bacteriological parameters of groundwater quality

The safety of groundwater depends on how free the source is of harmful hydro-chemical properties of the aquifer, bacteriological, and other anthropogenic sources of pollutants, as presented in **Table 11**.

Table 11. Results of water quality analysis.

Sample source-boreholes	**Districts: Wa Municipal Borehole: Danko**	**Districts: Wa West district Borehole: Dorimon**	**Date of analysis**	**Time sample was taken: Wa Municipal: 12:30 PM Wa West: 12:00 PM**
Sample source: Boreholes (Mark Sams Limited)				
Tested parameters	**Date of sampling: 14/06/2017**	**Date of sampling: 19/04/2017**	**Ghana standards**	**Remarks**
Ph	6.84	6.7	6.5–8.5	Satisfactory
Conductivity (us/cm)	272	106.9	1000	Satisfactory
Total dissolved solids (mg/L)	136	53.5	≤500	Satisfactory
App/true colour (HU)	<5	5	≤5	Satisfactory
Turbidity (NTU)	2.42	4.62	0–5	Satisfactory
Total alkalinity (as $CaCO_3$) – mg/L	54	49	200	Satisfactory
Total hardness (as $CaCO_3$) – mg/L	164	141	500	Satisfactory
Calcium hardness (as $CaCO_3$) – mg/L	83	74	N/A	Satisfactory
Magnesium hardness (as $CaCO_3$) – mg/L	81	65	N/A	Satisfactory
Calcium (mg/L)	33.2	29.6	100	Satisfactory
Magnesium (mg/L)	19.7	15.8	50	Satisfactory
Chloride (mg/L)	28.4	22.7	≤250	Satisfactory
Nitrate-Nitrogen (NO_3) (HR)	4.6	0.740	≤50.0	Satisfactory
Nitrite-Nitrogen (NO_2) HR	0.05	0.001	≤3.0	Satisfactory
Total iron (as Fe) – mg/L	0.21	0.023	≤0.3	Satisfactory
Fluoride (as F^-) – mg/L	0.49	0.28	≤1.5	Satisfactory
Sulphate (as SO_4^{-2}) mg/L	12.45	3.1	≤400	Satisfactory
Ammonia (NH^-_3-N) – mg/L	0.61	0.04	≤1.5	Satisfactory
Arsenic (as As) –mg/L	0.0	0.0	≤0.01	Satisfactory
Aluminium (Al) – mg/L	0.0	0.01	≤ 0.2	Satisfactory
Total coliform (CFU/100 mL)	0	0	0	Satisfactory
Faecal coliform (CFU/100 mL)	0	0	0	Satisfactory
E. coli (CFU/100 mL)	0	0	0	Satisfactory

Source: Provided by CWSA, Wa- September 2019.

The World Health Organisation [WHO] [63] lists improved sources of water in order of priority, namely household piped water connections and public standpipes as treated surface water sources; groundwater sources such as boreholes, protected dug wells, and protected springs; and finally harvested rainwater. Other sources, such as unprotected wells and springs, vendors, and water tankers providing services, as well as bottled water are labeled as unimproved sources of water. Available borehole water quality test results in **Table 11**, for some communities in the Wa Municipal and Wa West District of the Upper West Region, show conformity to acceptable water quality standards and are safe for human consumption. **Table 11** shows that the groundwater was free of hydro-chemical and bacteriological contaminants and so safe for direct consumption. However, the limitation is that the tests were performed on specific boreholes without adequate sampling of boreholes to ascertain their water quality conditions for most boreholes constructed in the communities. Responding to the question of the performance of water quality tests for groundwater supply facilities, the hydrologist of the CWSA reported that:

Most households and schools use water from local hand-dug wells, privately constructed boreholes, or philanthropist or donor-funded boreholes. Some of these are constructed without following the due processes of seeking abstraction rights from the Water Resources Commission or impact assessment and permits from the EPA, especially the local wells. However, due to a lack of adequate funding from the District Assemblies, it is usually difficult to ban the use of such facilities without providing

alternative sources of safe drinking water for the communities. Ensuring compliance with the bans is a challenge for us.

6.6. Health effects

During a focus group discussion with Community Water and Sanitation Board members at Gberu in the Wa municipality, responding to the question on the quality of the borehole water, a participant said:

"The borehole is the main source of our drinking water, so whether it is good or not, we have no choice. The water is clear in the rainy season, but in the dry season between January and March, the water turns brownish and is not clear enough to see through very well. But it still tastes good, and we drink it."

Asked whether they conduct water quality tests for their borehole, another participant said that:

"We are not aware of any water quality tests. But some children grow up in this community with brown teeth, and when we take them to the hospital, the doctors say it is from the water they drink."

Figure 9 shows the suspected case of dental fluorosis.

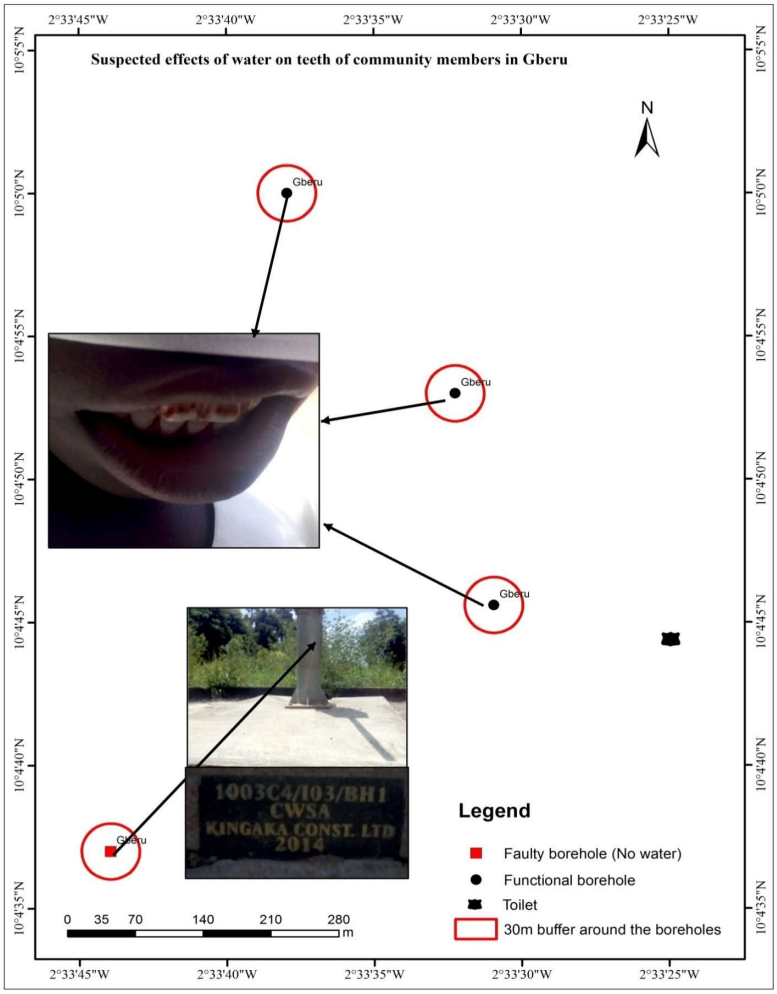

Figure 9. Suspected case of dental fluorosis at Gberu.

