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Local Artisans' Knowledge of Flood Resilient Construction and Adaptation of Residential Buildings in Flood-Prone Informal Settlements in Dar es Salaam, Tanzania

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ABSTRACT: Flood-prone informal settlements are among the most complex and challenging construction sites that require adequate knowledge to enhance flood resilience and adaptation. While such settlements present construction challenges that need the attention of professionals, anecdotal observations and experiences in developing countries and Tanzania, in particular, indicate a vast preference to engage and prioritise local artisans in such areas under the pretext of the high cost of affording professionals. This article sought to understand how the local artisans were knowledgeable of construction of residential buildings in flood-prone informal settlements in Dar es Salaam. To understand this phenomenon, various flood-resilient and adaptive measures that local artisans presumed to be aware of and which they were using in constructing buildings in flood-prone areas were analysed. The article adopted a case study design where qualitative data were collected using key informant interviews and focus-group discussions and analysed thematically. Results showed that local artisans constructing houses in the flood-prone areas of Msasani Bonde la Mpunga were well informed of various flood-resilient and adaptation measures, including engineering-related skills (structural) and tacit categories. These measures include raising/elevating ground floor levels, using reinforced foundations and aprons around the foundation plinth and using waterproof building materials such as waterproof cement. However, using stilts/columns was rarely applied because it was conceived as a complex and costly flood construction measure. The article concludes that most local artisans in the Msasani Bonde la Mpunga settlement had good and relevant knowledge to enhance flood resilience and adaptation of buildings. However, they require the technical proficiency of professionals. The article calls for regular training and inseminations of flood-resilient construction techniques for local artisans. Such training will blend the engineering and local knowledge/expertise fundamental for enhancing sustainable urban planning and resilient building construction in flood-prone informal settlements. Local artisans' training should be synchronised with sensitisation to enlighten communities about the significance of utilising skilled and trained local artisans.

KEYWORDS: Flood-prone, resilience, adaptation, local artisans' knowledge, informal settlement.

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1. INTRODUCTION

Globally, informal settlements contribute significantly to housing the majority of urban residents in developing countries despite negative perceptions portrayed in such areas. This is because informal

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settlements substantially address housing problems for low-income people, especially in developing countries (Sakijege, 2019; Zhang, 2016).

Despite their disproportionate exposure to climate change-related hazards such as floods and heat waves, informal settlements offers dwelling spaces of nearly a billion people in the world (Abunyewah et al., 2018; Dodman et al., 2022; Satterthwaite et al., 2020; UN-HABITAT, 2020;). Informal settlements are often situated in the hotspots of flood plains, including valleys, marshy areas, and watercourses (Abunyewah et al., 2018; John, 2020; Richmond et al., 2018; Sakijege et al., 2014). About 19 per cent of the world population is directly exposed to substantial risks during 1-in-100-year flood events (Rentschler & Salhab, 2020). Therefore, building houses in such areas is in a way risky. However, due to population density growth and the inability of the government to provide adequate housing in cities (Richmond et al., 2018), low-income urban residents opt for informal settlements, including the ones that are often vulnerable to flood risks, poor construction activities (Abunyewah et al., 2018; Amoako & Inkoom, 2018; Risi et al., 2013) accentuate flood skills. This has been observed in most poor countries, including Tanzania.

Builders in flood-prone informal settlements in many developing countries enlist the engagement of professionals and local artisans to apply flood-resilient and adaptive construction knowledge and skills to avoid vulnerability and flood exposure (John, 2015; Kikwasi & Mbuya, 2019). This study focuses on the local artisans' knowledge of construction in flood-prone areas. The term 'local artisans' is associated with diverse interpretations denoted by a galaxy of synonyms, such as informal craftsmen, construction craftsmen, draftspersons, masons, casual builders, and master craftsmen (Mselle & Alananga Sanga, 2017; Smith, 2001). According to Mselle & Alananga Sanga (2017), local artisans entail people whose construction knowledge emerges informally through skills transfer mechanisms or learning by doing (Mselle & Alananga Sanga, 2017). This study adopts 'local artisans' because this is a sense of interpretation shared and well understood by most scholars who have written on the subject or related issues in the context of Tanzania (Kikwasi & Mbuya, 2019; Mbuya et al., 2018; Mselle & Alananga Sanga, 2017; Sakijege et al., 2012; Sakijege et al., 2014; Sakijege, 2019).

The choice of local artisans in flood-resilient construction is commensurate with house builders' income (Kikwasi & Mbuya, 2019; Mbuya et al., 2018). This choice suggests a positive co-existence between vulnerability and disaster resilience/adaptation, denoting that resilience and adaptation can be related to "strength in the presence of stress", as Usamah et al. (2014) view. Because most residents in informal settlements are regarded as less fortunate, they are most likely to opt for the services of the local artisans. Scholars have noted that constructing buildings in flood-prone areas is challenging because of exposure to floods, economic limitations of house owners, and inadequate housing construction techniques (Hambati & Yengoh, 2018; Usamah et al., 2014). Some scholars' concerns hinge on residents' limitations, while others have focused on local artisans. These arguments partly explain why some buildings may not have flood-resilient/adaptive measures in flood-prone informal settlements.

Given the many challenges builders in house construction in flood-prone areas experience, it would be expected that urban plans and regulations consider these aspects. However, this is not often the case, as scholars have noted that many urban planning and development policies in most regions of the world tend to exclude flood-prone informal settlements and their dwellers from development planning considerations (Dangol & Carrasco, 2019; Satterthwaite et al., 2020). For instance, in Tanzania, the urban planning policies view flood-prone informal settlements as environmentally fragile land unsuitable for residence (URT, 1999; URT, 2004). However, despite these prohibitive policies, urban dwellers are increasingly constructing houses in these areas (Abunyewah et al., 2018). This tendency is attributed to the rapid urbanisation trend, inadequate urban planning policies, and city population growth, which consequently accentuate the demand for housing high (Jahangir, 2018). The urban planning policies have therefore tended to ignore the reality of people with low incomes contributing to the vulnerability of residents (Dangol & Carrasco, 2019). However, residents continue to take initiatives for flood-resilient/adaptive knowledge in building construction in flood-prone areas.

Building construction in flood-prone informal settlements involves informal construction processes using self-help techniques (Feliciano et al., 2022; Satterthwaite et al., 2020). These include using local artisans in building construction instead of professionals like architects, planners and engineers with qualifications and knowledge of flood-resilience/adaptive measures. According to Feliciano et al. (2022), housing construction measures in flood-prone informal settlements are usually organised by the house owners, who hire house builders with practical construction knowledge. Conversely, other studies (Goldwyn & Gonz, 2022; Kikwasi & Mbuya, 2019) note that houses in many flood-prone informal settlements are informally built mainly by engaging builders, friends, or family members who acquired construction knowledge mainly through learning by doing as local artisans. The use of local artisans in building construction has been witnessed in the poorest countries, but have eluded the scholars' attention.

A few studies have been conducted focusing on local artisans' knowledge of flood-resilient/adaptive buildings in informal settlements. Moles et al. (2013) recognise the contribution of local artisans, local people, and strong knowledge of their local culture and general context critical for resilient buildings to floods. Other scholars have acknowledged community resilience in disaster risk settlements, including flood-prone areas (Hambati & Yengoh, 2018; Petersson et al., 2020). However, these studies did not address the knowledge of the local artisans in contributing to community resilience in flood-prone informal settlements. Studies on how to make buildings flood-resilient/adaptive have been conducted, particularly on the engagement of professional knowledge, paying little attention to local artisans (Brisibe, 2018; Brisibe & Pepple, 2018). Studies have documented the necessity of advancing building materials and material technologies (Anh & Phong, 2014; Golz et al., 2013; Golz et al., 2015); the architectural design innovations to increase flood resilience (Anh & Phong, 2014; Proverbs & Lamond, 2017); improving planning regulations, laws, policies and building codes that cover the aspects of severe, and extreme flood related climate change situations (FEMA, 2011; Rogers et al., 2015) are underscored.

In the context of Tanzania and Dar es Salaam City, in particular, there is limited literature on flood-resilient knowledge and adaptation of buildings by local artisans. The existing studies (e.g. Kikwasi & Mbuya, 2019) have mainly focused on construction knowledge in flood-prone informal settlements using different approaches and methods, including experimental methods, to assess the vulnerability of buildings to floods. They note that most buildings were vulnerable to floods attributing this to local artisans' lack of knowledge/skills used mainly by residents in construction, among other factors. The study by Kikwasi & Mbuya overlooked the significance, role and contribution of local artisans' knowledge in reducing vulnerability of buildings to flooding. Similarly, using quantitative and qualitative methods, Sakijege et al. (2014) investigated adaptation strategies to flooding in flood-prone informal settlements. In their study, the authors do not bring out the local artisans' knowledge and how this could be tapped to enhance resilience in building construction. Just like Kikwasi & Mbuya, Sakijege and others discourage the use of local artisans while, in reality, poor residents may not afford or have no viable alternative.

In addition to the limitations in the studies above, there is still a scanty body of literature concerning local artisans' knowledge of flood-resilient construction and adaptive buildings in Tanzania, particularly from a qualitative method perspective, while in reality they are actively involved in building construction. This is the rationale for conducting this research, focusing on the "Msasani Bonde la Mpunga' flood-prone informal settlement in Dar es Salaam City. This study addresses the basic research question: What knowledge do local artisans possess and use in constructing flood-resilient and adaptable residential buildings in flood-prone informal settlements? This question aligns with the acknowledgement that local artisans' knowledge requires exploring and documenting, especially regarding flood resilience and building adaptations (Iloka, 2016; Kikwasi & Mbuya, 2019). This study offers valuable contributions to literature. Firstly, it uncovers the diversity of knowledge local artisans possess, ranging from tacit to engineering (structural). It also exposes the knowledge spectrum of the communities that mainly engage local artisans in designing and constructing buildings in flood-prone areas. Therefore, this study is a work-up call to local actors and authorities to proactively help and support local artisans to address grey areas of flood resilience and adaptation among low-income housing in flood-prone informal settlements, where local artisans are popularly and largely used as key actors.

The preceding section has provided the context and background to the study. The subsequent sections are organised as follows: Section two reflects on the relevant literature and concepts. Section three explains the study's methodology, whereas section four presents and discusses the findings. Finally, section five provides conclusions and recommendations drawn from the study.

2. LITERATURE REVIEW

2.1. Local artisans' knowledge: reasons and implications for resilient construction

This study's focus is on the knowledge of local artisans stemming from the fact that they are primarily engaged in local construction processes, including flood-prone areas, especially in informal settlements (Mbuya et al., 2018; Kikwasi & Mbuya, 2019; Sakijege et al., 2014; Sakijege, 2019). Islam et al. (2013) note that in Bangladesh, about 83% of the houses constructed in flood-prone areas followed non-engineering construction techniques, as they mainly employ local artisans' construction knowledge to increase flood resilience in their residential buildings. This phenomenon is consistent with another study by Sakijege et al. (2014) conducted in flood-prone informal settlements of Keko Machungwa, Dar es Salaam, Tanzania and Sangkrah in Indonesia. In these settlements, Sakijege and others observed that about 89% and 82%, respectively, of the house owners in Keko Machungwa and Sangkrah engaged local artisans instead of professionals in constructing their houses. Sakijege's (2019) study at the Keko

Machungwa settlement adds that nearly 95% of the buildings were built through informal construction processes, such as; using untrained local artisans without consulting professionals. Evidence from Tanzania and Bangladesh indicates that local artisans are popularly utilised.

Scholars have highlighted several factors that determine the engagement of local artisans. Goldwyn & Gonz (2022) state that hiring local artisans in informal construction processes, particularly in flood-prone areas, is driven by various factors, including the need for affordable and accessible housing, weak regulatory housing construction enforcement, house owner preferences, and builder experiences. A study by Ahadzie et al. (2016) in Kumasi, Ghana, established that a score of urban communities was aware that living in a flood-prone informal settlement implies a high risk of flooding and were constantly anxious during the wet seasons. However, they felt that there was nothing they could do without government support. This observation may represent a range of reasons, including a lack of resources to construct more flood-resilient buildings. Likewise, Kikwasi & Mbuya (2019) reveal that house owners in flood-prone informal settlements hire local artisans for housing construction because of limited income (low affordability), ease of access, availability and flexibility of engagement, which professionals cannot guarantee to offer. This argument is consistent with Sakijege's (2019) observation that the frequency of hiring local artisans instead of professionals/experts in constructing buildings in flood-prone settlements is linked to low prices/charges they offer compared to using professionals. This situation explains why studying and documenting their knowledge of flood resilience and adaptation of buildings in flood-prone informal settlements accommodating the bulk of the urban population is important.

Other factors noted for using local artisans are related to regulatory enforcement and the costs involved. Studies show that the local authorities and municipal professionals rarely enforce code provisions or monitor construction works in flood-prone informal settlements (Clancy et al., 2020; Sakijege, 2019). Technically, all builders (formal and informal) are required to seek the Local Government Authority's permits to construct a building in urban areas. However, builders utilise local artisans because they operate outside the formal processes (urban planning regulations), as their operations are hardly monitored. Local artisans construct houses in flood-prone areas using local knowledge and experience. This condition can be considered a crucial approach to adopt because even countries that have tended to use and invest heavily in structural engineering measures of flood prevention using professionals still report regular flood incidences (Kumar et al., 2021). Nevertheless, this does not mean that local artisans' knowledge of flood resilience supersedes that held by professionals. Iloka (2016) asserts that local knowledge is valuable and worth using to rescue urban residents from the consequences of floods affecting their buildings. This argument concurs with Uphoff's (1991) viewpoint that while it cannot be assumed that local people have all the needed technical construction knowledge, it should neither also be assumed that they do not have anything to contribute. In addition, the services of local artisans are cheaper than those of professionals. It can be noted that local artisans offer reasonable building construction prices/charges that favour house owners' affordability of increasing flood resilience/adaptation in flood-prone informal settlements (Sakijege et al., 2014; Sakijege, 2019). However, there has been doubt concerning the knowledge of local artisans despite the fact their services are widely used.

There has been concern regarding local artisans' construction knowledge in flood-prone areas. Scholars have argued that the knowledge that local artisans possess might not be adequate to enable them to apply resilient construction measures in informal settlements (Mbuya et al., 2018; Kikwasi & Mbuya, 2019; Sakijege et al., 2014; Sakijege, 2019). Goldwyn & Gonz (2022) raise concerns that using local artisans may contribute to doubtable housing design details and the consequent structural performance that may extensively vary among local artisans. They add that this can generate unsafe housing situations, with house owners (builders) perceiving them as safe, whereas the houses have substantial flood hazard vulnerabilities. This argument suggests that despite appreciating local artisans' flood-resilient/adaptive construction knowledge, it requires an overstretched expert/professional knowledge. If anything, the two knowledge and skills need to be blended. This view further suggests that the local artisans' knowledge of flood resilience/adaptation construction measures requires checks and balances to enhance resilience in safeguarding local communities in flood-prone areas. In other words, it can mean that the local artisans' knowledge of flood-resilient/adaptable buildings is useful if it can respond to housing designs and construction.

It is also worth noting that professionals primarily work with local artisans in building construction processes, particularly in developing countries, notably in informal settlements, including flood-prone areas (Goldwyn & Gonz, 2022). As such, the scholars argue that it is sometimes challenging to identify their line of separation, especially when some flood-resilient/adaptive measures employed appear similar. This argument indicates that housing designs and building construction knowledge from the local artisans' perspective is vital and a prerequisite in flood-resilient and adaptable buildings. Although

professionals and local artisans sometimes work together, poor residents rely entirely on the latter rather than the former. On the other hand, it is not surprising that local artisans who have closely worked with professionals such as architects and engineers gradually learn and improve their knowledge and skills.

2.2. Resilience and adaptation: a conceptual understanding

In assessing the local artisans' flood-resilient knowledge level in this study, two recurring terms played pivotal roles in the debate. These are 'resilience' and 'adaptability'. In this study, resilience and adaptability are commonly applied and sometimes used interchangeably; hence, they are worth clarifying. The reason is that the two concepts are mutually inclusive in reducing buildings' vulnerability to floods. As such, it was essential to define these concepts delineating how they are operationalised in the study. The critical point to note here is that the two terms (resilience and adaptability) used in this study are debatable in the literature. Understanding the existing discourse regarding the concepts was vital to comprehending local artisans' knowledge of flood resilience and building adaptations.

As for resilience, scholars argue that a system is resilient if it can demonstrate the capacity to continue or adapt by changing to attain an adequate level of functionality and structure (Hillmann & Guenther, 2021; UNISDR, 2010). The International Strategy for Disaster Reduction (UNISDR) equates this capacity to a degree to which such a system can combine possible resources, strengths and attributes to help minimise and control disaster risks while strengthening resilience. Thus, a flood-resilient system entails the ability to respond to flood risks and effects with the capacity to prepare for them (Miguez & Veról, 2017). Also, Ferreira et al. (2021) see resilience as the ability of the system to recover its planned functionality or resume its original situation after it has experienced a disturbance. These scholars' arguments show that the definition of resilience is diverse and context-based. Since the context of this study concerns building designs and construction in flood-prone areas, it adapts a definition by Hooli (2016). Hooli argues that in terms of building designs, resilience entails making buildings, regions and communities capable of mitigating threats resulting from exacerbated weather and climate change by engineering buildings to face severe weather impacts, including using waterproof building materials impermeable to water damage.