Source: Field survey, September 2019.

Responding to a questionnaire on the health effects of bad water quality, an official of the GHS in Wa stated that:

"Most rural people drink water from boreholes, wells, and streams that have not been tested for water quality analysis. So, most cases of dental fluorosis, I mean brown teeth caused by the presence of too much fluoride in water and other unsafe water-related diseases are reported by patients from the villages."

This is consistent with an assertion by Cobbing [47], that hydro-geological health scientists use signs such as the prevalence of dental and cancerous health problems to detect the consumption of unsafe water by patients. The extreme left of **Figure 9** shows a basic school student in the Gberu community of the Wa municipality with a suspected case of dental fluorosis.

In line with the report above, Taonameso et al. [64] investigated the potential health risks of borehole water in rural South Africa. They found that inadequate distribution of improved sources of water causes uneven access by rural households, which exposes disadvantaged ones to water-related health risks due to the consumption of water contaminated by pathogens. Their study found E. *coli* and fecal coliforms in samples of borehole water. These cause gastrointestinal disturbances and diarrhoea. The authors also blamed the gaps in rural water supply on the inefficiencies of municipalities.

7. Conclusions

By the spatial unit, it was found that the Wa municipality is located in the tropical continental climatic belt of Ghana, which has semi-arid weather conditions. It has a single maximum rainfall regime, with a mean annual average between 1000 mm and 1150 mm, compared to the other climatic zones in Ghana, which all exceed 1150 mm. This impacts negatively on both surface and groundwater resources, as some boreholes experience dry well conditions during the dry season (from November to April) and lack of adequate surface water to recharge groundwater. With a rural population of 36,453, which represents 34% of the population of the municipality, 54% depend on boreholes fitted with hand pumps, and another 36% depend on dug wells, summing up to 90% of the rural households depending on groundwater resources as drinking water, based on the respondent population of 400 as a sample. In terms of sanitation, 45%, 65%, and 70% of urban, peri-urban, and rural households, respectively, make use of open dump sites for waste disposal, which is a threat to both surface and groundwater quality through pollution.

Hydrogeologically, granite and sandstone constitute the major aquifer rocks of the Wa municipality. Granite weathers into clayey soils, both of which are associated with lower transmissivity values and slow infiltration of surface runoff into groundwater. Sandstone, on the other hand, weathers into sandy soils and has high porosity and transmissivity values. This study found that the average transmissivity of borehole aquifers in the municipality was 8.88 mbgl, with an average aquifer thickness of 56.8 mbgl.

Residents use biophysical indicators of aquifers, such as valleys and sandy-clay soils, as well as tall trees, termites, and anthills. Generally, places on the lower DEM had more favourable conditions of groundwater for borehole construction than those

on higher elevations. The average groundwater depth was 62.2 mbgl, compared to the standard groundwater depth of 60 mbgl and the global standard of 50 mbgl for boreholes fitted with hand pumps. The groundwater situation was observed to be ideal for meeting domestic water needs and has the potential to be exploited for agricultural purposes as well. The major challenge was confined aquifers, which impeded borehole construction.

Hydrochemically, available groundwater quality test results showed conformity to acceptable safe drinking water requirements. However, most boreholes and wells are not tested for water quality, making dental fluorosis common in some communities due to the excess of fluoride in the water.

By revisiting the conceptual framework of this study, the spatial unit characterised by population characteristics, dominated by rural households, and the location in terms of climatic belt and accessibility to water and sanitation demonstrated features of rural communities. These make groundwater a basic necessity in the area. Findings further demonstrated the linkages between the spatial unit from which hydro-geological and hydro-chemical parameters emanate. It was also revealed that the hydro-chemical properties of groundwater were directly related to the geology, or the soil and rocks constituting the aquifers. The outcomes manifested in the form of borehole water, water yield with an average of 14.54 L/min., and drilling success rates ranging from 85% to 100%. Lack of water quality tests results in the use of borehole water contaminated with fluoride, which causes the adverse health effects of dental fluorosis.

A number of recommendations are advanced to address the major problems identified. In the spatial context, it is recommended that the CWSA extend its role in sensitizing communities to the effects of poor waste disposal practices on water resources in the study communities. Providing training on cheap and sustainable methods of waste disposal, such as composting, waste reuse, and recycling methods, and linking communities to business units engaged in waste collection for recycling could be prioritised.

Hydrogeologically, the Wa Municipal Assembly, in collaboration with the CWSA and other groundwater resource development partners, should engage the services of geological surveyors. It was found that granite and clay soils, as well as sandstone and sandy soils, dominate in the study communities. Since aquifers with granite rocks and clay soils are less porous and have low transmissivity levels, geological surveys could detect aquifers with sandstone and sandy soils spreading over wider lowland areas for borehole construction to ensure high transmissivity, greater aquifer thickness, and water yield throughout the year.

For areas with dry well experiences in the dry season, the artificial groundwater recharge method is recommended. By doing so, dugouts could be constructed to store water in the rainy season, which could serve as artificial water recharge for boreholes in the dry season, providing safe drinking water on a sustainable basis. In other words, since Ghana is already running the One Village, One Dam program, the Wa Municipal Assembly, in collaboration with the CWSA, should list communities with groundwater scarcity challenges and recommend the same for inclusion in the village dam program. Surface dugouts or small dams could then be constructed at preferred locations in the communities where both surface and groundwater sources are needed.

This should go along with the construction of boreholes with hand pumps. In the rainy season, both boreholes and dugouts would be recharged by rainwater. In the dry season, both borehole aquifers and surface dugouts are expected to gradually dry up. But part of the groundwater would infiltrate into groundwater aquifers for aquifer recharge. Although the dams would dry out, the adjacent boreholes would continue to yield safe drinking water for a longer time than if they depended on the groundwater table.

For the cost implications of using surface dugouts to boost aquifer recharge, there is already an ongoing program for villages in Ghana, and so the costs of the projects should be contingent on the overall program budget. The social feasibility of the surface dugout-borehole combined project for water supply is that it would contribute to the achievement of SDG 6, which is about clean water and sanitation for all. In terms of economic feasibility, the aquifer thickness, transmissivity, conductivity, and water yield of boreholes could be enhanced to go beyond domestic and livestock uses and include dry-season irrigated farming. The environmental cost of the project, in terms of possible mosquito breeding by the dams and possible increases in malaria incidences, should not be taken for granted. Malaria prevention education and the provision of preventive and curative healthcare services should also be enhanced.

For areas with confined aquifers and deep groundwater depths that impede borehole construction, the Wa Municipal Assembly, in collaboration with the CWSA and WaterAid Ghana, should work towards the adoption of the PolDaw Ultra Deep Well technology, described in the analysis section of the paper. WaterAid Ghana would be resourceful in such a project if this recommendation were to be implemented.

To address the hydro-chemical problems related to groundwater quality, the CWSA, in collaboration with the Municipal Assembly, the Water Resources Commission, and the EPA, should organize training workshops for Community Water and Sanitation Management Boards (CWSMB) in rural and small-town communities. The aim should be to sensitize them about the dangers of indiscriminate borehole and well construction, which could lead to the consumption of water contaminated with dangerous substances such as fluoride, arsenic, and fecal coliform, which cause diseases such as dental fluorosis, cancer, and diarrhea. The CWSMBs could then be used as a task force to prevent indiscriminate boreholes and well construction and to educate community members about the right procedures to follow when constructing groundwater point source facilities. The Wa Municipal Assembly should also vote for part of the common funds for water quality testing of all existing boreholes and wells in rural and small-town communities in the municipality. All the boreholes and wells that fail the tests should be locked down or refilled.

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Review

A survey of sustainable development of intelligent transportation system based on urban travel demand

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Abstract: This paper provides a comprehensive exploration of urban travel demand forecasting and its implications for intelligent transportation systems, emphasizing the crucial role of intelligent transportation systems in promoting sustainable urban development. With the increasing challenges posed by traffic congestion, environmental pollution, and diverse travel needs, accurate prediction of urban travel demand becomes essential for optimizing transportation systems, fostering sustainable travel methods, and creating opportunities for business development. However, achieving this goal involves overcoming challenges such as data collection and processing, privacy protection, and information security. To address these challenges, the paper proposes a set of strategic measures, including advancing intelligent transportation technology, integrating intelligent transportation systems with urban planning, enforcing policy guidance and market supervision, promoting sustainable travel methods, and adopting intelligent transportation technology and green energy solutions. Additionally, the study highlights the role of intelligent transportation systems in mitigating traffic congestion and environmental impact through intelligent road condition monitoring, prediction, and traffic optimization. Looking ahead, the paper foresees an increasingly pivotal role for intelligent transportation systems in the future, leveraging advancements in deep learning and information technology to more accurately collect and analyze urban travel-related data for better predictive modeling. By combining data analysis, public transportation promotion, shared travel modes, intelligent transportation technology, and green energy adoption, cities can build more efficient, environmentally friendly transportation systems, enhancing residents' travel experiences while reducing congestion and pollution to promote sustainable urban development. Furthermore, the study anticipates that intelligent transportation systems will be intricately integrated with urban public services and management, facilitating efficient and coordinated urban functions. Ultimately, the paper envisions intelligent transportation systems playing a vital role in supporting urban traffic management and enhancing the overall well-being of urban construction and residents' lives. In conclusion, this research not only enhances our understanding of urban travel demand forecasting and the evolving landscape of intelligent transportation systems but also provides valuable insights for future research and practical applications in related fields. The study encourages greater attention and investment from scholars and practitioners in the research and practice of intelligent transportation systems to collectively advance the progress of urban transportation and sustainable development.

Keywords: urban transport; sustainable; intelligent transportation; deep learning; flow forecast

1. Introduction

With accelerated urbanization and the continuous increase in population, traffic

congestion has gradually become the norm in urban life [1]. In recent years, the demand for urban travel has increased, and the travel modes are diverse [2]. Urban traffic is a global challenge, especially in the context of rapid urbanization and population growth. Traffic congestion, environmental pollution, and other problems have become increasingly prominent. The traffic situation is a key feature that reflects the health and order of urban operations, production, and life [3]. As an important part of the national economy, the transportation industry interacts with and promotes economic development. The transportation industry can drive economic activities, and economic development can promote the construction of the transportation industry [4]. The traditional traffic management mode can no longer effectively cope with the diverse travel needs of urban residents, so it is urgent to introduce intelligent transportation systems to improve the efficiency and quality of traffic operations. Predicting urban travel demand is important for perceiving the future state of a city, deploying public transportation resources, and building intelligent cities [5]. Research on travel time prediction shows its importance in the rational planning of travel arrangements and traffic congestion mitigation [6]. Urban travel demand shows a diversified and personalized trend, including commuting, shopping, tourism, and other travel purposes and ways. At the same time. Traffic flow prediction has always been the focus of research in the field of intelligent transportation systems, which is conducive to the more reasonable allocation of basic transportation resources and the formulation of transportation policies [7]. Large-scale traffic data mining provides a new solution to alleviate traffic congestion and improve traffic service [8]. How to fully utilize these data to improve the accuracy of predictions has received extensive attention [9]. Forecasting urban travel demand has important implications for sustainable development. Above all, accurate travel demand forecasts can help urban planners optimize transportation system design, improve transportation efficiency, and reduce congestion and emissions. By analyzing factors such as population growth trends, economic development levels, and residents' travel patterns, future changes in travel demand can be predicted. Based on these predictions, urban planners can rationally plan roads, public transportation facilities, bicycle lanes, etc. to meet future needs and reduce energy consumption and environmental pollution. Especially, travel demand forecasting also plays a positive role in promoting the development of sustainable travel methods. In urban travel, the excessive use of private cars has led to problems such as traffic congestion and exhaust emissions. By accurately forecasting travel demand, urban planners can promote the development of public transportation and non-motorized travel modes. Based on demand forecasts, they can increase the coverage and frequency of public transportation lines, provide more infrastructure such as bicycle lanes and pedestrian streets, and encourage citizens to choose sustainable travel methods. This will help reduce dependence on cars, energy consumption, and environmental pollution. Accurate travel demand forecasts can provide business opportunities and development directions. For transportation companies and travel service providers, understanding future travel demand changes can help them optimize operational strategies and improve service quality and efficiency. For example, based on demand forecast results, they can adjust vehicle configuration and route planning to provide more flexible and intelligent travel solutions to meet the

needs of different groups of people.