At the property or household level, measuring flood resilience can be categorised mainly as water inclusion and exclusion strategies (Quandt, 2018; Proverbs et al., 2017). The water inclusion strategy entails using materials in building construction with water-resistant capabilities, such as water-resistant plasters, paints on the walls and materials with plastic units for designing and constructing spaces likely to have water, notably the kitchens (Olatunji & Adebimpe, 2023). The ones related to water exclusiveness involve integrating building structures with the ability to prevent water entry inside the building or property, such as flood barriers and dry-proofing materials (Proverbs et al., 2017). These categories are useful in exploring the local artisans' knowledge level of increasing flood resilience and adaptability of buildings in flood-prone informal settlements. Escarameia et al. (2012) propose that building resilience can be attained through measures such as using suitable building materials, construction techniques and flood-preventive products in particular. The proposal by Escarameia and other scholars reflects water inclusion and exclusion strategies.

It is also noted that enhancing building codes and infrastructure facilities, improving building services, the capability of anticipating and protecting assets, suitability of understanding risks by local authorities and community dwellers, sustainable urbanisation involvement from the local government, community involvement and putting values that emphasise local knowledge are critical (Dianat et al., 2021; UNISDR, 2010). With the aim of this study, resilience is studied in relation to knowledge of designing and constructing residential buildings against floods in flood-prone informal settlements using the local artisans' knowledge.

In so far as adaptability is concerned, Walker et al. (2004) describe it as the ability of actors in a given system with the capacity to influence resilience. Thus, adaptability may differ from resilience because it may not need measures to resist or stop floods but allows buildings to function despite flood occurrences (Norizan et al., 2021). Regarding building design and construction, adaptability needs building designs that are modifiable, adjustable to users and functioning despite flood events. According to Kronenburg (2015), making a building flood adaptive requires adhering to the capacity to adjust to diverse or varied functions, users, weather and climates or adjusting to changes in climate.

3. RESEARCH METHODS

3.1. The study area

The study was conducted in the Msasani Bonde la Mpunga, Dar es Salaam city. Being among the Coast Regions in Tanzania, the city was selected for the study because of its vulnerability to flood risks (CLUVA, 2013). On the other hand, "Msasani Bonde la Mpunga" is a flood-prone informal settlement located within an area comprising both formal and informal settlements. Previous studies show that Msasani Bonde la Mpunga settlement is approximately 0 to 3 up to 4 meters above the mean sea level (Salukele et al., 2017; Juma & John, 2018), thus prone to floods. However, there are variations in altitudes, with some parts raised between 4-10 metres due to sedimentations, alluvial deposits and landfilling done to prevent floods (Kemwita et al., 2022). Msasani Bonde la Mpunga is bordered by the Indian Ocean on the north and east, Msasani Road on the east, and Maandazi Road on the south-eastern, while old Bagamoyo Road is on the west and south-western side (Figure 1). Initially, before housing construction densified, the settlement had a natural stormwater drainage way that was used to channel water from higher parts of Dar es Salaam city towards the ocean (Salukele et al., 2017). As such, flooding over the past was manageable as opposed to the currently overstretched housing densifications in the settlement.

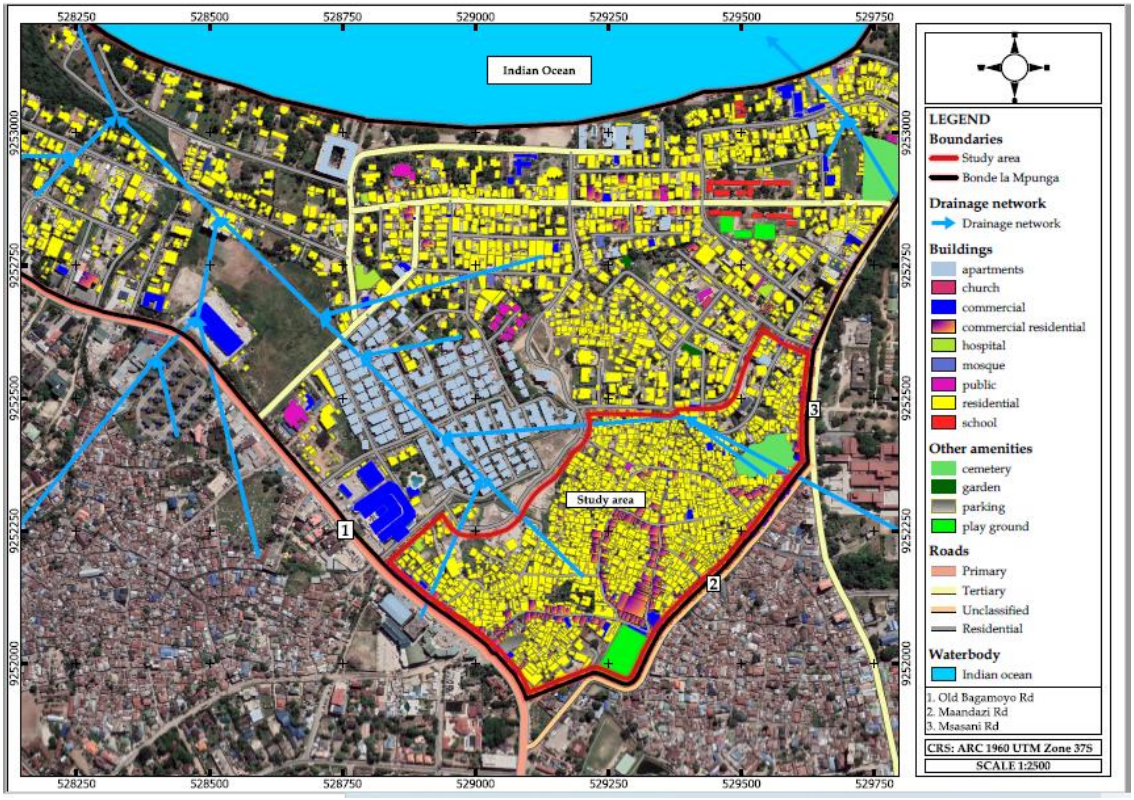

Figure 1. Location of Msasani Bonde la Mpunga; case study area
Source: Authors' drawing (2022)

The study was conducted in the often flooder segment of the settlement inscribed in red, characterised by depression (Figure 1). This area was considered information-rich for exploring local artisans' knowledge of flood resilience and adaptation. Yin (2009) observes that extensive exploration of real-life context is effectively carried out in information-rich areas. Therefore, this case study area was selected using various criteria. These include informal settlements in flood-prone areas, a settlement experiencing regular flooding, a settlement densely built regardless of flood occurrences, and a settlement formally acknowledged as flood-prone areas. Based on the report by the Pan-African START et al. (2011) regarding the flood level extent in informal settlements and the criteria stipulated above, Msasani Bonde la Mpunga was ranked among the first top-five flood-prone informal settlements in the city; thus, worth considering as a study area.

3.2. Research design

The article adopted a qualitative case study design to explore local artisans' knowledge of flood resilience and adaptation of buildings in flood-prone areas. The case study design opted to enable an in-

depth exploration of local knowledge regarding flood resilience and adaptation of buildings. Yin (2018) elucidates that case study design enables an in-depth exploration of the social phenomenon and the study of a contemporary phenomenon in a real-life context. As noted, flooding in the area started recently following the housing densifications, encroachment and blockage of the natural storm drain. Also, the design was considered suitable because it helps to understand how knowledgeable the local artisans are in constructing residential houses in flood-prone informal settlements.

3.3. Sample size and sampling procedures

A total of 20 local artisans were face-to-face interviewed. The number was reached following the recurring responses from the participants after indicating that no new information was emerging during interviews (saturation point). Participants were purposively selected through a snowballing sampling technique. Kothari (2004) argues that purposive sampling is desirable when the universe is small and a known characteristic is to be studied intensively. Local artisans were identified through snowballing because they were challenging to locate as they operate informally. Initially, the Ward leaders in the settlement were asked to initiate the exercise by identifying a few commonly known local artisans constructing houses in Msasani Bonde la Mpunga. Two local artisans well-known by the Ward leaders were nominated, and their mobile phones provided to ease their availability. These local artisans then continued identifying more participants as the interview process progressed. In addition, one group of 8 local artisans was selected for the focus group discussions after the face-to-face interview sessions was completed. This group of artisans was selected during the face-to-face, in-depth interviews. The selection based on experience the artisans had on building construction knowledge in flood-prone areas based on their views, suggestions and arguments.

3.4. Data collection methods/tools

The data collection methods employed in this study were interviews and focus group discussions. This fieldwork was conducted between February and April 2021 and supplemented in August 2021. The supplement data was sought from the local artisans who were missed during the first batch of interviews but considered to possess vital information regarding the knowledge of flood-resilient/adaptive buildings. Both methods were conducted concurrently (collected parallel, analysed separately, and merged during reporting), as posited by Creswell (2014). The process started with face-to-face, in-depth interviews with each local artisan asked to provide individual knowledge of flood resilience and adaptation of buildings in the study area. The local artisans were interviewed at their home places, construction sites or common spaces in the study area where they meet for gambling while waiting for any emerging construction works from the households/clients. As they operate informally, it was sometimes challenging to dentify them, so snow-balling techniques were useful. The interview covered issues related to local artisans' knowledge of making buildings flood-resilient/adaptive, such as materials and technicalities, among others. Most interviews were scheduled on weekends, especially on Sundays, as most local artisans were available at home, free from work-related preoccupations. The Interviewees who were missed at home during the interview period were scheduled for other days. Open-ended and semi-structured interview questions were used, which enabled participants to express themselves freely. This facilitated collecting in-depth knowledge concerning flood-resilient and adaptation of buildings.

In-depth interviews were conducted in Kiswahili language between 45 minutes to 1-hour time. Focus group discussions (FGD) with the selected local artisans were used to capture any possible flood-resilient knowledge gaps skipped during in-depth interviews. This method enhanced the information collected from individual local artisans' interviews. The FGD was held at a particular open area; the local artisans call "*Kijiweni*[1]", where they usually gather and wait for clients. Between 1-2 hours were spent discussing issues concerning the artisans' flood-resilient and adaptive knowledge and how it was being applied or otherwise. During the discussions, equal chance was provided for each participant to contribute their opinions and ideas. In both methods (interviews and the focus group discussion), consent was sought from the participants to permit recording of the responses. Responses were transcribed into English for the analysis process.

[1] "Kijiweni" is a typical Swahili word where people, in this study the local artisans meet for making stories and playing games.

3.5. Data analysis

For data analysis, translated and transcribed interviews were coded and organised based on pre-determined themes and interpreted. The participants' responses in terms of sentences and paragraphs were coded and arranged in rows and columns for thematic analysis. Concepts were formed from the interviews by linking the correlated codes. Such concepts were then classified into six themes (sections 4.1 and 4.2) and analysed with the aid of qualitative data analysis (MAXQDA), Microsoft Word (MS) and Excel Programs.

4. RESULTS AND DISCUSSION

In this section, results are presented and discussed. The results are categorised into two themes. The first category presents and discusses local artisans' knowledge of flood-resilient and adaptation measures/techniques in residential buildings. The second category discusses the sources of knowledge local artisans possess and their variations in building construction.

4.1. Local artisans' knowledge of flood-resilient adaptation measures/techniques

Local artisans' knowledge and adaptation measures/techniques were assessed through criteria the that included familiarisation with flood resilience and building adaptation, flood preventive architectural features, desirable plinth height, optimum foundation design category used and determining the ground floor height as summarised in Table 1. The criteria and flood-resilient measures were established epistemologically based on the various scholarly works concerning flood prevention and mitigation measures of the buildings constructed in flood-prone areas (Brisibe, 2018; Brisibe & Pepple, 2018; Jabeen et al., 2010; Oladokun et al., 2017; Proverbs et al., 2017; Thorn et al., 2015). These criteria and measures are presented and discussed in the subsequent sections.

4.2. Familiarisation with flood resilience and building adaptation

Regarding familiarisation with flood resilience, mitigation and adaptation measures, as shown in Table 1, results show that all (20) local artisans in Msasani Bonde la Mpunga were familiar with and knowledgeable about why they had to raise foundation plinth walls/floors and defensive walls. The respondents reported that many of the residents in Msasani Bonde la Mpunga applied these measures and believed that such measures were important for flood-resilient and adaptive interventions for buildings constructed in flood-prone areas. More so, they were affordable. It was also reported that raising the foundation plinth walls is a common practice which can be conducted even in non-flood-prone settlements to prepare for unforeseen future flood events and for aesthetic reasons/purposes. In addition, using defensive walls, such as fence walling and short-resistant walls around the veranda and on the entryways, were reported among flood measures that the local artisans mostly knew. Portraying familiarisation with flood resilience and adaptation of buildings to flooding, one of the interviewees noted:

> "*To prevent floods, one must be conversant with various techniques. Firstly, we prepare drainage systems around the houses to protect residents from floodwater. Then, we elevate the foundation plinth level to a height of not less than seven courses equivalent to 1.05m of 230mm thick masonry block walls above the ground. This height is based on the past flood water mark of the nearby houses' walls. Further, we also built an apron wall around the houses finished with a smooth sand cement surface. We apply waterproof cement to prevent the building walls from floodwater penetration and protect such walls from moulds caused by the effects of floodwater contact on the walls"*[2].

Another participant in the FGD had the following to say:

> *"I agree with my fellow concerning the techniques we use to construct our houses against floods. But, the first and foremost intervention we pursue when a house is hit by severe flooding is to build a short wall around the house to reduce flood effects before any other strategies are pursued"*[3]

The preceding quotations show that even without input from professionals, the local artisans have some notable knowledge to enhance flood resilience and make adaptive buildings through structural solutions, such as floodwater entry preventive techniques. This situation indicates competence among local artisans regarding flood prevention using structural engineering solutions in Msasani Bonde la

[2] A reaction from a local artisan aged 53 years during a face-to-face interview in Msasani Bonde la Mpunga held on 05.03.2021

[3] A reaction by a male participant aged 45 during FGD at Bonde la Mpunga, March 2021

Mpunga. However, these measures were supplemented by the knowledge of providing drainage systems and sandbags to help reduce the speed of flood water that may flow into the buildings. However, such measures serve as immediate flood prevention measures rather than offering permanent flood resilience solutions. Nguyen et al. (2021) note that although structural measures revealed in Msasani Bonde la Mpunga to flood resilience are popular flood mitigation measures in buildings, they are inadequate flood-resilient and adaptation measures because they can only work better in less severely flood-impacted localities.

Table 1. Local artisans' knowledge in flood-resilient construction and adaptation measures

Knowledge Assessment Criteria	Flood resilient knowledge and adaptation measures/techniques	No. of local artisans (out of 20)
Acquaintances with flood resilience, mitigation and adaptation	Raised floor level and reinforcement foundation	20
	Use of water proof techniques	15
	Use of water proof building materials	7
	Defensive walls	20
	Use of adaptable spaces and services	Nil
Architectural features supplemented as preventive measures against floods	Raised floor levels of the foundation	20
	Use of water proof techniques	15
	Construction of aprons around the buildings' envelope	20
	Defensive walls	20
	Use of water proof building materials	20
	Creation of emergency exit and escape routes	Nil
Desirable height to raise the ground floor	0-0.6m	4
	0.6-0.9m	12
	1-1.5m	20
	1.6-2.0m	Nil
	Over 2.1m	Nil
Optimal design type for raised ground floor	Use of stilts/columns	4
	Creating water drainage (path) around or under building	4
	Filling of whole raised floor	20
	Creation of basement	4
Raised ground floor height determinants	Reference made to official datum point	Nil
	Reference made from main access road	12
	Reference made from previous flood water mark	20
	No, reference point used to determine floor level	Nil

The knowledge about raising the foundation plinth walls and associated techniques for preventing floods witnessed in Msasani Bonde la Mpunga in Tanzania is also practised in other flooding settlements. Sakijege et al. (2014) study in Keko Machungwa, Tanzania, and in' Surakarta, Indonesia, flood-prone informal settlements report that the residents in both case study areas were aware of flood problems and enlisted the services of local artisans for relevant flood prevention (mitigation) measures. The local artisans employed a variety of structural and non-structural measures to adapt to the impact of floods, including retaining walls raising stairs and plinths, among others. These measures were reported as affordable and easy to use. It is further argued that despite local artisans' awareness of structural strategies for checking flooding, these measures still require scrutiny regarding their effectiveness in mitigating building damage (Nguyen et al., 2021). This phenomenon may point to the fact that the practices of local artisans concerning flood resilience and building adaptation for effective engineering solutions are still limited.

This study reveals that three-quarters (15 out of 20) of the interviewed local artisans were aware of using waterproofing measures/techniques to complement the raised ground floor/foundation plinth walls (Table 1). Such measures include using building materials such as cement admixtures, chemical lining, waterproof cement, and wet and dry-proofing techniques. However, it was noted that the most reported waterproofing knowledge techniques include using Damp-Proof Membrane (DPM), Damp Proof Course (DPC), waterproof cement and admixtures. These materials were reported as locally available and easy to use. Of these techniques, DPM, DPC and waterproof cement were highly used as flood-resilient and adaptive materials in Msasani Bonde la Mpunga. Thomsit-Ireland (2018) in the UK reveals corresponding

findings, noting that DPM and DPC are regarded as regularly used building materials for they act as barriers for water rising from the ground through capillary actions. Apart from DPM and DPC, the other waterproof materials used in flood-prone areas entail materials such as waterproof cement admixtures, chemicals, asphalt or bitumen-based linings, rubber or plastic sheet layers and other applications for increasing resilience (Brisibe & Pepple, 2018; Brisibe, 2018). This is corroborated by Escarameia et al. (2012), who argue that using DPM and DPC materials in flood-prone areas helps to reduce floodwater impacts and increases flood resilience and adaptation by preventing floodwater penetrations or accommodating it to lessen building wall damages.