However, several challenges remain in achieving accurate travel demand forecasts and translating their impacts into practical actions for sustainable development. Data collection and processing is a key issue. Urban travel involves a large amount of data, such as demographic data, traffic flow data, etc. Accurately forecasting demand requires the collection and integration of this multi-source data, as well as effective analysis and modeling. At the same time, privacy and information security issues also need to be properly addressed to protect the security and privacy of personal data.

In summary, accurate urban travel demand forecasting has an important impact on sustainable development. It can help urban planners optimize transportation system design, promote the development of sustainable travel methods, and provide business opportunities and development direction for enterprises. However, to achieve this goal, we need to overcome challenges such as data collection and processing and focus on protecting personal privacy and information security. Only through scientific prediction and reasonable planning can the goal of sustainable development in urban travel be achieved.

2. Document filtering standards

In view of the investigation direction of this paper, we need to cite some kinds of literature to support the views of this paper and provide relevant research background and theoretical basis. The following are the relevant standards for the references in this paper.

2.1. Literature inclusion criteria

The following are the inclusion criteria for the references in this article, as shown in **Table 1**.

Table 1. Literature inclusion criteria.

1) Relevant literature on predictive city factors	
Yes	Inclusion
No	Exclusion
2) Relevant literature on traffic flow prediction	
Yes	Inclusion
No	Exclusion
3) Relevant literature published after 2009	
Yes	Inclusion
No	Exclusion
4) The content is related to sustainable development literature	
Yes	Inclusion
No	Exclusion
5) The research involves related literature in the field of transportation	
Yes	Inclusion
No	Exclusion

(1) Relevant literature on predictive city factors.
(2) Relevant literature on traffic flow prediction.
(3) Relevant literature published after 2009.
(4) The content is related to sustainable development literature.
(5) The research involves related literature in the field of transportation.

2.2. Literature exclusion criteria

(1) The picture is unclear in the relevant literature.
(2) Related literature with unclear language expression.
(3) Relevant literature with significant gaps in experimental directions.
(4) Relevant literature with questionable experimental results.
(5) Relevant literature published too early.
(6) Non-academic related literature (such as non-academic newspapers and magazines).

3. Materials and methods

In order to further explore the relationship between urban mobility demand and intelligent transportation systems, we conducted field research and case studies. Through the analysis of traffic data and the construction of intelligent transportation systems in many cities, it has been found that intelligent transportation systems have played a positive role in meeting urban travel demand, reducing traffic congestion, and improving traffic efficiency.

Although much of the work considers multi-task scenarios, it does not explore the potential spatial information between subtasks [10]. Based on the above research results, we believe that with the acceleration of urbanization, the demand for urban travel continues to grow, putting tremendous pressure on the urban transportation system and environment. In order to achieve sustainable development of urban travel, we need to take a series of initiatives to predict and meet future travel needs: Obviously, strengthen the research and development of intelligent transportation technology to improve the intelligent level and service capability of the system. Deep learning parallel plays an important role in accelerating model training and improving prediction accuracy [11]. Signally, to promote the deep integration of urban planning and intelligent transportation systems to ensure the coordination between system construction and urban development, we can use data analytics and intelligent traffic management systems to predict urban travel demand. By collecting and analyzing traffic flow, population migration, economic growth, and other data, we can understand travel demand in different regions and time periods and make accurate predictions. In this way, the traffic management department can make corresponding planning and dispatch in advance according to needs to avoid traffic congestion and waste of resources. Specially, strengthen policy guidance and market supervision, promote the healthy development of the intelligent transportation industry, and promote the intelligent transportation system to play a greater role in the sustainable development of the city. Promoting sustainable development requires encouraging the use of public transport and non-motorized travel modes. Increase investment in the public transportation system, improve service quality and

coverage, and enable more people to choose to travel by public transportation. At the same time, a complete network of walking and cycling paths should be built to provide a convenient and safe non-motorized travel environment, encourage citizens to walk and cycle, and reduce reliance on motor vehicles. Promoting shared travel mode is also one of the important measures for sustainable development. New modes of travel such as shared bicycles and cars can effectively reduce vehicle ownership and improve resource utilization efficiency. The government can cooperate with relevant enterprises to provide policy support and preferential measures to encourage citizens to use shared travel services. At the same time, in the process of promoting shared travel, management and supervision must be strengthened to ensure operational safety and order. Another point, the introduction of intelligent transportation technology and green energy is an important means to achieve sustainable travel. Intelligent transportation systems can optimize traffic flow, improve road utilization, and reduce congestion and emissions. At the same time, promote the popularization of electric vehicles and the construction of charging facilities, promote the application of green energy in urban travel, and reduce tail gas emissions and reliance on fossil energy. Publicity and education are also important measures to promote the development of sustainable travel. By carrying out publicity activities on travel modes, we can enhance citizens' knowledge and awareness of sustainable travel and guide them to change their travel habits and choose more environmentally friendly and low-carbon ways. Traffic safety education can be strengthened to improve citizens' traffic literacy and reduce traffic accidents and casualties. In short, measures that combine forecasting urban travel demand with sustainable development are the key to achieving sustainable development of urban transportation. Through data analysis, the promotion of public transportation and non-motorized travel, the promotion of shared travel modes, the application of intelligent transportation technology and green energy, and publicity and education, we can build a more convenient, efficient, and environmentally friendly urban transportation system. This will help improve residents' travel experience, reduce traffic congestion and pollution, and promote sustainable urban development. The sustainable development of intelligent transportation systems needs to be fully integrated with urban planning in order to realize the positive interaction between system construction and urban development. The intelligent transportation system should also be closely integrated with the overall urban planning, fully consider the future development direction of the city and changes in population structure, and ensure that the system construction is coordinated with urban development. At the same time, the intelligent transportation system should be organically integrated with the construction of urban infrastructure, and make full use of information technology means to improve the efficiency and intelligent level of urban traffic operation.