Although most local artisans in Msasani Bonde la Mpunga showed adequate knowledge of waterproofing measures and techniques, less than half demonstrated knowing waterproofing materials use (Table 1). This finding implies that the knowledge concerning waterproofing materials used among local artisans in Msasani Bonde la Mpunga is minimal despite their understanding of waterproofing techniques/measures. Local artisans, who demonstrated having good and relevant knowledge of waterproofing materials, reported that such materials are more effective in protecting (increasing resilience) houses from flood water penetrating inside the houses. This argument aligns with Sakijeges et al. (2014) findings that local artisans engaged in constructing residential buildings have limited knowledge about waterproofing techniques (measures). Local artisans could not acquire knowledge of waterproofing techniques because most houseowners were adamant about buying waterproofing materials due to financial limitations. The implication is that the knowledge about using a certain flood-resilient and adaptive measure can be limited by lack of practice, which ultimately affects the pace of increasing flood resilience and adaptation efforts. Indicating the significance of the practice, one interviewee attested:

> *"I have lived in Msasani Bonde la Mpunga from 1990. Before I came to this settlement, I already had construction knowledge acquired through my fellow local artisans. When I arrived here, some house owners recognised I was a builder. They started contracting me for some construction work. By that time, my construction knowledge was too general. By working together, I had to learn more about constructing houses in flood-prone areas from experienced local artisans. Over time, I gained experience and became accustomed to building houses in flood-prone areas. Currently, I am widely engaged in building houses for my customers, even in other flooding settlements across the city."*[4]

The quotation above conforms to the adage that 'practice makes perfect'. It indicates the power of the experience that a local artisan could acquire through intuitive learning and eventually build trust among house owners who hire him for their house construction works in a flood-prone environment. It further amplifies the fact that if residents cannot hire local artisans and construct resilient and adaptive houses, the local artisans' knowledge would remain limited.

As for the use of adaptable spaces and services, such as elevated spaces for emergence exits and raised electric sockets/switches, respectively, results showed that none of the local artisans in Msasani Bonde la Mpunga possessed such knowledge (Table 1). However, these are essential flood-resilient/adaptive mitigation measures. Likewise, Brisibe (2018) adds that in Yenagoa flood-prone settlements, no builders designed and supervised residential houses with inclusive escape routes and emergency exits in case of severe flood impacts. Sharma (2021) notes that residents living across the Lower Karnali River Basin of Nepal had little knowledge about making adaptive spaces and measures for flooding prevention, particularly on the escape means in case of flood emergence. Adaptable spaces, escape routes and services are among the architectural features that safeguard households' safety if buildings face severe floods (Thorn et al., 2015). Kim et al.(2022) suggest that adaptable spaces and services such as escape routes and emergence exits during floods are important because they can help survivors move towards the elevated (higher grounds) positions and wait for rescue.

The lack of adaptable spaces, exit routes, and emergency escapes in buildings represents a scantiness of knowledge among local artisans. It also indicates that it is difficult for rescue people to save house owners during severe floods, specifically those with physical disabilities, pregnant women, children and the elderly, if such knowledge is scantly known. Also, it suggests that urban dwellers in flood-prone settlements are not yet acquainted with the escape and adaptive space considerations in increasing flood resilience and adaptive capacity to live with floods. Therefore, they need to inform the local artisans to incorporate adaptable spaces, exit routes, and emergence escapes. This view suggests that flood-resilient and adaptive buildings related to adaptable spaces' knowledge constructed in flood-prone areas are still low among local artisans and communities. This viewpoint is especially true for flexible spaces and services in building design constructions in such areas.

[4] Responses from the same local artisan supplementing to his previous reactions in apostrophe[3].

4.3. Flood preventive architectural features

Regarding the architectural features added as preventive measures to increase flood resilience and adaptation of buildings, the results in Table 1 reveal that all (20) local artisans were knowledgeable about the apron walls construction around the foundation plinth walling and applying waterproofing materials and techniques. These measures were reported as common flood-resilient and adaptive measures practised to increase flood resilience in Msasani Bonde la Mpunga. For instance, it was revealed that the apron walls constructed around the foundation plinth help to prevent flood water from penetrating the house foundation. Apron walls help avoid wetting the foundation plinth walls or mould growth around the walls from floodwater. This assertion suggests an adequate understanding concerning house foundation protection to increase flood resilience and adaptation capacity. It was also noted that using apron walls as a structural engineering measure for flooding helps reduce flood risk by delaying flood water penetration that could damage building foundation walls. However, this does not work as a permanent flood prevention solution, as various scholars argue, since threats from flooding have continued to increase (Chen & Lin, 2018; Sayers et al., 2015).

From Table 1, only 4 out of 20 local artisans were conversant about architectural features, such as suspending buildings on slits (columns) to allow spaces under the ground floor to ensure floodwater flows on either side. This finding represents imperative need to know such architectural features among artisans in Msasani Bonde la Mpunga. Despite being critical facilities in flood prevention, other architectural features, such as emergency exits and escape routes, were relatively unknown by most local artisans, as covered in section 4.1. As for the reason (s) for this shortfall, the artisans pointed out that such flood measures (facilities) required in-depth knowledge and expertise to implement, and they did have such expertise. Moreover, the artisans reported that only the well-off house owners could afford such facilities. However, most of the Msasani Bonde la Mpunga residents are low-income earners. Similar findings were reported by Brisibe (2018), noting that as residents strived to save cost, about 90% of the houses constructed in Yenagoa, a flood-prone settlement, used fully covered foundations with earth soil filled before the concrete bed was applied. Local artisans practised this despite knowing other flood resilient and adaptive measures of flood prevention, particularly structural measures such as using stilts (columns) and introducing basement floors. Local artisans mostly comply with the house owners' level of affordability.

4.4. Desirable height to raise the foundation plinth

All (20) local artisans in Msasani Bonde la Mpunga suggested a foundation plinth height range between 1-1.5 metres or beyond (Table 1). Such measurements of heights were reported to be the appropriate levels preferred for raising the buildings to ensure flood prevention and increase resilience. Such heights were considered reasonable based on the experience of the past floodwater level in the settlement observed on the houses' walls. It was reported that floodwater in Msasani Bonde la Mpunga often reaches below window sill levels unless under exceptional severe cases of flooding. This situation suggests that the appropriate level to raise the foundation height to prevent floods can be learned from the experiences of floodwater observed over time. Explaining the desirable height to raise the foundation plinth, one of the participants in the FGD remarked:

> *"As local artisans, we know how to construct houses in flood-prone areas. First, you must ensure your building is elevated enough to prevent flood water from entering the house. As for me, I must ensure that the building is raised to at least three feet, equivalent to 0.9m and not less. Our experience working in this area shows that most flood water depths may reach the window sill level, a height of between 0.9 to 1 metre. Here, we count four courses of masonry blocks with their base laid in six-inches."*[5]

The knowledge about the height range revealed by local artisans in this study does not align with other building codes suggested in other areas practising building codes in flood-prone areas. For instance, the Foreign Exchange Management Act (FEMA) (2011) recommends that buildings constructed in coastal areas, like Dar es Salaam City and those under Special Flood Hazard Areas (SFHA), should be elevated not below 1 foot high (30cm) to exclude flood water entry into the houses. Nevertheless, Xian et al. (2017) offer a different view, arguing that such a raise can reflect only less severity of the hazards determined using the Base Flood Elevation (BFE) but not the generalisation about vulnerability facing the houses. This difference in height determinants suggests that building elevation height in flood hazards should not have a fixed standard as FEMA (2011) proposes but rather be determined based on the context of flood severity incidences. This argument underscores the viewpoint that the knowledge of deciding adequate height to

[5] A response from an FGD local artisan aged 39 at Msasani Bonde la Mpunga March 2021.

raise the building based on the experience of past flood events in flood-prone areas is substantively essential.

In contrast, the American Society of Civil Engineers (ASCE) emphasises that the lowest standard for raising buildings in flood-prone settlements requires adhering to the building codes (Xian et al., 2017). However, this works in areas where building codes that guide building/house designs and construction in flood hazards exist. This phenomenon is nonexistent in the Msasani Bonde la Mpunga, where people build houses without pre-determined guidelines.

Despite the local artisans' knowledge regarding the foundation height range preferred, it was demonstrated that not all houses are raised above the window sill level (Table 1). The reason established was that most house owners lack financial resources. As shown in Table 1, some of the foundation plinth heights of the houses appeared elevated only 0.6 metres high; some are below this height commensurate with the income of households, yet flood enters their houses. This finding supports the findings by Harun-Or-Rashid et al. (2022) in Bangladesh that most buildings constructed in flood-prone areas had plinth walls elevated to at least 0.9 metres above the ground. As such, in the Msasani Bonde la Mpunga settlement, the economic implications may dictate or determine the height/level of the building foundation and sometimes not the extent and context of flood occurrences. These findings are consistent with those reported by ží et al. (2017) in the Czech Republic, who note the low uptake of flood risk mitigation measures due to financial limitations despite flood knowledge. Xian et al. (2017) note that elevating building foundation heights to floods and preventing flood risk mitigation measures require considering the flood hazard, vulnerability and exposure characteristics, including the houses' value, size, lifespan, and ground height.

4.5. Optimum foundation design category used

Concerning the optimum design category of the ground floor level, results show that all (20) artisans had good and relevant knowledge regarding raising the ground floor with complete filling (Table 1). The local artisans claimed that such flood measure is simple and considered cheaper to construct. Most households can afford it rather than complex measures, such as basement creation or building suspensions on stilts/columns, requiring complicated details and costs. Therefore, local artisans had acquired knowledge in raising the ground floor with the complete filling because house owners often gave them such tasks. These revelations are similar to what Brisibe (2018) reports in Yenagoa, where most local builders opt for the complete filling of the foundation plinth rather than better flood preventive measures on the grounds of affordability and ease of comprehension by most local artisans. This observation shows that building owners' affordability level of a certain flood measure can deprive local artisans of knowledge exposure to flood-resilient/adaptive measures. Although the complete filling technique allows flood water to reach the building walls, it was considered an appropriate flood-resilient/adaptive measure. This is because such flood measure provides the possibility of flood water protection from flowing into the houses. In this measure, all foundation ground plinth levels are sealed. Proverbs et al. (2017) note that the raised houses' ground level restricts the prospect of floodwater beyond the protective design level.

On the contrary, results (Table 1) show that less than a quarter of the local artisans interviewed had good knowledge that spaces created under the foundation plinth level and using stilts/columns can increase flood resilience and adaptation of houses. These are considered water paths (drainage) useful for allowing flood water to flow on either side, creating resilience against damage to building walls. The flood measures (stilts/columns) require more reinforced structures, which are expensive and unaffordable for most low-income families despite their usefulness in increasing flood resilience/adaptation. Local artisans refrain from regularly practising such measures. In Msasani Bonde la Mpunga, local artisans demonstrated little awareness regarding complicated flood resilient/adaptive techniques. Only a few artisans (Table 1) proposed creating pathways, such as using concrete culvert boxes and basement floors under the elevated floor levels to homeowners. When interrogated regarding the knowledge of using columns/stilts to suspend the building above the ground level to allow floodwater to navigate either side, a bricklayer local artisan:

> "*Some of us understand that construction of houses using stilts or columns is the best way of preventing floods and building adaptation capacity to reduce severe flood risk. But, the big issue is that most houses built in flood-prone areas are owned by low-income earners. This situation forces us to construct houses in areas that match their limited financial capacity*"[6].

The quote implies that some knowledge can be ignored because of low income or unaffordable, reducing flood prevention opportunities. Van Long et al. (2020) in Can Tho, Vietnam, note that although

[6] A response by an interviewee aged 45 held on 24.03.21 in Msasani Bonde la Mpunga settlement

using stilts/columns increased the safety of buildings during severe and intensive flooding, most house owners' cost of affording such techniques was low. Brisibe & Pepple (2018) confirm that none of the buildings constructed in flood-prone areas of Yenagoa adopted columns/stilts as flood-resilient/adaptive measures because of the low financial affordability of most households.

4.6. Determinants of the ground floor height

Regarding the knowledge of determining heights of the ground floor level to raise the foundation plinths, results as indicated in Table 1 show that all artisans (20) in Msasani Bonde la Mpunga take references from neighbouring houses based on past floodwater mark experiences. This approach includes taking references from the adjacent access road, neighbours' house premises, and normalised water flow direction declared by more than half (12 out of 20) of the local artisans interviewed (Table 1). Such references give the possibility to approximate new levels regarding the next floodwater level to protect buildings from the possible effects of flood damage. Also, it was established that each local artisan employed at least the reference point for determining the building foundation floor level elevation to increase flood resilience and adaptations. Similar findings were reported by Burlotos et al. (2020) in Haiti that the buildings constructed in flood-prone areas used traditional methods, such as taking references from the neighbours' buildings and the neighbouring access roads, but did not use established official datum points. This option offers house owners safety concerning present and future flood events.

4.7. Local artisans' source of knowledge and variations

The criteria and flood resilient knowledge measures (Table 1) used in this article show that most local artisans engaged in constructing buildings in Msasani Bonde la Mpunga have sufficient and relevant knowledge about flood resilience and adaptation of buildings. This is why the study found it critical to probe and explore the sources of knowledge these artisans possess and how such knowledge was acquired. Results (Table 2) established two major sources of the construction knowledge the local artisans acquired it from in flood-prone areas. These include experience gained through learning by doing from their fellow experienced artisans and formal training for those who have attended the Vocational Education and Training Authority (VETA). Osuizugbo & Ibrahim (2022) report similar findings in Nigeria, noting that most young people acquire construction knowledge through formal or informal apprentices. Ikediashi et al. (2012) support this, arguing that formal and informal construction knowledge simultaneously involves in-class directives and on-the-job training.

Table 2. Local artisans' knowledge sources and variations in flood resilient construction

Knowledge sources	No of local artisans (out of 20)	Knowledge variations	No of local artisans (out of 20)
Vocation training (VETA)	5	Ability to read and interpret drawings	5
		Bargaining for work (labor charge estimates)	3
		Making quotation for works	5
		Material cost estimations	5
Experiential knowledge (learning from fellow local artisans)	15	Ability to read and interpret drawings	5
		Knowledge of bargaining for work (labor charge estimates)	7
		Knowledge of making quotation for works	11
		Knowledge of making cost estimations	6
Induced by professionals (architects, engineers or technicians)	Nil	Nil	Nil

Results established that about three-quarters (15 out of 20) of the local artisans interviewed acquired building construction knowledge through intuitive learning (experience) while working with fellow local artisans. In contrast, the remaining quarter (5 out of 20) of the artisans have acquired it from VETA. The ratio of 1:4 indicates that most local artisans in the area received their knowledge through a self-help approach rather than formal training in colleges. Such variations/differences suggest potential knowledge gained through experiences and perceptions worth valuing in the community to influence

policy-making persuasions that could help increase flood resilience and adaptations of buildings. G'Nece (2012) supports this argument, positing that the authorities need to consider local knowledge from the grassroots level since it can help to prevent, mitigate, prepare for and recover from the effects, such as floods. In contrast, none of the local artisans in Msasani Bonde la Mpunga demonstrated sources of knowledge from professionals, such as architects, engineers and technicians (Table 2). However, from experience, it is evident that some local artisans learn and acquire construction knowledge from professionals when they are engaged to work together, even though this was not revealed in the Msasani Bonde la Mpunga area. This source of knowledge is worth adding to other various sources, including those discussed in this study. Combining such knowledge sources can promote tacit and intuitive knowledge obtained from individuals' natural ability. This suggests that the involvement of local knowledge can help reduce flood hazards in housing construction. It can also help improve the limited access to professionals' knowledge required to meet housing construction requirements, especially in developing countries

In addition, it is worth examining local artisans' variations/differences in construction knowledge regarding flood resilience and adaptation of buildings. The variations entailed the ability to read and understand sketches/drawings used in construction and making building material quantity estimates. These differences revealed that all local artisans who were trained in VETA colleges had a proficient understanding of the drawings/sketches used during the design and construction of the kind of buildings erected in Msasani Bonde la Mpunga and materials used than those with intuitive learning (Table 2). The kind of residential buildings dominantly constructed in the study area of Msasani Bonde la Mpunga entailed mostly single storeys category (close to 90%), and the rest few being double storeys (nearly 10%). Single-storey houses were mostly the "Kiswahili"[7] and "Banda"[8] types/styles. Both house types were constructed using masonry blocks for walls, sand, aggregate, concrete on the floors, sand cement screed, floor or wall tiles (few) and waterproof cement on the floors and walls as finishing materials. The roofing was mainly gable, mono-pitch and hips styles with at least a 20-degree angle for the flow of flood water, especially during high rain seasons. Usage of these building materials and techniques requires the knowledge, proficiency, and expertise of the artisans to be able to appropriately use them to increase flood resilience and adaptations of buildings.

This does not mean that the local artisans with experiential knowledge failed to practice building construction in flood-prone areas. Instead, it was revealed that artisans who had learned construction techniques through intuitive approaches might do physical measurements on the ground using tape measures if they do not have designed drawings/sketches on paper. For instance, concerning building material quantity estimates, the local artisans with experiential learning demonstrated purchasing building materials bit by bit until house construction was completed, as they could not prepare a proper schedule of materials and estimates. This phenomenon differed from local artisans with formal training knowledge who demonstrated good and relevant knowledge of estimating the quantities of materials for construction without difficulty. It also reflects the power of education, suggesting that integrating the two knowledge sources can increase construction knowledge in flood-prone areas than relying on only one side of the knowledge base. Eraut (2000) notes this, arguing that having explicit knowledge about something created through reflection or collected from other sources is possible. However, it may be unlikely to replace tacit knowledge because it allows instant response to a phenomenon (Iloka, 2016; Mselle & Alananga Sanga, 2017). This argument suggests that as much formal training knowledge is necessary, it does not completely replace an engagement of the tacit knowledge.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The study has established that most local artisans in the Msasani Bonde la Mpunga are aware of various flood-resilient and adaptive measures of both the engineering and tacit nature. The knowledge sources of such measures is mainly acquired through experiential learning (implicit/tacit knowledge) when working with their fellow local artisans or through self-training. However, a few artisans demonstrated acquired construction knowledge through explicit (formal training) sources, including attending vocational training education. The most reported local artisans' knowledge of flood-resilient and adaptive measures was raising the foundation walls, applying waterproofing materials techniques, and constructing short-resistant walls and aprons. However, other flood-resilient/adaptive measures,

[7] "Swahili houses" house types with a double bank system, i.e., having a corridor (passage) in the middle separating rooms on the left and right sides with a verandah at the rear and front part of the house

[8] "Banda" is a Swahili name for the house types with rectangular shape, single bank system without a corridor accessed directly from outside.

such as creating a basement under the building's foundation plinth and using stilts/columns, were scantly recognised by most local artisans regardless of being the effective flood-resilient/adaptive measures. This finding is because such measures are complex and involve sophisticated construction techniques that require professional knowledge proficiency and huge costs. As such, they are less applied in low-income structures such as those in the Msasani Bonde la Mpunga settlement.

The study concludes that local artisans' knowledge on flood-resilient and adaptive measures in flood-prone Msasani Bonde la Mpunga, especially of complex/sophisticated engineering construction techniques, is relatively low. Most importantly, the study found that local artisans possess valuable knowledge and capacities in the form of local (informal) knowledge to facilitate many urban poor households to reduce hazards and disasters, notably those related to floods. For complex/sophisticated construction techniques, the study establishes that house owners' income limitations constrain local artisans' knowledge that helps to address the impact of floods. As such, artisans rarely get opportunities to put into practice some of their knowledge on issues, such as flood-resilient material choices and freedom of applying diverse construction techniques to increase building resilience to floods. This situation is also attributed to the lack of modern scientific knowledge and technology to enhance flood resilience and adaptation of buildings. It can also be concluded that local artisans and professional practitioners can benefit from each one's knowledge, especially the local artisan's tacit knowledge, if considered in flood disaster incidences. Thus, experiential knowledge of local artisans and communities is a crucial empowerment instrument that makes a difference in making flood-resilient/adaptive buildings in flood-prone informal settlements.

Despite the fact that the local artisans had quite satisfactory tacit and engineering knowledge about flood resilient and adaptive measures of buildings in Msasani Bonde la Mpunga, this article concludes that such knowledge is sometime hard to implement. This is especially because most households in the area are low-income earners. This observation suggests that, despite this knowledge dissemination among local artisans, realising flood-resilient and adaptive buildings in settlements with low-income households may take time. However, it is hard to ignore local artisans' knowledge and efforts to increase flood resilience and adaptations of buildings in such areas. This is because building houses in flood-prone areas entails taking into consideration various factors, including climate change impacts, informal settlement development and rapid urban population growth.

5.2. Recommendations

Local artisans working with local communities need to practice and widen their tacit knowledge to increase flood resilience and adaptation of buildings to ensure sustainable future flood prevention, mitigation, preparedness, response, and recovery. This observation can be achieved through demonstrating housing improvements by instituting training about flood resilience and adaptation of houses for local artisans, sensitising the populations and receiving responses from the local people in flood-prone informal settlements areas. Having in place the formal mechanisms, such as VETA colleges and professional persons (architects, engineers and technicians) to develop the capacity of local artisans, would be an essential step towards more effective and sustainable interventions to the impacts of risks in the flood-prone informal settlements in the city of Dar es Salaam. The article further recommends that practitioners working to manage floods in flood-prone informal settlements should consider integrating or blending their knowledge with the one acquired by the local artisans and communities to achieve hybrid flood resilient/adaptive measures. The reason is that local artisans have relevant local knowledge worth adopting and integrating with the formally acquired knowledge to increase flood resilience and adapt buildings in flood-prone areas. It is also worth suggesting that practitioners managing flood-prone areas require integrating modern scientific knowledge with local artisans' knowledge to make flood-resilience and adaptation of buildings interventions more effective. The study emphasises that it is critical to document indigenous/tacit knowledge on flood-resilient construction and adaptations of buildings of the local artisans from various local communities since knowledge tend to vary. This suggestion will contribute to recognising the local artisans' knowledge of flood-resilient measures that can be improved and reciprocated in other communities living in flood-risk areas. Such knowledge is worth learning and documenting because such flood measures can be applied even in the non-flood-prone areas.

Given the importance of the local artisans in enhancing community resilience in flood-prone areas, their knowledge (mostly tacit/indigenous) should be linked with the National Disaster Management initiatives and activities related to low-income housing construction. Notably, the indigenous knowledge

and construction skills the local artisans use to enhance flood resilience and adaptive buildings are critical areas requiring further research to underscore the potential of available skills and knowledge to help improve the exacerbating challenges of buildings constructed in flood-prone settlements. This study's findings may only be generalised to other areas in Dar es Salaam City or other places with a related context.

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An AHP GIS-based Methodology for the Stability Assessment of the Djebel El Ouahch Collapsees on the Numidian Flysh Formation in Northeast Algeria's Constantine Region

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ABSTRACT: This study presents a comprehensive investigation into the factors underlying the collapse incident that occurred in the Jebel El Ouahch Tunnel in the Numidian flysch, Constantine region, Northeast Algeria. This methodology focuses on evaluating landslide susceptibility through the application of the Analytic Hierarchy Process (AHP) along the reconfigured path of the collapsed A1 highway tunnel section in the Constantine region of northeastern Algeria. Various influential factors contributing to landslides were analyzed, including lithofacies, slope gradient, slope aspect, elevations, fault density, plan curvature, distance from streams, and distance from roads. Utilizing a Geographic Information System (GIS), these eight causative factors were prepared for assessment. The findings indicate that slope gradient and lithology play pivotal roles as primary controlling factors in landslide susceptibility. The model exhibited a commendable success rate of 93% in predicting landslide susceptibility, as demonstrated by the area under the curve (AUC) plot generated from the landslides susceptibility map. Most of the new road falls within the highly susceptible area to landslides. This validated model can serve as an effective tool for mapping landslide susceptibility zones along the newly established road path following the collapsed tunnel. Moreover, its applicability extends to similar environments, showcasing its potential as a valuable resource for hazard assessment and planning in comparable terrains. The deviation road, as well as tunnel T01 of the A1 highway, is in a state of proven instability. It is certain that they will experience continuous, recurrent, and intense landslides. A radical solution to all the geotechnical issues plaguing this section of the highway is to reroute it far away from the Subnumidian formations. A deeper comprehension of the geological and geotechnical intricacies in challenging terrains can significantly enhance the safety and reliability of transportation networks in these demanding contexts.

KEYWORDS: tunnel collapse, geological complexities, landslide susceptibility, Analytic Hierarchy Process, construction hazards.

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1. INTRODUCTION

Highway tunnels are vital for facilitating transportation and sustainable development in the mountainous terrains of Mediterranean countries. However, these regions pose significant challenges due to their complex geological, geotechnical, and hydrological conditions.

The morpho-structural context contributes to the frequent occurrence of collapse disasters in tunnel construction, resulting in substantial economic losses (Zhang et al., 2015; Zahri et al., 2016; Qiao et al., 2020). The intricate geological composition and dynamic hydrological systems in these areas make tunnel construction particularly vulnerable to collapse incidents. These disasters not only disrupt the construction process but also impose substantial financial burdens due to the extensive damages incurred.

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Therefore, addressing these challenges demands a comprehensive understanding of the geological complexities to develop robust engineering solutions. Enhancing the resilience of tunnel infrastructures through advanced construction techniques, innovative monitoring systems, and meticulous risk assessment strategies is imperative (Chen et al., 2022). By integrating scientific knowledge and technological advancements, it becomes possible to mitigate the risks associated with tunnel collapses, ultimately ensuring safer and more sustainable tunnel infrastructure in these challenging landscapes. There are many factors that can cause construction collapse in underground tunneling. Among them, some may stem from internal and external influences. Internal factors encompass design flaws, planning errors, and construction defects, including inadequacies in the temporary tunnel lining. Conversely, external factors relate to inadequate control over ground characteristics, including earthquakes, high-stress conditions, and water inflow (Kerbati et al., 2020; Boubazine et al., 2022; Benyoucef et al., 2023).

Several research studies have extensively investigated these deformations, shedding light on their underlying mechanisms and causes (Leichnitz, 1990; Hoek, 2001; Bonini & Barla, 2012; Feng & Jimenez, 2015; Lin et al., 2017; Kallel et al., 2018; Bagwan et al., 2023). An extensive review of the academic literature on landslide prediction and management highlights a wide range of techniques used for assessing susceptibility to geological hazards, particularly landslides (Guzzetti, 2021). These methodologies encompass quantitative, semi-quantitative, and qualitative approaches, providing both direct and indirect means of estimating and zoning landslide susceptibility. Quantitative methods include heuristic direct estimation, as well as deterministic, statistical, and probabilistic models. Researchers and practitioners have access to a multitude of bivariate and multivariate techniques, such as Frequency ratio (FR), Linear indexing (LI), Weighted evidence (WoE), Artificial neural network (ANN), Logistic regression (LR), and Analytic hierarchy process (AHP), among others (Conforti & Ietto, 2021). The diverse range of methodological options highlights the effectiveness of utilizing GIS techniques to evaluate and classify landslide hazards (Goetz et al., 2015; Juliev et al., 2019). Moreover, the integration of artificial intelligence (AI) and data mining (DM) techniques holds great promise for enhancing the field of landslide susceptibility assessment, offering unprecedented levels of relevance and validity (Zêzere et al., 2017; El Mekki et al., 2017; Reichenbach et al., 2018; Mahdadi et al., 2018; Achour et al., 2021; Manchar et al., 2022; Taib et al., 2022, 2023a, b).

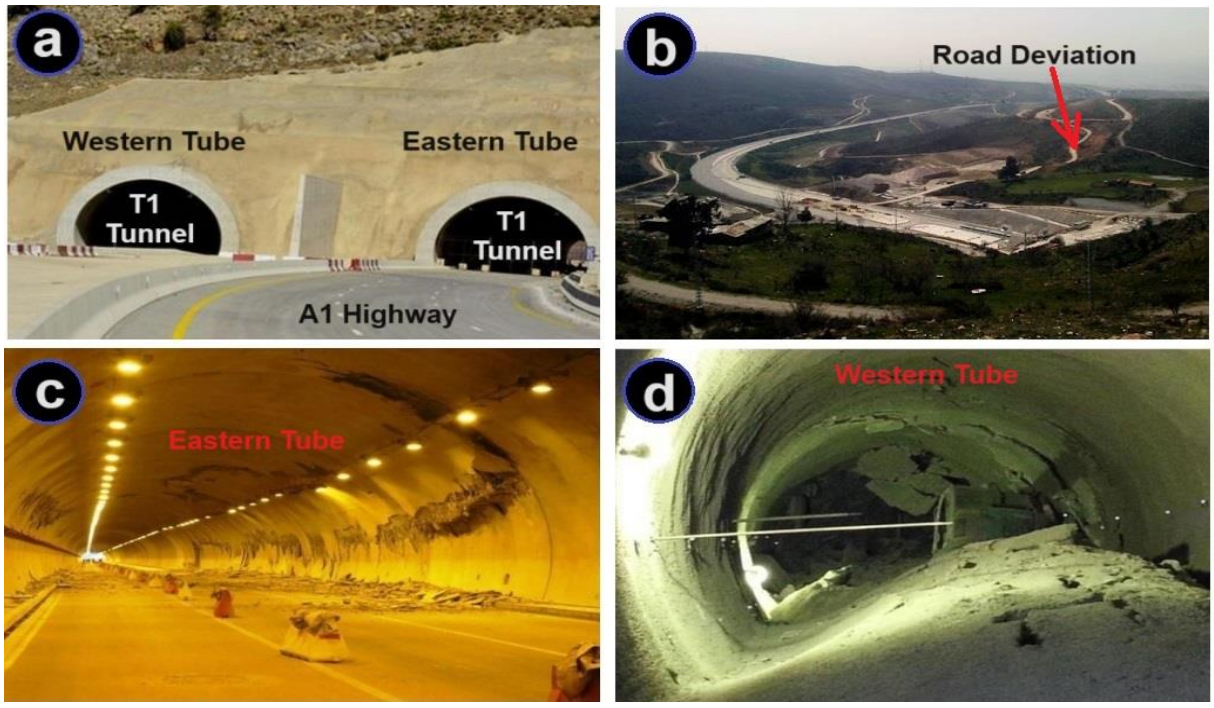

Figure 1. (**a**) Western Entrance of Tunnel T1. (**b**) Mountain bypass of the A1 highway route. (**c**) Partial collapse of the Right Tube (East). (**d**) Total collapse of the Left Tube (West). Source: Berkane et al. (2022), COSIDER SPA, Highway Management Agency (AGA).

In mountainous regions of the Algerian Atlas chain, tunnels play a crucial role in ensuring mobility and fostering socio-economic development. The Jebel El Ouahch Tunnel, situated in Algeria's eastern Tell region within the Numidian Chain, traverses unstable lithological formation comprising argillite in the basement, sandstone-clay intercalations in the middle, and grey marl at the top (Figure 1a) (Karim et al., 2019). This region is particularly prone to gravitational disturbances due to chaotic formations within the Numidian Nappe (Kimour et al., 2023). On January 1, 2014, during excavation operations, a sudden collapse occurred in the left tube (West) of tunnel T1, part of the A1 highway between PK 206+152 and PK 206+265, spanning a distance of 113m (Figure 1a, c, d). This collapse not only damaged the two tubes but also led to severe cracks in the final lining along PK 206+199 to 262, covering a distance of 63m (Kitchah et al., 2021). This alarming incident prompted extensive geoengineering works to investigate the root causes and origins of the observed local disorders while traversing the sub-Numidian clays (Dahoua et al., 2017a; Fredj et al., 2020; Saadoune et al., 2020). To link both ends of the collapsed tunnel section and ensure the durability of traffic flow, a hasty solution was initiated by the construction of a 12.41 km temporary sinuous deviation over a steep relief between PK 205+393.000 and PK 207+284.500.

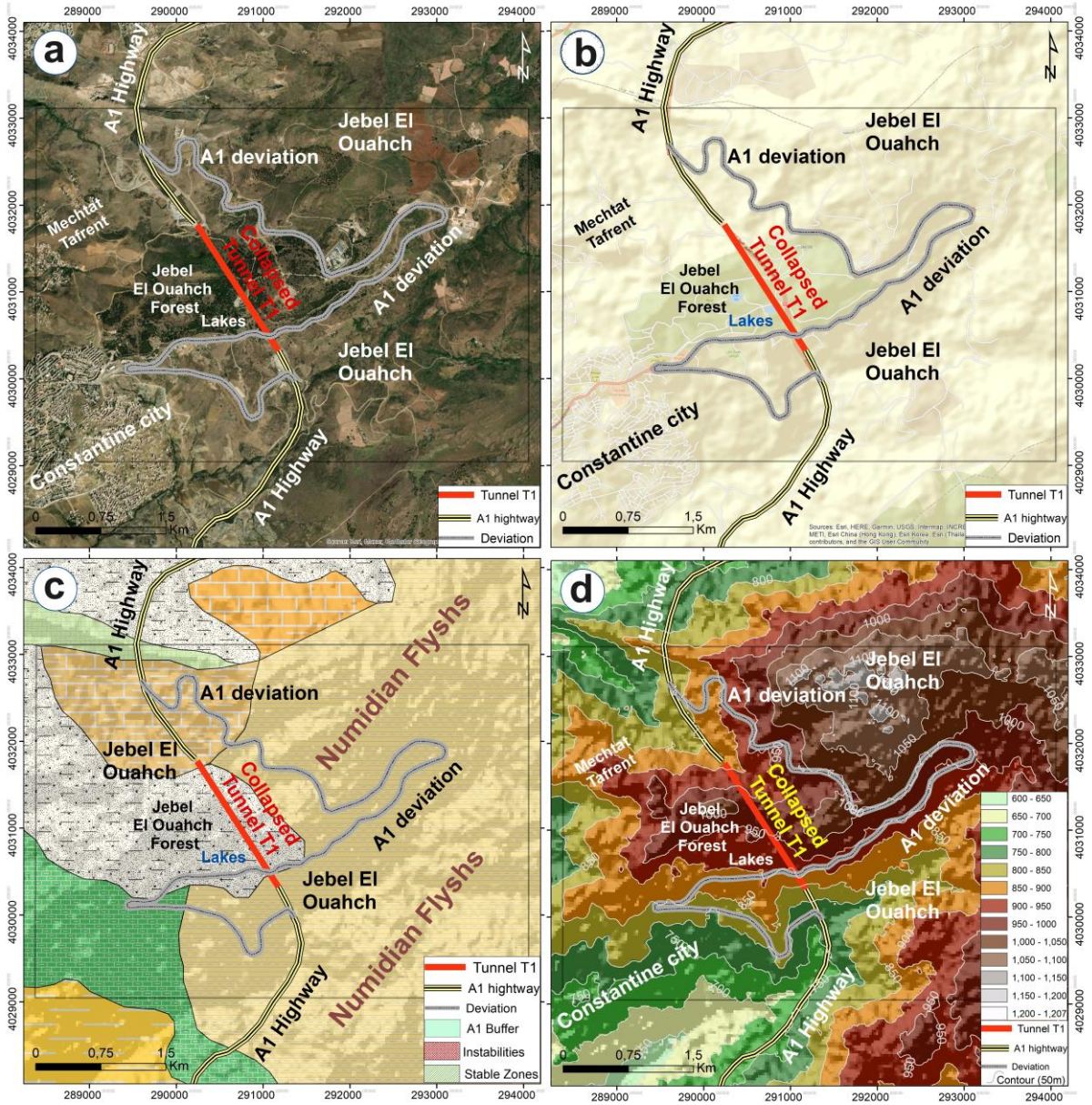

Figure 2. (**a**) The new Djebel El-Ouahch deviation on satellite images. (**b**) The new Djebel El-Ouahch deviation on street map. (**c**) The new Djebel El-Ouahch deviation on numidian (beige) formations. (**d**) The new Djebel El-Ouahch deviation on steep landscape (DEM).