4. Results and discussion

With the rapid development of the transportation and automobile industries, trajectory prediction has become a focus in the field of transportation big data [12]. The impact of urban travel demand on intelligent transportation systems is mainly reflected in the following aspects: Above all, the research on travel time prediction

has shown its importance and significance in rational planning of travel arrangements and alleviating road congestion [13]. The diversified travel needs require the intelligent transportation system to have higher flexibility and intelligence levels to meet the travel needs of different groups. Next, predicting the population density of key areas of the city is crucial [14]. The complexity of traffic scenarios and the spatial-temporal feature correlations pose higher challenges for traffic prediction research [15]. In order to ensure the smooth operation of the traffic network, it is necessary for the intelligent transportation system to have dynamic adjustment ability due to the changes in peak and low periods of urban traffic demand. Thirdly, the formation of urban functional regions is closely related to the travel behaviour of people [16]. It is beneficial to urban travel planning, the alleviation of traffic congestion, and urban commercial planning [17]. The construction of intelligent transportation systems needs to fully consider urban development planning and demographic changes to achieve long-term sustainable development. The traffic condition of the target area is affected by the surrounding area or the further area, which makes the urban traffic area have a certain spatial dependence [18]. And, the movement of humans in cities is an important reference standard for the division of urban functional regions [19]. The hierarchy of city nodes is an important characteristic of relative spatial distribution [20].

As a means of intelligent traffic management, intelligent transportation systems can effectively respond to the diversified travel needs of cities. Through real-time data collection and analysis, the intelligent transportation system can accurately grasp the traffic conditions in different time periods and regions so as to dynamically adjust according to the travel needs of urban residents. The intelligent transportation system also supports the information interconnection of various modes of travel, including public transportation, self-driving vehicles, shared travel, etc., to provide more convenient and efficient travel options for urban residents. The intelligent transportation system can also achieve a refined response to urban traffic demand through intelligent signal control, traffic information release, and other ways to improve traffic operation efficiency and service level.

Intelligent transportation systems not only meet the needs of urban travel but also play an important role in reducing traffic congestion and environmental protection. Through intelligent road condition monitoring and prediction, the intelligent transportation system can find the possibility of traffic congestion in time, reduce the probability of congestion, and improve traffic efficiency through intelligent signal control, traffic route optimization, and other means. By promoting intelligent public transport systems, public transport operation efficiency, and service quality will be improved, citizens will be encouraged to choose low-carbon travel modes, and the impact of urban transport on the environment will be reduced. Of course, intelligent transportation systems can also reduce energy consumption and environmental emissions by reducing vehicle idling, optimizing road design and other measures, and making positive contributions to sustainable urban development.

With the continuous development of information technology and the acceleration of urbanization, intelligent transportation systems will play a more important role in the future. Flow forecasting is significant for planning transportation and allocating basic transportation resources [21]. In recent years,

deep learning has played an essential role in computer science and other fields [22]. With the extensive application of new generational information technologies such as artificial intelligence and big data, intelligent transportation systems will become more intelligent, providing more personalized and convenient travel services for urban residents. With the development of big data and artificial intelligence, we can also more accurately collect and analyze various data related to urban travel, including traffic flow, population migration, economic growth, and other information. By applying advanced data analysis technology and building intelligent models, future travel needs can be effectively predicted. At the same time, with the help of cloud computing and Internet of Things technology, real-time monitoring and analysis of traffic data can be achieved, and timely and accurate prediction results can be provided. At present, research on deep learning focuses on the fusion of different neural network structures, absorbing the advantages of different architectures, so that the model has better accuracy and stability [23]. Deep learning can discover the patterns and trends of urban travel demand through the analysis of historical traffic data. Traditional statistical methods and models may not be able to handle complex nonlinear relationships and high-dimensional data, but deep learning can automatically learn and extract features from the data by building multi-level neural network models, thereby more accurately capturing urban travel and changing trends in demand. Deep learning can also improve the accuracy and precision of urban traffic predictions. Moreover, deep learning models have strong nonlinear modeling capabilities and can handle complex traffic data and relationships, thereby improving the accuracy and precision of predictions. At the same time, deep learning can provide personalized travel suggestions and services. Through the analysis and learning of user travel data, deep learning can understand users' travel preferences and habits, thereby providing users with personalized travel suggestions and services. Deep learning can facilitate the development of sustainable transportation options. In the context of sustainable urban development, it is important to encourage and promote the use of sustainable transport modes. Deep learning can analyze large amounts of travel data to discover people's needs and preferences for sustainable transportation methods such as public transportation, walking, and cycling, thereby providing decision support for urban planning and transportation management departments. The ensemble learning method can combine the advantages of different models and has high stability [24]. Self-supervised learning can use unlabeled data for pre-training and transfer the learned model to downstream tasks, which can alleviate the requirement for labeled data [25]. With the development of deep learning, significant technological breakthroughs have been made in the fields of image, speech, and natural language processing [26]. The intelligent transportation system will be more closely integrated with urban public services, urban management, and other aspects to achieve efficient operation and collaborative development of various urban functions. Finally, urban travel demand forecasting is significant in improving traffic conditions and traffic management [27]. Intelligent transportation systems will also provide more possibilities for sustainable urban development, become an important support for urban traffic management, and bring more convenience and well-being to urban construction and residents' lives.

5. Conclusions

This study provides an in-depth exploration of urban travel demand forecasting and its impact on intelligent transportation systems, as well as the important role of intelligent transportation systems in sustainable development. Through analysis of traffic data and case studies of intelligent transportation systems in multiple cities, we draw the following conclusions:

Accurate urban travel demand forecasting is of great significance for urban planners to optimize the design of transportation systems, promote the development of sustainable travel modes, and provide business opportunities and development directions for enterprises. However, achieving this goal still faces many challenges, including issues such as data collection and processing, privacy protection, and information security. In response to these challenges, we have proposed a series of countermeasures, including strengthening the research and development of intelligent transportation technology, promoting the deep integration of intelligent transportation systems and urban planning, strengthening policy guidance and market supervision, promoting the development of sustainable travel methods, and introducing intelligent transportation technology and green energy, etc. In addition, intelligent transportation systems play an important role in reducing traffic congestion and protecting the environment while meeting urban travel needs. Through intelligent road condition monitoring and prediction, intelligent transportation systems can promptly detect the possibility of traffic congestion, reduce the probability of congestion through intelligent signal control, traffic route optimization, etc., improve traffic efficiency, and thereby reduce the impact on the environment. With the continuous development of information technology and the acceleration of urbanization, intelligent transportation systems will play a more important role in the future. In recent years, deep learning has played an important role in fields such as computers. In the field of transportation, deep learning can also more accurately collect and analyze various data related to urban travel, thereby more effectively predicting future travel needs.

In short, this study believes that through the comprehensive application of data analysis, the promotion of public transportation and non-motorized travel, the promotion of shared travel modes, the application of intelligent transportation technology and green energy, and publicity and education, more convenient, efficient, and environmentally friendly urban transportation systems can be developed, thereby improving residents' travel experiences, reducing traffic congestion and pollution, and promoting sustainable urban development.