However, due to landslides occurring along the new route, reinforcement work was necessary, involving the installation of over 1,000 piles across the 12.41 km stretch (Fig. 1b). The Djebel El-Ouahch deviation (Figure 2) required a public investment of more than 10 million USD, entrusted to national companies following the withdrawal of the Japanese consortium. The primary objective of this study was to identify viable solutions to prevent similar incidents in the future, including assessing the susceptibility of the new route to landslides and prioritizing risk into different classes, particularly those requiring immediate intervention. Despite technical and technological efforts, the issue remains unresolved, necessitating further scientific investigation (Manchar et al., 2018; Anis et al., 2019). Semi-quantitative methods utilizing Geographic Information Systems (GIS) have become integral in assessing geological hazards. The Analytic Hierarchy Process (AHP), pioneered by Saaty in 1977, remains an indispensable tool for mapping landslides due to its enduring relevance and efficacy. Its versatility is evident in various applications, including site selection, suitability analysis, regional planning, and the assessment of landslide susceptibility (Ayalew et al., 2005). Numerous researchers have successfully employed AHP for landslide susceptibility mapping, demonstrating its robustness and applicability (Achour et al., 2017). AHP involves constructing a hierarchical structure of decision elements or factors, followed by systematic comparisons among these elements. This method facilitates a structured and rigorous approach to decision-making, enabling a comprehensive evaluation of landslide susceptibility and contributing factors within a geographic context. This study provides valuable insights into the intricate geological complexities contributing to the tunnel collapse event, laying the groundwork for effective strategies to mitigate such hazards in future tunnel constructions. The findings of this research hold significant potential to improve the safety and sustainability of tunnel infrastructure projects in regions facing similar geological challenges.

2. STUDY AREA

The study area is located in Constantine city, a major metropolis in northeastern Algeria, approximately 350 km away from the capital, Algiers (Figure 3).

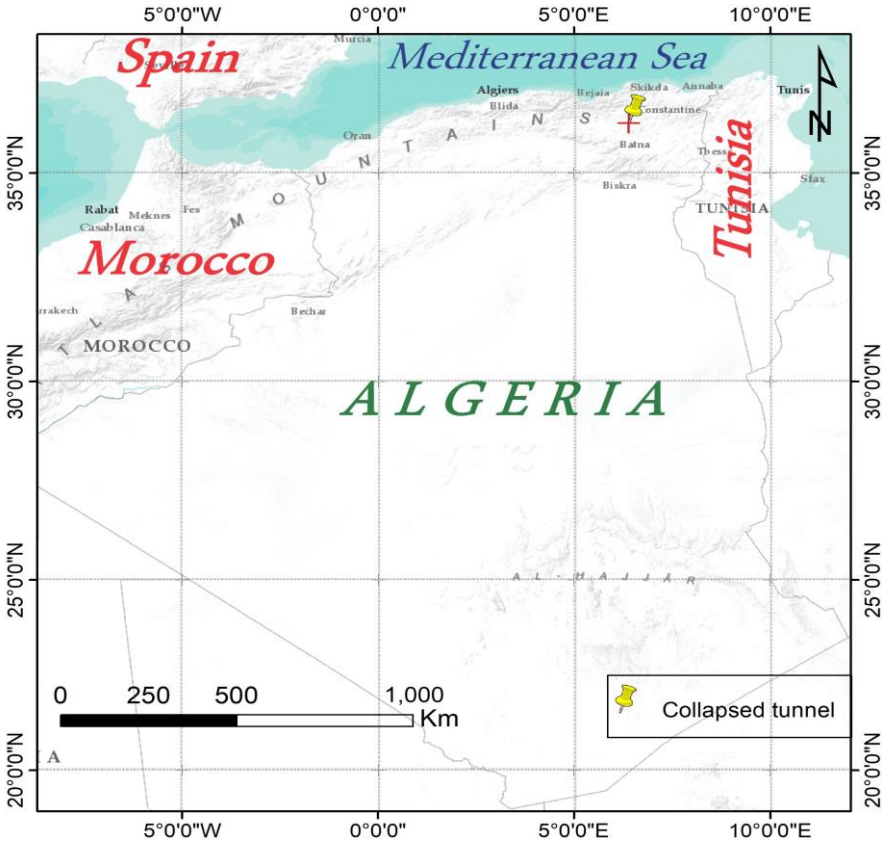

Figure 3. Geographical location of the study area in Algeria map.

The region is traversed by the A1 (E-W highway), situated on the eastern side of the chief town. This highway passes through a mountainous terrain covered with dense forests, known as Jebel El Ouahch Park. To overcome the steep relief between PK 205+393.000 and PK 207+284.500, the engineers opted to construct a two-tube tunnel spanning a distance of 1,891.5 m (Figure 4a).

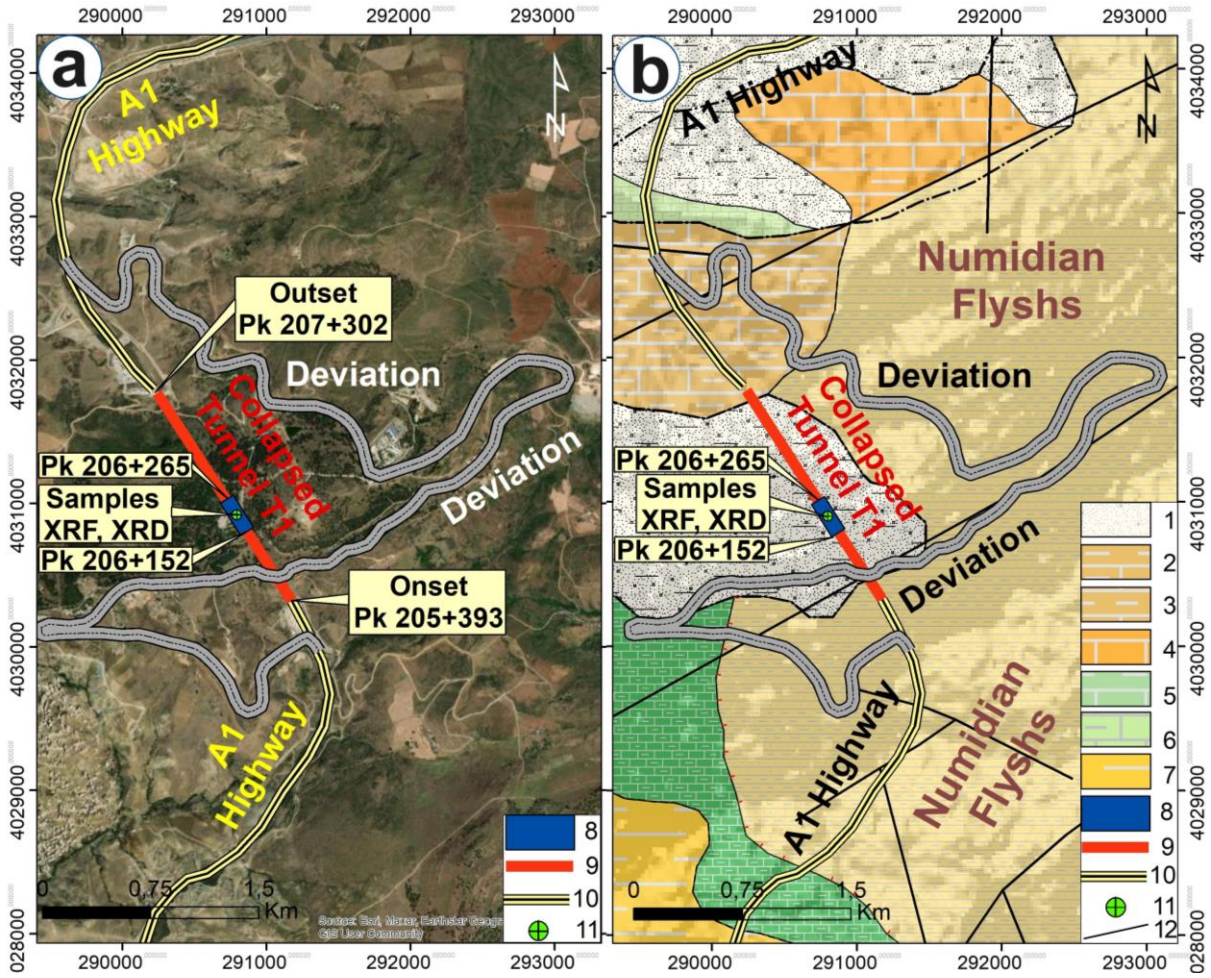

Figure 4. (**a**) Satellite image of the study area, showing the tunnel (T1), the highway (A1) and the deviation. (**b**) Simplified geological map of the study area, with samples points. [Legend: 1 = Quaternary (Holocene): Current alluvial deposits, occasional slope debris, and piedmont accumulations. 2 = Oligocene: Series of clays at the base and sandstones at the top. 3 = Paleocene-Maastrichtian: Marls and marl-limestones. 4 = Lower and Middle Eocene (Ypresian and Lower Lutetian): Limestones with flint and marl-limestones, sometimes with gypsum. 5 = Lower Cretaceous (Aptian): Marls, shales, and limestones. 6 = Upper Cretaceous (Coniacian-Maastrichtian): Grey marls and limestone beds at the top. 7 = Middle Eocene (Upper Lutetian): Marls, clays, and locally conglomerates. 8 = Collapsed zone. 9 = Tunnel T1. 10 = A1 Highway. 11 = XRD and XRF samles. 12 = Faults.]

The Eastern (right) tube of the tunnel was completed and opened to traffic in April 2013, while the West tube (left tube) was still under excavation.nHowever, an unfortunate incident occurred on January 1, 2014, when the West tube suffered a catastrophic collapse during construction, causing significant disruptions and damage to the operational East tube, which had been in service for only a few months. As a result of this disaster, the East tube had to be closed off to ensure traffic safety. To address the closure of the East tube, a temporary sinuous road was hastily constructed as an alternate route. This detour, extending over 12.41 km, winds its way up the slopes of Jebel El Ouahch, starting from the southern entrance and exiting on the northern side of the tunnel. However, this temporary road poses a considerable risk, particularly for heavy vehicles, and requires immediate attention. The northeastern region of Constantine showcases a fascinating and intricate geological landscape, characterized by brittle tectonics. This complexity is attributed to the presence of various thrust sheets, including the Numidian,

Tellian, and Constantinois neritic sheets. The area is of significant importance as it houses a major highway, with Tunnel T1 serving as a notable engineering feat. Jebel El Ouahch, a prominent mountain in the region, is primarily composed of massive Numidian sandstones, which are visually impressive and structurally significant. As we venture towards the southern part of this mountainous massif, an intriguing geological phenomenon unfolds - the presence of Massylian flysch formations (Zerzour et al., 2020, 2021; Benmarce et al., 2021). These flysch deposits, characterized by sedimentary rocks containing microbreccias, provide valuable clues about the ancient environmental conditions and depositional processes. Moreover, these flysch layers rest upon extensively deformed Ultra-Tellian formations, a geological unit that spans a considerable timespan from the Barrémian to the Lower Lutetian periods. The dating of these formations has been established through the work of Moretti et al. (1991). Notably, underneath the towering Numidian sandstone of Jebel El Ouahch, we find the exposure of sub-Numidian Tubotomaculum claystone on the eastern side of the site. These claystones offer insights into the geological history and can reveal crucial information about the rock's origin, composition, and formation processes (Hadji et al., 2013; Boulemia et al., 2021), (Figure 4b). Samples were taken from the core drillings carried out at depths ranging from 107m to 128m. An examination of the lithological sections of the drill revealed nearly identical lithology for all three samples. The top formation (from 0 to 18m) consists of sandy and loamy clays, sandy loam, and clayey sands, followed by monotonous lithology down to 128m, composed of clays. These clays exhibit a grayish, sometimes greenish hue, with a schistose appearance. The schistosity planes are shiny and smooth, marked by the presence of fine white material. Occasionally, these clays display reddish and greenish patina. This description was supplemented by observations made inside the West tube (collapsed tunnel) and in the field. At this clayey level, we conducted sampling by collecting three samples at different depths for each drilling. Samples of sandstone were also collected from the sandstone layers to prepare thin sections for the study of their mineral composition. Observation of the thin sections under a polarizing microscope revealed that these sandstones are primarily composed of 95% quartz grains. These grains are sub-rounded and have a microscopic size. There is also a presence of biotite, but in very low percentages, sometimes found within the quartz grains.

3. RESEARCH METHODS

3.1. Landslides susceptibility mapping

The study began with the preparation of a landslide inventory map based on field surveys. Analytic hierarchy process was used for landslide susceptibility mapping for the studied area in a GIS environment. The statistical analysis is carried out utilizing SPSS package. After reclassification using the natural break classification method, the resulted maps represent the final landslide susceptibility models. Finally, validation of the model was carried out to select the valid land slide susceptibility map for the study area. The followed methodology of the work is shown in Figure 5.

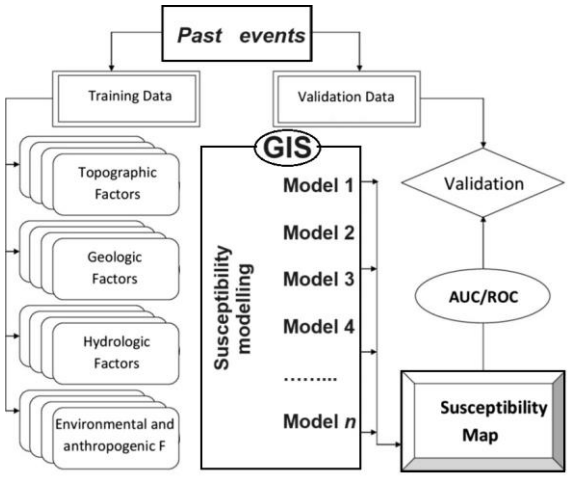

Figure 5. The methodological flow shart used in the GIS modelling.

3.1.1. Analytic hierarchy process

The Analytic Hierarchy Process (AHP) serves as a multi-criteria decision-making method that involves pairwise comparisons between various factors represented in a matrix to assign weights to each factor and establish a consistency ratio (Saaty, 1980). This process determines the relative importance of each factor to all other factors. In the AHP methodology, each factor is assessed against every other factor by assigning values typically ranging from 1 to 9 for factors with a direct relationship. Conversely, reciprocal values between 1/2 and 1/9 are used when the relationship between factors is inversely proportional. The essential steps in the AHP procedure include standardizing the factors, determining the weight of each factor, and aggregating the criteria. Initially, standardization ensures that factors and their spatial representations are aligned on a common scale, facilitating meaningful comparisons. Subsequently, a comparison matrix is constructed, enabling the assessment of each factor's importance to others. The quality of these comparisons is evaluated using the consistency ratio, which is calculated based on the consistency index and the random index. An acceptable level of consistency is indicated by a consistency ratio of less than 10%. A lower consistency ratio implies that the computed weights for each factor are reliable. Utilizing a weighted linear combination, the landslide susceptibility map is generated. This involves overlaying layers representing controlling factors and multiplying them by their corresponding weight values, providing a comprehensive depiction of areas prone to landslides based on the amalgamation of these influential factors.

3.1.2. Conditioning factors

The selection of factors for landslide susceptibility mapping lacks rigid guidelines but revolves around key parameters such as lithofacies and slope angle, which have been proven to be highly influential in the genesis and triggering of instabilities. This method has been applied by various researchers (Hadji et al., 2014a, b, 2016, 2017; Dahoua et al., 2018).

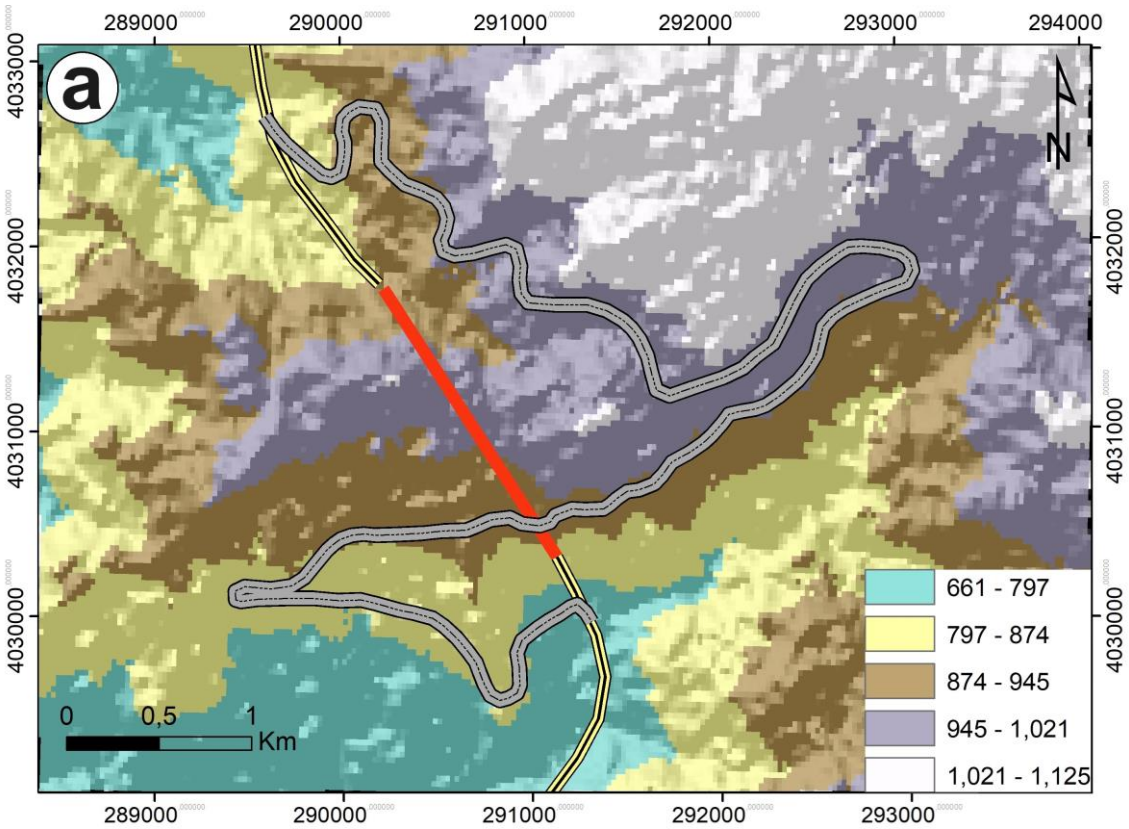

Figure 6. (**a**) Elevation map.

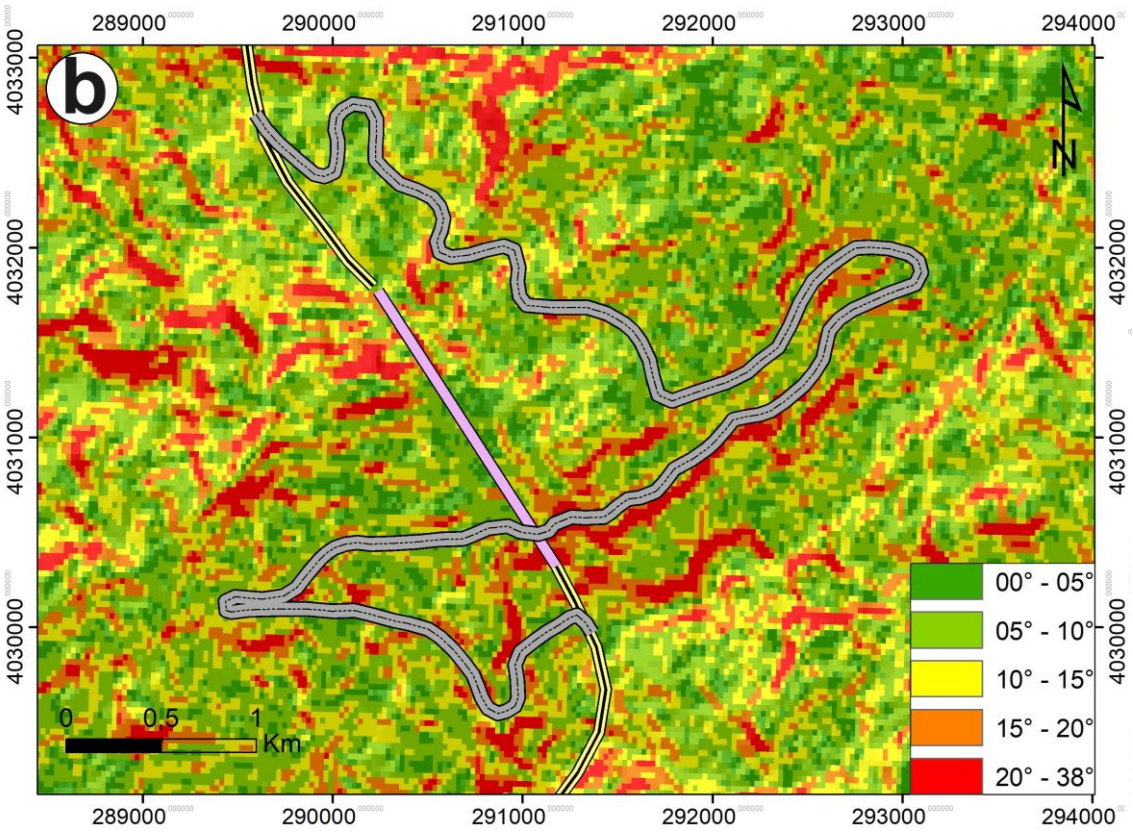

Figure 6. (**b**) Slope map.

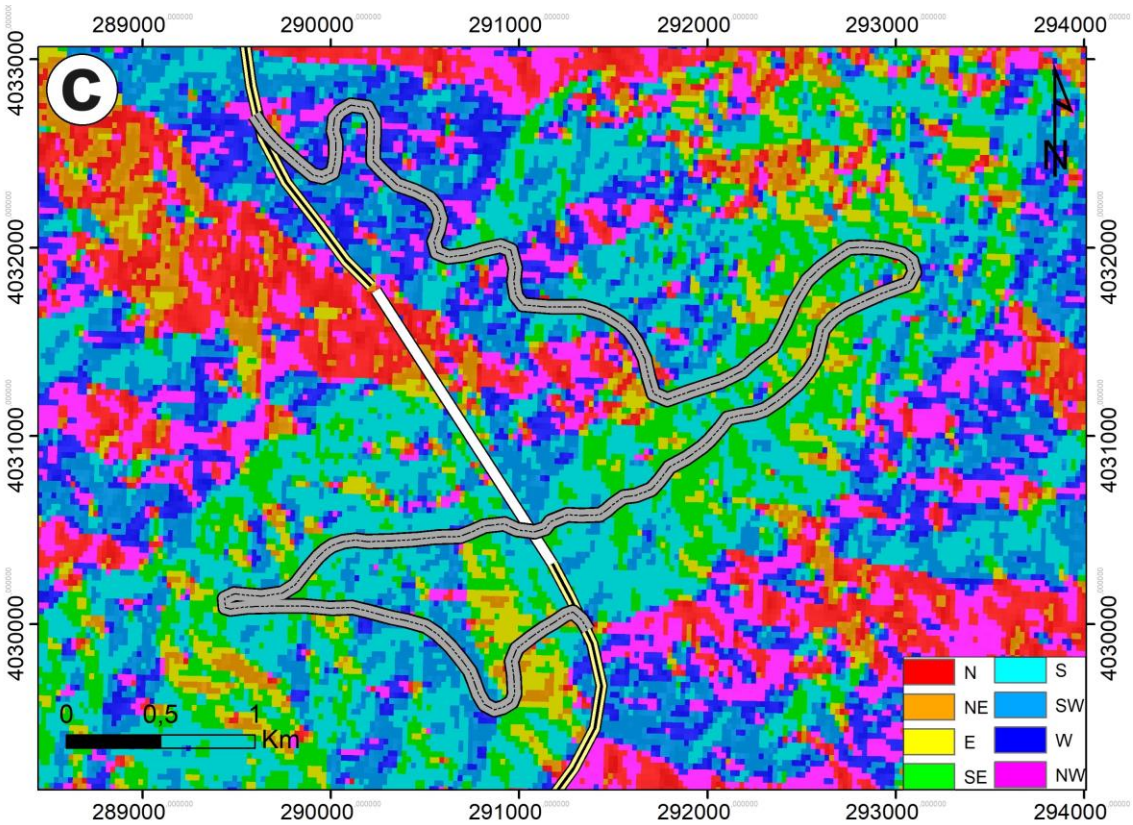

Figure 6. (**c**) Aspect map.

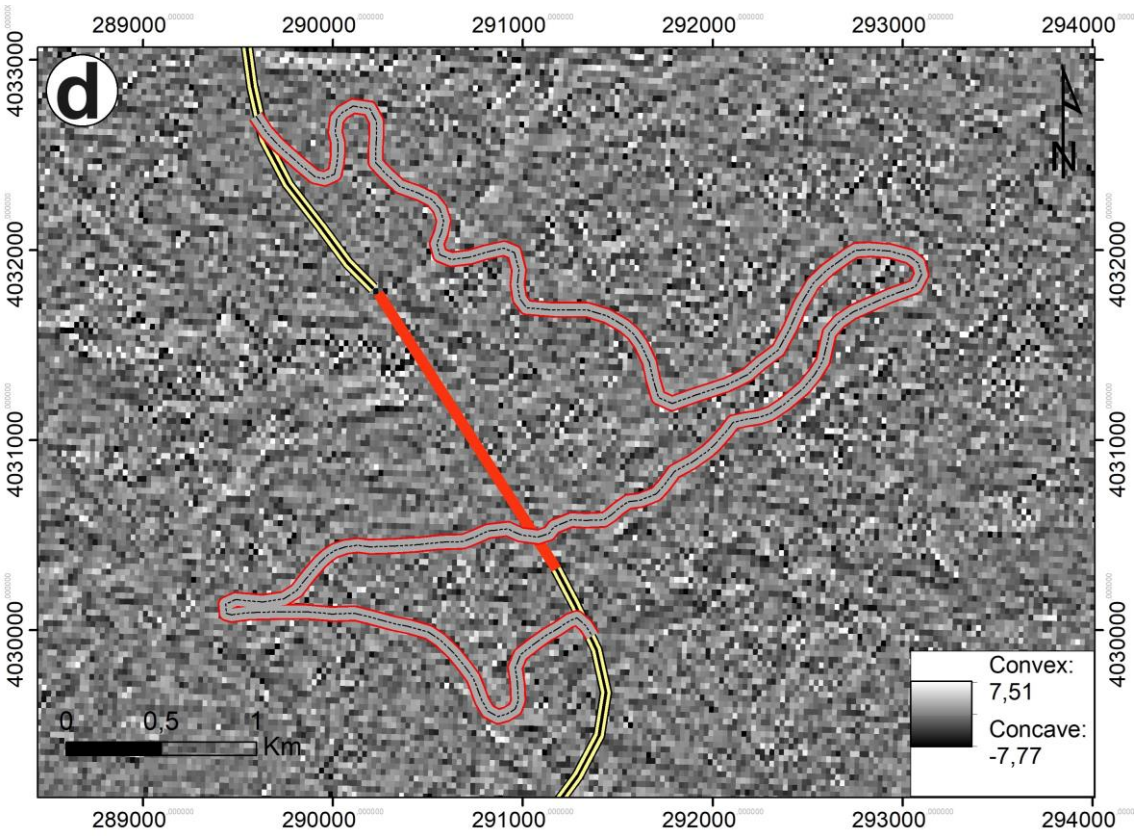

Figure 6. (**d**) Plan curvature map.

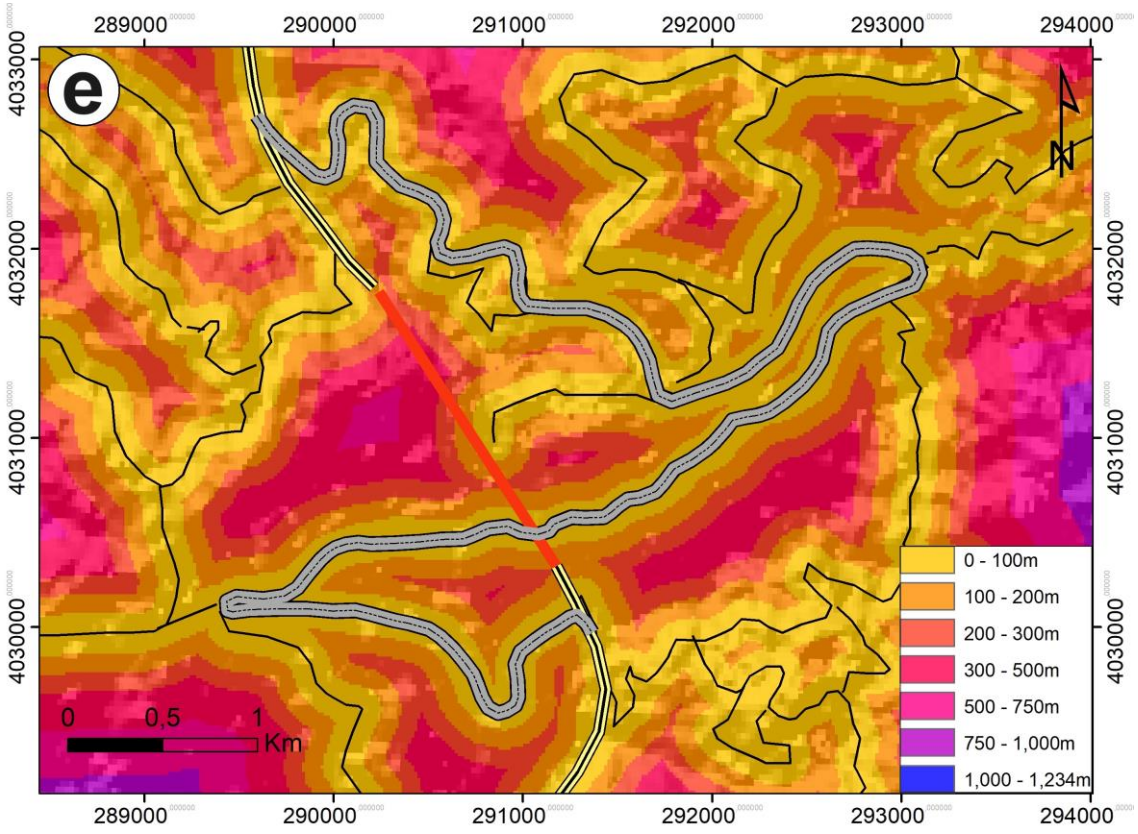

Figure 6. (**e**) Distance to roads map.

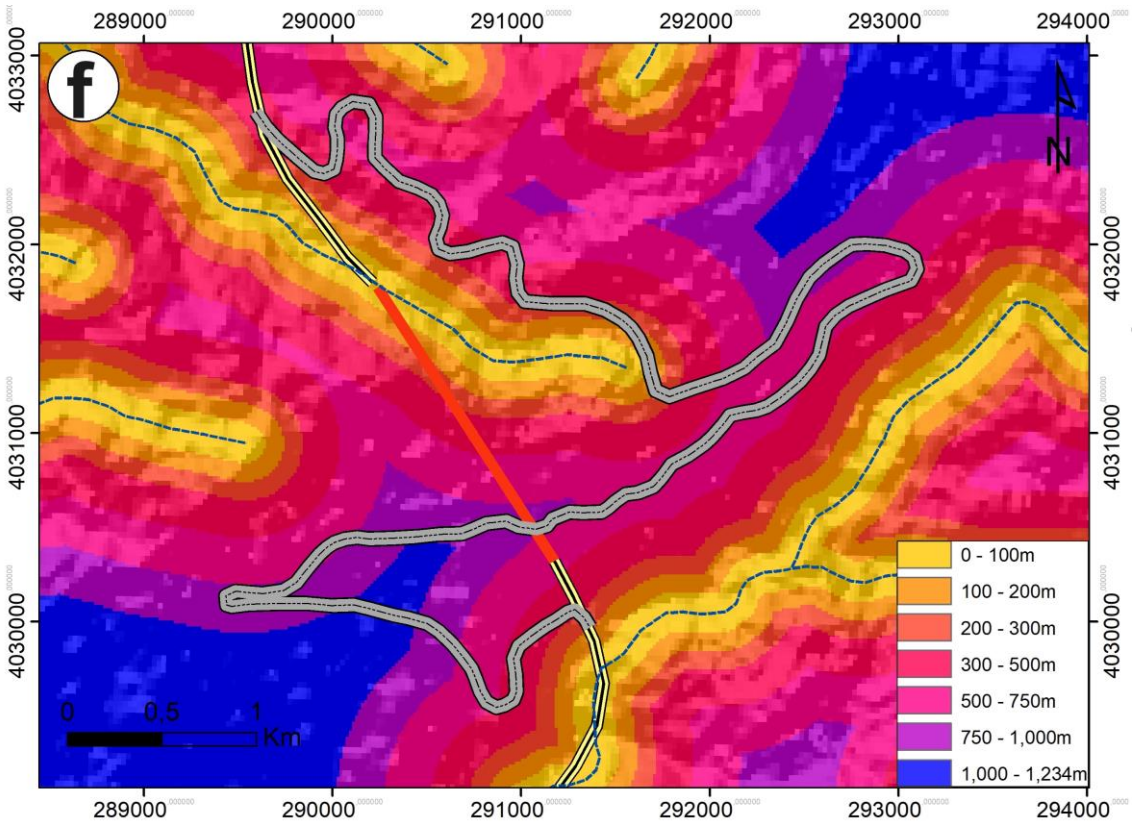

Figure 6. (**f**) Distance to streams map.