In the future, intelligent transportation systems will be more closely integrated with urban public services, urban management, and other aspects to achieve efficient operation and coordinated development of various urban functions. Intelligent transportation systems will bring more possibilities for sustainable urban development, become an important support for urban traffic management, and bring more convenience and well-being to urban construction and residents' lives.

Through the work of this study, we have a clearer understanding of urban travel demand forecasting and the development trend of intelligent transportation systems, and it also provides a certain reference value for future research and practice in

related fields. We look forward to more scholars and practitioners paying attention to and investing in the research and practice of intelligent transportation systems and urban sustainable development in the future and jointly promoting the development and progress of the urban transportation field.

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Review

Sustainability through digital transformation: EU practices

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Abstract: The significance of sustainability efforts has been reaffirmed by negative circumstances, such as the escalating visible consequences of climate change, floods resulting from erratic weather patterns in certain areas, and fires and extreme droughts in other regions. The logical rationale behind employing digital tools for sustainability purposes lies in the efficiency of digital transformation, supported by artificial intelligence, in improving remote access, control, and decision-making processes, as well as accomplishing tasks that are unachievable through human effort alone. Upon analyzing practices worldwide, it becomes apparent that the European Union (EU) is the singular entity that places utmost importance on digitalization as a means to ensure sustainability. Additionally, it provides comprehensive allocations for projects pertaining to this subject and supports the collective wisdom of its members through the established union. Hence, the purpose of this study is to examine the current literature in detail via a systematic review to extract the EU practices of sustainability through digitalization. Findings reveal the particular EU focuses and key themes on achieving sustainability with a visual representation of the results. Besides, the EU practices with other well-known countries on sustainability through digitalization efforts are compared and discussed. Thus, a practitioner can understand the findings of this research to use as the first step when generating research questions to start a new study.

Keywords: systematic review; sustainability; Industry 4.0; digital transformation; digitalization

1. Introduction

Industry 4.0 (viz., the Fourth Industrial Revolution) and sustainability goals are of paramount importance for the European Union (EU) owing to the numerous significant advantages in terms of economic competitiveness [1], new job fields' creation [2], market growth [3], environmental consciousness [4], natural resource usage efficiency [5], energy independence [6], and social inclusion [7]. Sustainability and Industry 4.0 are not mutually incompatible concepts [8]. Indeed, the EU is working extensively to merge these two agendas [9,10]. For example, in this context, smart/digitalized, and sustainable manufacturing techniques can assist the EU in meeting its climate targets by enabling real-time monitoring and resource usage optimization [11], thus, lowering the environmental effect. Furthermore, the EU has created policies and financial initiatives to help both Industry 4.0 and sustainability, proving its dedication to attaining these sustainable development goals [12,13].

The companies reach sustainability goals through Industry 4.0 by utilizing advanced digital technologies and data-driven approaches [14]. Efficient use of resources can be achieved through insights from data; hence, predictive maintenance and smart energy management can be fulfilled [15,16]. Besides, circular economy (CE) is another important part of reaching sustainability by monitoring the product lifecycle and having the ability to customize/personalize [17,18]. In a broader context,

supply chain optimization can be attained by greener manufacturing implementations, and by higher supplier collaborations via real-time visibility [19,20]. As a result of doing so, traceability and transparency improve consumer engagement [21], Waste management can also be achieved in terms of both solid waste mitigation [22] and emission and energy use reduction [23].

The main technologies enabling Industry 4.0 are robotics, IoT/sensor technology [24,25], digital twins [26,27], big data [28,29], cloud computing [30,31], artificial intelligence (AI) [14,32,33], additive manufacturing [34,35], augmented reality [36,37], and cybersecurity [38]. The companies can facilitate these technologies in order to obtain Industry 4.0 benefits.

Therefore, the motivation of this study is based on this valuable background knowledge, emphasizing the importance of Industry 4.0 paving the way to sustainability. Moreover, according to worldwide industry reports, the USA, Germany, Japan, France, China, and South Korea are the most well-known countries leading to the industrial revolution [39]. However, although there are some particular countries preparing future plans and investing in cutting-edge technologies to have applications of Industry 4.0, like Italy [40], the EU falls behind within this competitive market environment. Indeed, there is also a gap in the literature focusing on the EU practices of Industry 4.0 in pursuit of sustainability (see Systematic Review section).

Hence, the purpose of this study is to extract the details of Industry 4.0 implementations in EU countries in order to achieve sustainability goals via a systematic review. Both the industrial reports and academic papers were included in the review to determine the mutual points adopted by the EU and to interfere with common application trends.

The following parts of this paper cover a systematic review, results, discussion, and conclusion.

2. Systematic review

In order to identify the triggering causal relation of Industry 4.0 (I4.0) to sustainability, the Scopus database, including well-known publishers such as Elsevier, Springer, Emerald, Sage, Wiley, Taylor & Francis, Routledge, etc., is searched with Industry 4.0/digital transformation/digitalization, sustainable/sustainability, and "European Union" keywords, and 174 document results were obtained in October 2023.

Accordingly, the number of "EU Industry 4.0 applications for sustainability (EU I4.0 Sustainability)" papers has been increasing since 2017 and has an increasing trend beginning this year. In comparison to the worldwide paper volume, although there are 9458 documents about that topic, only 174 of them are about EU applications. Therefore, it is obvious that despite the defined sustainability goals of the United Nations, the EU countries are falling back within this field of study in terms of publications. Moreover, EU I4.0 Sust papers include mainly articles (62%), conference papers (21%), reviews (6%), book chapters (6%), conference reviews (3%), notes (1%), and short surveys. Besides, social sciences (18%), computer science (14%), environmental science (13%), engineering (12%), energy science (9%), economics (9%), business and management (8%), and other disciplines contribute to the EU I4.0 Sust field of study. Furthermore, the major funding organizations are the

European Commission, Horizon Programme, European Regional Development Fund, Fundação para a Ciência e a Tecnologia, Javna Agencija za Raziskovalno Dejavnost RS, Ministry of Education and Science of Ukraine and Erasmus+. EU I4.0 Sust research is supported by Italy, Germany, Poland, Romania, Spain, Russia, Portugal, France, Greece, and the Netherlands.

EU-specific papers on I4.0 and sustainability are mainly eightfold: 1) sustainable development focus; 2) carbon-neutrality; 3) information and communication technology (ICT) use of individuals; 4) e-commerce/digital economy; 5) technology adoption and public policy making; 6) blue economy (referring to the industries relying on waterways/oceans to enhance tourism, transport, marine biotechnology, fishing, wind energy and agriculture); 7) digitalization affecting environmental sustainability, and agriculture. The following sub-sections entail EU I4.0 for sustainability research.

2.1. Sustainable development (SD) focus of the EU

The European Union (EU) prioritizes SD with a remarkable effort to address many factors that can be roughly classified as (i) economic; (ii) environmental, and (iii) social dimensions [41,42]. The economic dimension mainly covers resource-efficient economic growth, green technology investments, and green finance, while the environmental dimension addresses climate change, biodiversity and conservation, and the circular economy [43]. Thirdly, the social dimension emphasizes social inclusion, quality of life, and gender equality [44]. Here, the policy frameworks and regulations of governments are significant to monitor and report the industries in a transparent way [45,46]. Indeed, global cooperation like the Paris Agreement and the United Nations Sustainable Development Goals (SDGs) are paramount of importance to maintaining the SD [47].

The SD focus of the EU indicates that there is a strong link between digitalization and SD in EU countries [48]. Smart transportation [41], smart cities [49], smart mobility [50], smart organizations [51], smart agriculture [52], smart life cycle assessment [53], smart use of energy [54], smart waste management [45], smart recommendation systems [55], smart procurement and notification systems [56], smart food processing [57], smart process treatment/monitoring/controlling [58], smart tourism [59], smart finance [60], smart healthcare technologies [61], smart recycling [62], and cybersecurity [63] are the major implementation fields of EU academicians within EU I4.0 for sustainability research.

2.2. Carbon-neutrality (CN) focus of EU

The EU has established a high target of reaching CN by 2050, which entails balancing greenhouse gas emissions with reductions or cuts, ultimately attaining a net-zero carbon footprint [64]. There are significant factors to achieve CN such as controlling climate change, international cooperations/commitments [49], reducing air pollution/greenhouse gas emissions [65], mitigating the damages in natural habitats, protecting biodiversity [66], renewable energy use like wind and solar alternatives instead of fossil fuels [67], promoting waste management/circular economy/recycling/sustainable production and consumption [45], investing on cutting-edge technologies like carbon capture and storage [64], supporting electric

vehicles in public transportation and individual mobility [50], suggesting energy use optimization in manufacturing industries [68], encouraging reforestation and sustainable farming [69], CN education to improve the awareness [70], government policies and regulations for CN [71].

2.3. Individuals' information and communication technology (ICT) focus of EU

The ICT use of individuals in the EU is affected by several elements, such as access through a digital infrastructure that is directly linked to internet availability and affordability [1], digital skills/literacy that can be improved by training/education to close the generation/age gaps, socioeconomic elements that can be shaped by income and employment status [44], digital inclusion strategies with governmental initiatives and accessibility standards [71], cultural elements with attitudes of people and social norms [72], digital privacy and cybersecurity [38], content relevance and local language [73], and regulations [74]. The aforementioned variables are interrelated and their influence on ICT use varies by EU member state. Authorities, politicians, and other parties in the EU are working on addressing these variables in order to encourage wider and more equal access to and usage of ICT across the area.

2.4. e-Commerce (eC) and digital economy (DE) focus of the EU

The eC focus enabling the DE has remarkable benefits, particularly the financial sustainability focus, however, there are some major concerns arising from the increasing logistics frequency and solid waste amounts [75]. eC and DE are affected by several factors in the EU, such as "Digital Single Market" strategy and "eC Directive" [76], protection of data/consumer/intellectual property [63], financial services/payment systems/fintech [3], cutting-edge technologies/5G/broadband access [77], global trade regulations/agreements/taxation [49], trust and preferences of customers [21], competitiveness [51], language problems for addresses [78], last-mile delivery/logistics [79], and digital literacy with training/education support.

2.5. Technology adoption (TA) and public policy making (PPM) focus of EU

The TA and PPM focus of the EU directly affects sustainability strategies in terms of innovation ecosystems and regulations. In other words, there is a significant background on how the technology is adopted by communities, how it is regulated, and what the result of this process is. This is a major concern of PPM in the EU. Within the context of laws and regulations, the standards for interoperability have an important role [56]. For the innovation ecosystem, research and development initiatives, startups and small and medium-sized enterprises are the fundamentals to foster the system [16]. Indeed, digital infrastructure [1], lifelong learning and workforce development through education [32], protection of data/privacy and cybersecurity [38], collaborations, funding mechanisms, public-private partnerships [80], competition in the market [51], digital inclusion with respect to accessibility and affordability [81], green technology and circular economy concern [79], public engagement and transparency [56] are all important factors affecting the TA and PPM in the EU.

2.6. Blue economy (BE) focus of EU

BE stands for the ocean/waterway's sustainable use by countries/authorities for financial welfare with both occupation opportunities and enhanced ecosystem protection, including several industries such as fishery, maritime transportation and biotechnology, tourism, aquaculture, and renewable energy [82]. BE depends on the coastal geography to access the sea [66], fisheries and aquaculture management, logistics infrastructure with the intermodality opportunity to enhance connectivity [79], recreation and coastal tourism [59], energy resources [54], training and workforce, regulations of EU [74], diplomacy for international cooperations [83], awareness of customers and entrepreneurship [11] to shape demand, ports, and shipyard infrastructure [84].

2.7. Digitalization effects on environmental sustainability (DEES) and agriculture (DEA) focus of EU

The DEES focus of the EU is twofold: positive and negative consequences. Energy efficiency via green information technology uses [68], renewable sources of energy usage [67], electronic management of wastes [45], smart mobility [50], remote working/sensing opportunities, traceability and transparency [66], digital document use instead of physical paper resources [76] are the positive consequences of digitalization on sustainability. However, storage/privacy/security/misuse/transfer of data consumes higher energy amounts [38], and solid electronic waste generation [45] has become a problem for EU countries.

With the introduction of digital technologies like IoT, digital twins, augmented reality, etc., the DEA's focus on the EU has gained momentum with the ability of remote control and monitoring [52], referring to "smart farming" or "precise/precision agriculture" or "agrifood 4.0/agriculture 4.0" [69]. 5G, broadband access, IoT/remote sensing, GPS use, and autonomous machinery are the main requirements of the digital infrastructure to enable connectivity [85]. Next, the gained data is analyzed to derive meaningful insights, for example, to optimize fertilizer/pesticide amounts, forecast the weather conditions/planting/harvesting times, manage the crops/livestock, etc. [86]. Here, resource conversation enables sustainable practices in agriculture. However, the existing farmers' resistance to change and to adopting new technologies is a common challenge that can be dealt with in training programs. Besides, mutual agriculture policies force these existing farmers to be a part of the change to achieve digitalization in agriculture. Moreover, the cost of these technologies is another issue for farmers. Indeed, consumer demands for more transparency through supply chain visibility encourage these farmers to keep up with new approaches [87].