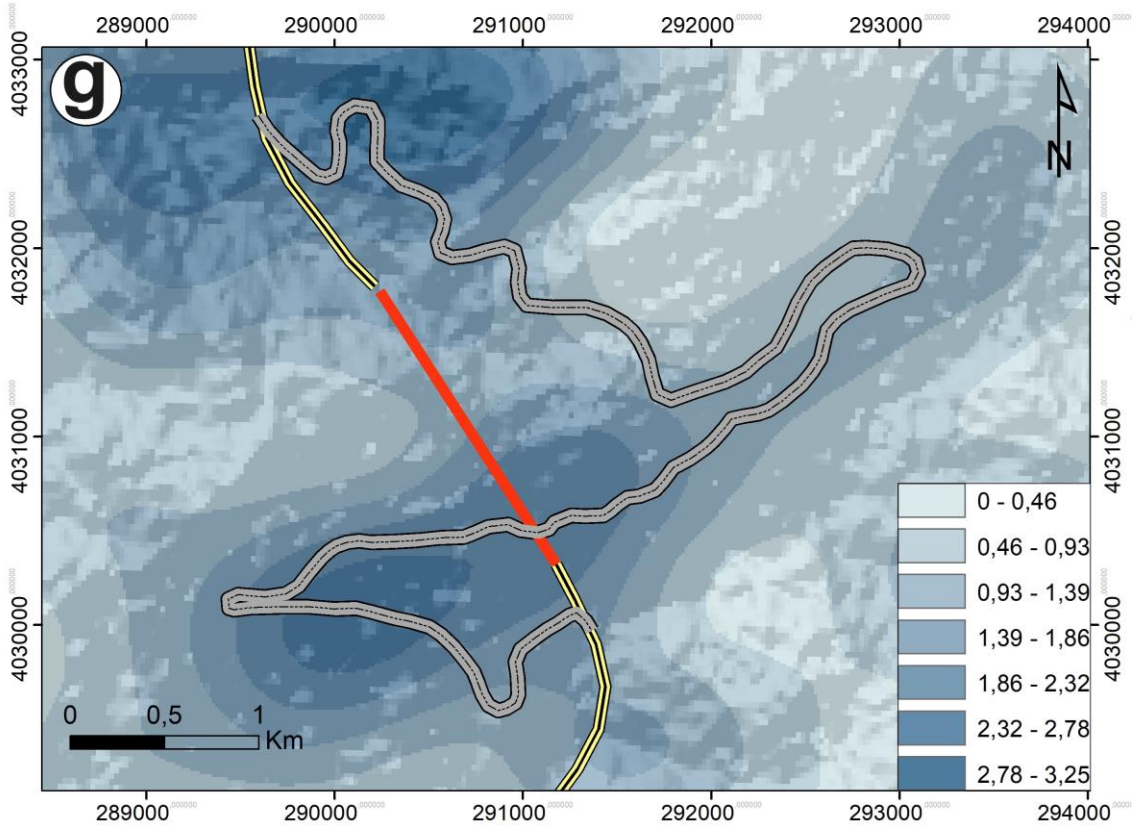

Figure 6. (**g**) Fault density map.

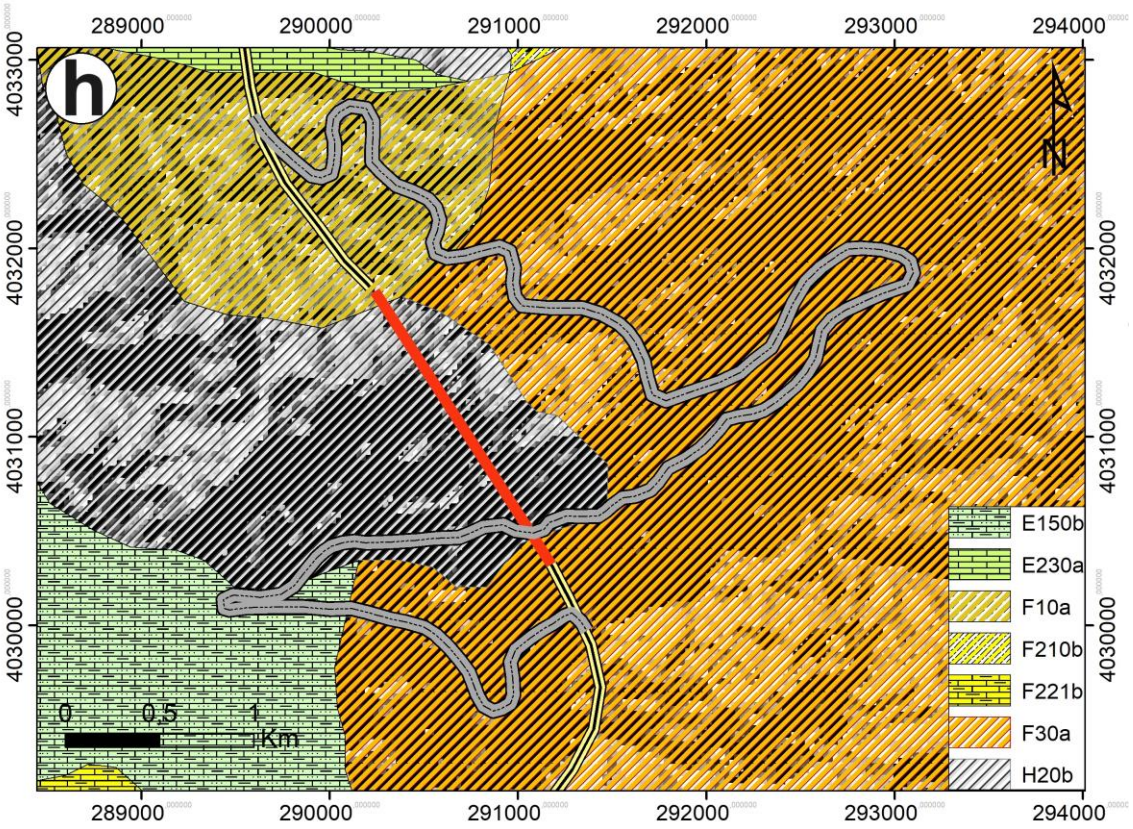

Figure 6. (**h**) Lithofacies map.

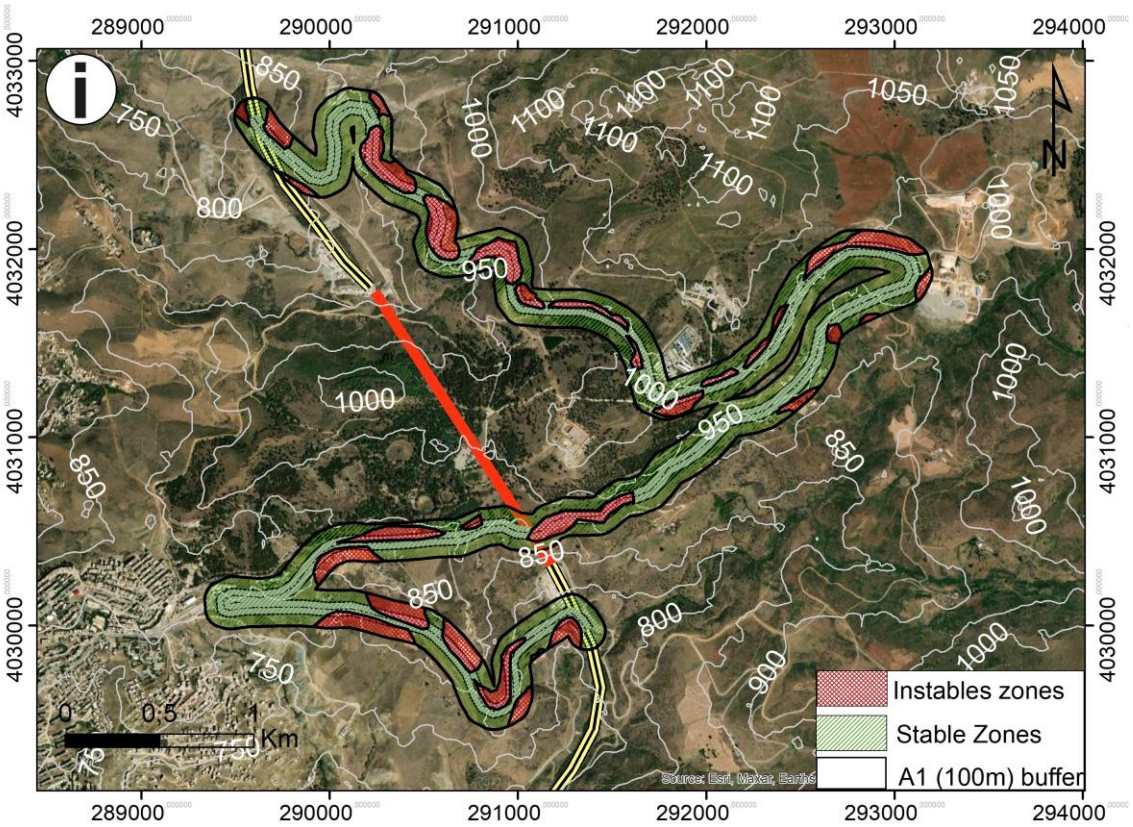

Figure 6. (**i**) Landslides inventory map.

Factors chosen for landslide susceptibility assessment must meet specific criteria; they need to be operational, comprehensive, and non-redundant attributes. Based on these criteria, eight pivotal

predisposing factors were considered in this study, encompassing lithofacies, slope gradient, slope aspect, elevations, fault density, plan curvature, distance from streams, and distance from roads (Zeqiri et al., 2019; Ncibi et al., 2021; Hamed et al., 2023). These factors are compared to the landslides inventory map (Fig. 6i).

Lithofacies significantly influence landslide predisposition and triggering due to variations in the strength and permeability of rocks and soils. In this study, lithostratigraphic outcrops were extracted from the 1:50,000 geological map of Constantine. These lithostratigraphic outcrops comprise various formations including Quaternary (Holocene) deposits, Oligocene clay series with sandstones, Paleocene-Maastrichtian marls and marl-limestones, Lower and Middle Eocene limestone variations, Lower Cretaceous marls, shales, and limestones, Upper Cretaceous grey marls and limestone beds, and Middle Eocene marls, clays, and conglomerates (Figure 6h).

Morphological factors such as slope gradient, slope aspect, and terrain elevation play pivotal roles in landslide control (Figure 6a, b, c). These parameters were derived from the digital elevation model and categorized into ascending classes using the Jenks method and field observations (Achour et al., 2020).

Fault lineaments were digitized from the geological map of Constantine and fieldwork. Increased fault density heightens the likelihood of landslides (Figure 6g). Additionally, the construction of roads involving cutting and filling the embankments can trigger slope instabilities. The distance from roads was factored into the assessment through a multiple-buffer procedure (Figure 6e).

Streams can adversely affect slope stability through erosion or saturation of the toe materials, reducing their shear resistance. For this study, a distance from streams map was categorized into five classes: 0–50 m, 50–100 m, 100–250 m, 250–500 m, and >500 m (Figure 6f). Furthermore, the concavity and convexity of slopes also play a crucial role in water flow and infiltration conditions (Figure 6d).

3.2. Geologic characters

3.2.1. X-ray diffraction (XRD) analysis

The fundamental design of an X-ray diffractometer (XRD) consists of a monochromatic radiation source and an X-ray detector positioned on a graduated circle at the center of a powder specimen. There are divergent slits placed between the X-ray source and the specimen, as well as between the specimen and the detector. These slits serve multiple purposes, including limiting scattered radiation (non-diffracted), reducing background noise, and collimating the radiation. To ensure synchronized movement, the detector and specimen holder are mechanically connected to a goniometer. This setup enables the detector to rotate through 2x degrees while the specimen rotates through x degrees, maintaining a fixed 2:1 ratio (Figure 7).

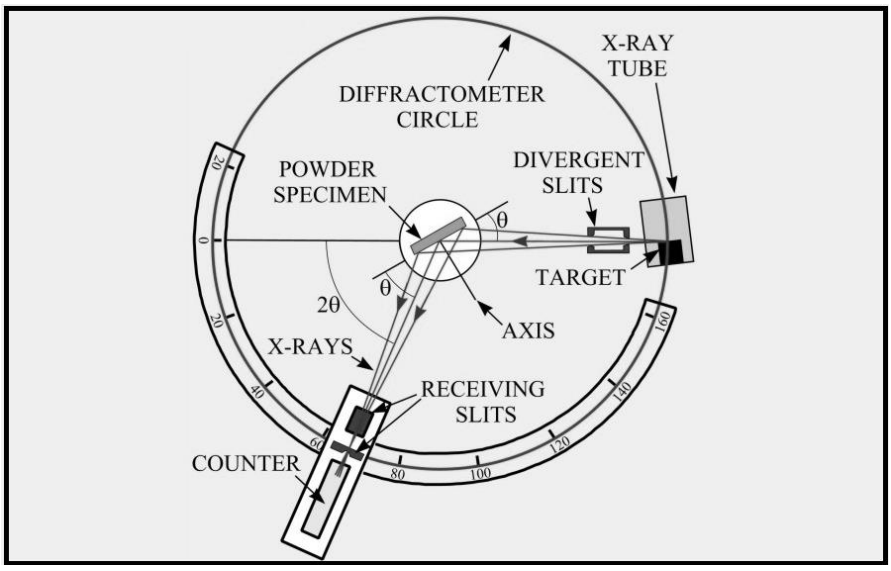

Figure 7. The USGS XRD protocol Shemes (Cullity, 1956).

Based on the U.S. Geological Survey Open-File Report 01-041, our investigation began with XRD analysis of powdered samples. These samples were obtained through mechanical grinding and meticulously analyzed to discern the crystalline phases present in each specimen. Moreover, oriented thin sections were meticulously prepared to enhance the identification of clay minerals within a fraction smaller than 80 μm. These thin sections underwent a series of treatments to facilitate detailed mineral analysis. Exposure to Natural Conditions: Thin sections were exposed to open air under natural atmospheric conditions. Saturation with Ethylene Glycol: To facilitate the swelling of smectites, thin sections underwent a 12-hour saturation process with ethylene glycol. Heating Process: A heating process at 490°C for 2 hours was employed to characterize heat-sensitive minerals. This specific temperature ensures the destruction of kaolinites while preserving chlorites. The powdered samples and treated thin sections underwent diffractometric analysis using a PANalytical diffractometer, and the resulting data were meticulously processed using specialized Height-score software for thorough interpretation.

3.2.2. X-ray fluorescence (XRF)

We conducted an elemental chemical analysis on the collected samples at the National Office of Mines Tunis. For this purpose, we employed the Perkin-Elmer apparatus, which is equipped with a flame. The apparatus has the flexibility to utilize either acetylene or nitrous oxide-acetylene, adapting to the specific requirements needed for precise and accurate elemental analysis.

4. RESULTS

4.1. Landslides mapping

The AHP analysis revealed the weightage assigned to each parameter, highlighting the slope angle as the most influential factor with a value of 0.309. It was followed by lithofacies at 0.202, and subsequently, distance from roads and terrain elevation, both carrying a weight of 0.119. Conversely, factors such as distance from faults, aspect, land use, and distance from streams displayed lower significance in this analysis. In this study, the calculated consistency ratio stands at 0.015, indicating a satisfactory level of consistency. This level of consistency ensures reliability in determining the weight of each factor, affirming the credibility of the analysis. To construct the Landslide Susceptibility Index (LSI) (Dahoua et al., 2017b), the integration of various causative factors was computed using specific weightings attributed to each factor. The formula utilized for LSI integration involves multiplying each factor by its respective weight: LSI = Fault density * 0.073 + Distance to streams * 0.025 + Slope gradient * 0.309 + Slope aspect * 0.075 + Lithofacies * 0.202 + Plan curvature * 0.071 + Distance from Roads * 0.019 + Terrain elevations * 0.019 (Table 1). With a consistency ratio of 0.015, the analysis underscores the reliability of the process in determining the weights assigned to each factor, ultimately contributing to the accurate construction of the Landslide Susceptibility Index.

Table 1. Pair-wise comparison matrix and relative weights of causative factor.