The following section derives from this important background to provide meaningful results and compares the EU and worldwide approaches to achieving sustainability through digitalization.

3. Results and discussion

By examining the EU I4.0 for Sustainability systematic review in detail, one can infer that the sustainable development of the EU can be categorized as the financial, environmental, and social triple bottom line of sustainability (see **Figure 1**). Here, e-

commerce/digital economy and blue economy practices directly affect financial sustainability, while carbon neutrality and blue economy practices have a direct impact on environmental sustainability. Moreover, social sustainability is supported by the privacy of the community, an enhanced workforce through community welfare, and the digital skills of people in terms of self-improvement. Besides, digitalization triggers both the digital economy and carbon neutrality practices by enabling real-time long-distance monitoring and controlling. However, individuals' ICT use and technology adoption are important to actualize digitalization, which fully depends on digital skills and public policies. In order to achieve this, there are three fundamental must-haves: (1) training/education, (2) laws and regulations, (3) privacy, data protection, and cyber security.

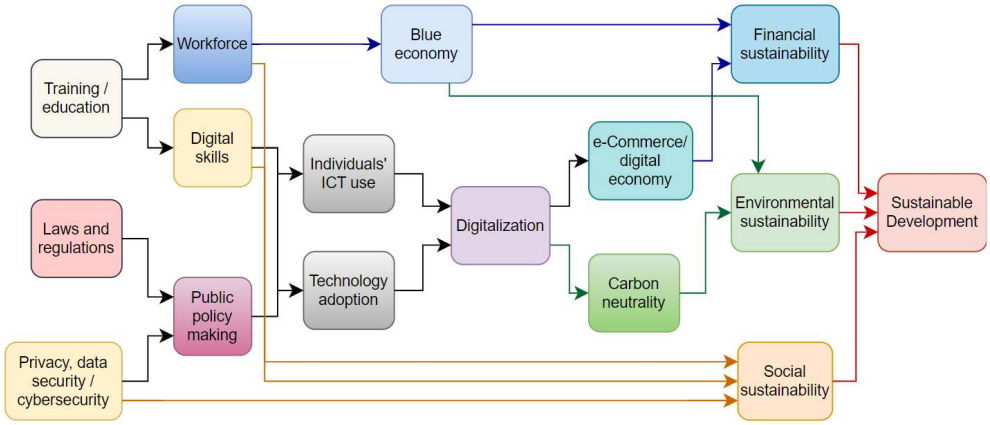

Figure 1. Causal relationship between EU I4.0 for sustainability research elements.

In order to compare the findings of this research with existing ones, an additional review is conducted. Accordingly, although the United States (US) has extended its digital infrastructure for sustainability, different states might have differentiated applications in terms of governmental policies. While EU countries have single mutual agreements like the "European Green Deal", the US implements public-private initiatives to achieve sustainability through digitalization. Furthermore, the EU supports the circular economy and smart city practices more, while the US seeks technology innovation, energy use optimization, and smart agriculture more [88–90].

China has again made efforts to monitor the environment and conduct green transportation solutions, however, the major difference between China and the EU is that the country's human population density is a challenge. Therefore, China has a focus on resource use minimization and efficiency through digitalization [91–93].

In addition, Japan is already familiar with the sustainability phenomenon, such as the "lean philosophy" that grounds "waste reduction" activities. Today's challenge for Japan is finding a workforce [94] in terms of social sustainability because they are shifting their workforce from China to Japan [95].

As another comparison, since Russia is prosperous in terms of natural resources, its focus is on smart enterprises to achieve digital transformation to point-to-point industrial systems by enhancing dynamic capabilities [96,97]. As a result, the systematic review indicates that the utmost efforts toward sustainability through digitalization are provided by the EU and the United Nations.

To highlight the scientific contribution of this research, the preliminary well-known and widely accepted conceptual frameworks of Kamble [98], Yadav [99], Birkel [100], Yadav [101], and Gupta [102] are all reviewed and adopted to generate this conceptual model. This study implements the mutual relationships of these frameworks in a parallel direction. A practitioner can understand by studying the [103–111] researchers to reach the details.

4. Conclusion

The European Union attributes paramount importance to Industry 4.0 and sustainability goals, as they offer significant advantages in terms of economic competitiveness, job creation, market growth, environmental consciousness, efficient use of natural resources, energy independence, and social inclusion. The concepts of sustainability and Industry 4.0 can be harmoniously integrated. The EU is actively engaged in merging these two agendas.

This study is motivated by valuable background knowledge that emphasizes the significance of Industry 4.0 as a pathway to sustainability. Furthermore, as indicated by global industry reports, the prominent nations that spearheaded the Industrial Revolution have been surpassed by certain countries that are strategically developing future plans and investing in cutting-edge technologies for the implementation of Industry 4.0, such as Italy. However, the European Union lags behind in this fiercely competitive market landscape. Furthermore, there is a noticeable lack of scholarly research that delves into the EU's practices in Industry 4.0 in the context of sustainability.

Thus, the aim of this study is to conduct a detailed examination of the current literature through a systematic review, with the goal of extracting and analyzing the European Union's sustainability practices in the context of digitalization.

The findings of this review reveal specific EU focuses and key themes on achieving sustainability in a visual format. Upon comprehensively analyzing the EU I4.0 for Sustainability systematic review, it becomes apparent that sustainable development can be divided into financial, environmental, and social aspects. A major influence on financial sustainability can be seen in e-commerce and digital economy practices, whereas a major impact on environmental sustainability can be observed in carbon neutrality and blue economy practices. In addition, a comparison and discussion of EU practices regarding digitalization and sustainability are also conducted.

Consequently, practitioners can use the findings of this research to generate new research questions for their own studies as a first step, which is also a theoretical contribution to scientific development. Many managerial implications can be derived by using the findings of this study in terms of decision-making, planning, and strategy-building by the authorities responsible for sustainability through digitalization in their institutions.

The research is limited to the EU practice literature; however, since the main idea of this research is to highlight the EU in detail, it might not be evaluated as a limitation. Besides, further studies might add more industry reports to emphasize EU practices, or more countries might be compared and discussed with EU practices.

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