Influencing factors		**(FD)**	**(DS)**	**(SG)**	**(SA)**	**(LF)**	**(PC)**	**(DR)**	**(TE)**	**Weight**
Fault density	(FD)	1								0.073
distance to streams	(DS)	1/4	1							0.025
Slope gradient	(SG)	4	7	1						0.309
Slope aspect	(SA)	1	4	1/4	1					0.075
Lithofacies	(LF)	3	6	1/2	3	1				0.202
Plan Curvature	(PC)	1	4	1/4	1	1/3	1			0.071
Distance from roads	(DR)	2	5	1/3	2	1/2	2	1		0.119
Terrain elevations	(TE)	2	5	1/3	2	1/2	2	1	1	0.119

The landslide susceptibility map produced through the AHP method is depicted in Figure 8a. This map was reclassified into five distinct hierarchical susceptibility classes, as shown in Figure 8b. The susceptibility conditions predominantly range from very high to high along most parts of the deviation road, as illustrated in Figure 8c. This particular area is primarily characterized by steep slopes, which significantly contribute to the heightened susceptibility observed in these regions.

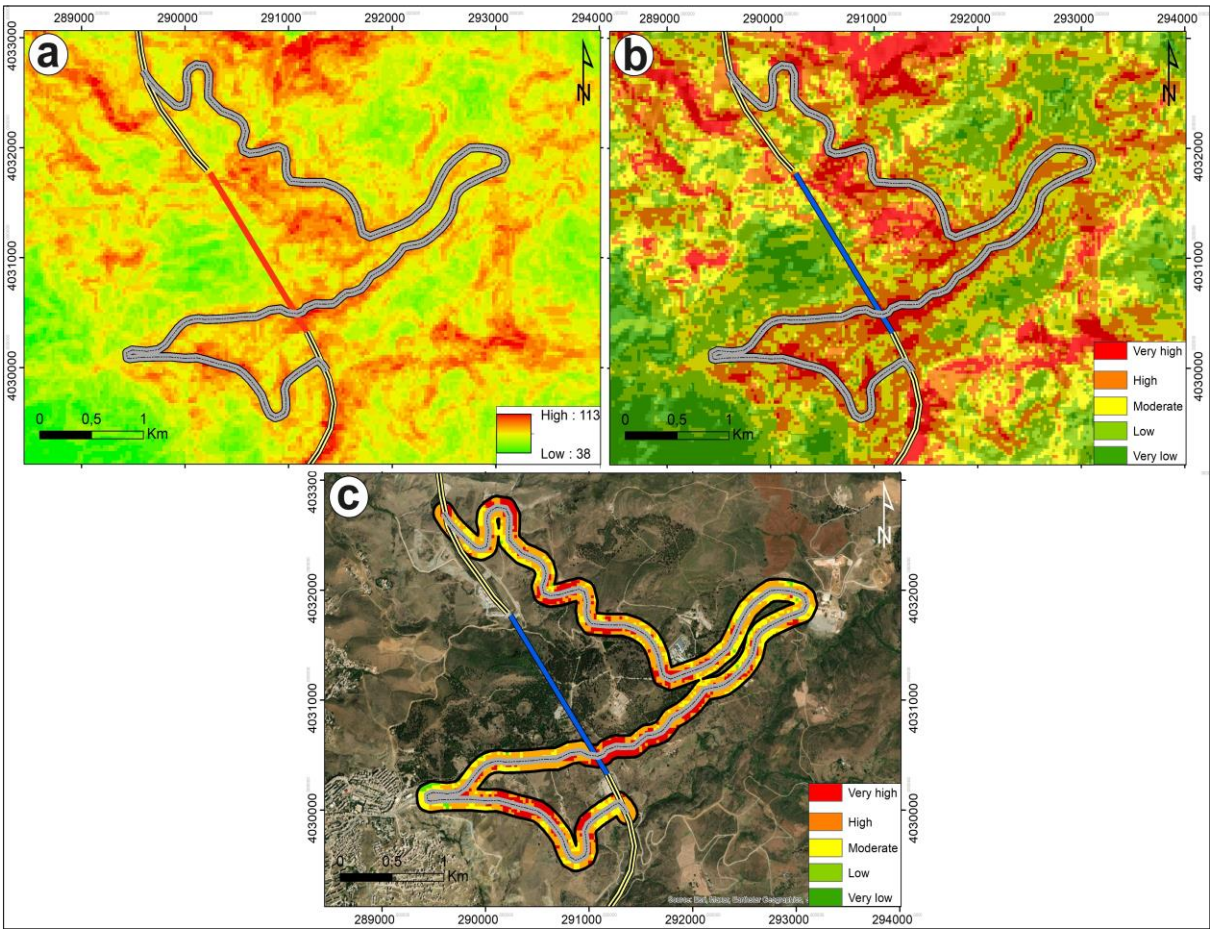

Figure 8. (**a**) Landslides susceptibility map on the study area in stretched mode; (**b**) Landslides susceptibility map on the study area in jenks-classified mode; (**c**) The susceptibility map of the road deviation (for buffer area); (**d**) Histogram of the susceptibility Classes map of the deviation road (for buffer area).

The area under the curve (AUC) value of 0.93 obtained for the landslide susceptibility map generated through the AHP method signifies a commendable overall success rate, as shown in Figure 9. This metric suggests that the performance of the landslide susceptibility mapping exhibits favorable prediction accuracy across the study area. A value of 0.93 indicates a substantial degree of reliability in predicting and assessing landslide susceptibility, reflecting the effectiveness of the AHP-based methodology in delineating areas prone to landslides within the study area.

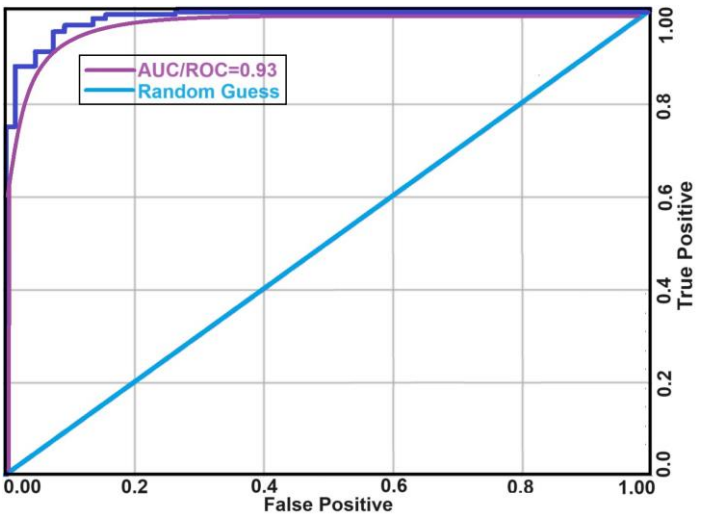

Figure 9. AUC/ROC curve of adopted AHP model.

4.2. Mineral, chemical, and petrographic characters

4.2.1. Mineralogical analyses

The X-ray diffraction (XRD) analysis conducted revealed crucial insights into the mineralogical composition of the samples obtained from the Jebel El Ouahch Tunnel collapse incident. Predominantly, quartz emerged as the primary mineral constituent (Figure 10), demonstrating its prevalent presence within the samples. Moreover, the X-ray fluorescence analysis further validated these findings, highlighting SiO2 as the principal element, closely followed by Al_2O_3.

The semi-quantitative analysis conducted on all samples unveiled a consistently similar mineralogical distribution pattern. Notably, the samples exhibited a significant proportion of total clays, averaging 43.75% (Table 2). Additionally, quartz emerged as a dominant mineral, accounting for an average of 41.37% across the samples. In addition to quartz, accessory minerals such as feldspar, calcite, dolomite, and traces of iron oxides and siderite were also identified.

Moreover, the diffractograms derived from the oriented samples provided intricate details of the clay mineral assemblage, unveiling the presence of Kaolinite, Illite, Chlorite, Smectite, and regular interstratifications. This extensive mineralogical and geochemical characterization sheds significant light on the composition of the tunnel's geological structure.

The correlation between these identified minerals, particularly the prevalence of quartz and the presence of clay minerals such as Kaolinite and Illite, serves as a pivotal link in understanding the geological vulnerabilities that may have contributed to the collapse incident in the Jebel El Ouahch Tunnel. These findings signify a crucial aspect, indicating that the geological and mineralogical characteristics played a substantial role as one of the primary causes and origins of the tunnel's collapse.

Table 2. Semi-quantitative analysis results.

	N° Sample		
Minerals	**S 1-2017**	**S 2-2017**	**S 3-2017**
Quartz	41	38	44
Argile totale	39	45	40
Feldspath	7	7	5
Calcite	3	2	1
Dolomite	6	4	5
Hématite	1	1	2
Sidérite	2	3	3

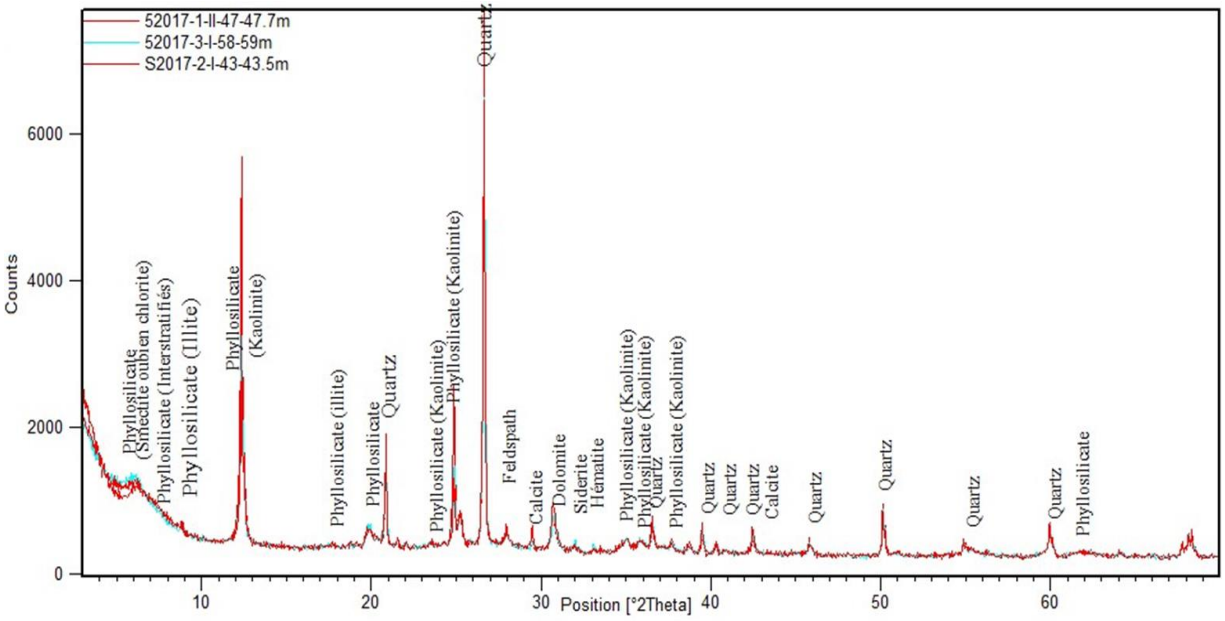

Figure 10. Diffractograms of S1 (drill) samples.

The mineralogical analyses conducted in this study have provided invaluable insights into the composition and distribution of minerals within the collected samples from the Jebel El Ouahch Tunnel collapse incident. Notably, the significant prevalence of quartz and kaolinite, along with the presence of various accessory minerals, provides crucial information regarding the geological characteristics of the analyzed clays. These findings contribute significantly to our understanding of the underlying geological features that could have contributed to the collapse incident. Of particular significance is the identification of multiple clay minerals, which greatly enhances our understanding of their potential influence on the behavior and properties of these clays in various geotechnical and environmental applications.

The semi-quantitative analysis of the clay fraction revealed a dominant presence of kaolinite, constituting approximately 37.92% of the mineral composition. Subsequently, smectite accounted for 20.51%, followed by chlorite at 18.88%, and illite at 13.70%. Additionally, regular interstratifications were observed with an average percentage of 8.99% (Table 3).

Table 3. Percentage of clay minerals.

	Samples		
Minerals	**S 1**	**S 2**	**S 3**
Smectite	34	10	30
Chlorite	18	21	22
Interbedded	4	13	11
Illite	17	19	8
Kaolinite	27	38	28

Understanding the prevalence and distribution of these specific clay minerals, notably the abundance of kaolinite, smectite, chlorite, and illite, provides crucial insights into their potential role as contributing factors to the collapse incident in the Jebel El Ouahch Tunnel. The presence and proportions of these minerals could significantly influence the mechanical behavior and stability of the geological formations, thus underscoring their relevance as key factors in the tunnel's collapse.

4.2.2. Geochemical analysis

The X-ray fluorescence (XRF) analysis, detailed in Table 4, provides crucial insights into the elemental composition of the claystone samples extracted from the Jebel El Ouahch Tunnel collapse incident. Predominantly, the results indicate the substantial presence of Silica (Si) and Aluminum (Al) as the most dominant constituents within the claystone samples. These elements are primarily attributed to the prevalence of quartz (SiO_2) and phyllosilicates, including Kaolinite ($Al_2Si_2O_5(OH)_4$), Illite [$(K, H_3O)Al_2Si_3AlO_{10}(OH)_2$], and chlorite $(Fe, Mg, Al)_6$ $(Si, Al)4O_{10}(OH)_8$. Additionally, the analysis indicates the presence of Calcium (Ca) and Magnesium (Mg), primarily associated with calcite and dolomite, albeit in smaller percentages. Notably, the carbonate content exhibited relatively low values of CaCO3. Iron (Fe) elements were identified, linked to siderite ($FeCO_3$) and hematite (Fe_2O_3).

Table 4. Geochemical analyses using XRF.

	S-1 (47.-47.47m)	**S-2(43-43,5m)**	**S-3 (58-59m)**
% Al_2O_3	15,3	16,18	14,35
% MgO	2,52	2,48	2,44
% CaO	2,66	2,4	1,94
% Na_2O	0,62	0,59	0,52
% K_2O	1,81	1,3	1,13
% Fe_2O_3	6,55	6,45	6,62
% SiO_2	57,97	57,38	59,84
% PF	9,94	10,77	10,44
% TiO_2	0,88	0,81	0,74

These findings gleaned from the XRF analysis are pivotal in understanding the elemental composition and chemical makeup of the claystone samples. The prevalence of silica, aluminum, and various phyllosilicates, coupled with the presence of accessory minerals such as calcium, magnesium, and iron-bearing minerals, significantly influences the geological and geotechnical behavior of the claystone.

Furthermore, these findings play a pivotal role in assessing the suitability and performance of the claystone in various geological applications. Understanding the chemical composition of these samples provides essential insights into their potential behavior in different environmental conditions. Moreover, these results underscore the importance of geochemical characteristics in evaluating the stability and performance of geological formations, offering valuable insights into the causes and origins underlying the collapse incident in the Jebel El Ouahch Tunnel.

6. DISCUSSION AND INTERPRETATION OF RESULTS

The collapse of the T01 tunnel in Jebel El Ouahch during the excavation phase in January 2014 shed light on the intricate geological and geotechnical challenges of the region. This tunnel traverses folded and fractured greyish claystone formations dating back to the Subnumidian age, which exhibits schistosity and fracture planes distinguished by the presence of kaolinite. Rigorous mineralogical analyses conducted via X-ray diffraction (XRD) unveiled the composition of the claystones, which comprise 43.75% total clay and 41.37% quartz, alongside accessory minerals such as feldspar, calcite, dolomite, and iron oxides (hematite and siderite). Additionally, X-ray fluorescence (XRF) confirmed the prevalence of silica and aluminum, attributed to quartz and phyllosilicates (kaolinite, illite, chlorite, and smectite), while minor percentages of calcium and magnesium were linked to calcite and dolomite, indicating low carbonate content. Fieldwork conducted inside the collapsed tunnel and along its axis revealed the vulnerability of the claystones due to schistosity, micro-folds, and fractures resulting from regional tectonic thrusting. The collapsed section represents a fragile zone, acting as a fault node where the material has disintegrated entirely. Consequently, the characteristics of these claystones deteriorate in this area, leading to the uplifting of the reinforced concrete lining of the tunnel under surrounding rock pressures. Accurate assessment of infrastructure stability, especially for critical public projects like the A1 highway, is of paramount importance in the planning and execution stages. This study employed a comprehensive approach, utilizing GIS-AHP-based modeling alongside geological identification, to generate landslide susceptibility maps along the deviation road impacted by the collapsed T1 tunnel on the A1 highway. Eight influential factors, including lithofacies, slope gradient, slope aspect, elevations, fault density, plan curvature, distance from streams, and distance from roads, were meticulously evaluated, and their specific weights were determined based on their impact. Validation results, analyzed using the ROC (Receiver Operating Characteristic) curve, indicated good acceptability, affirming the model's notable accuracy in predicting landslide susceptibility along the studied road. These landslide susceptibility maps serve as crucial tools for engineers, decision-makers, and planners, aiding in informed decision-making processes to mitigate damage caused by existing or potential landslides. The deviation road, as well as the T01 tunnel of the A1 highway, is in a state of proven instability. It will certainly experience continuous, recurrent, and intense landslides. A radical solution to all the geotechnical issues plaguing this section of the highway is to change the route far away from the Subnumidian formations. Thorough geological and geotechnical studies should precede the initiation of construction for new roads and highways to avert such technical challenges in the future. Tectonic and micro-tectonic aspects warrant thorough consideration in future projects to ensure stability and safety. Implementing proper reinforcement strategies, based on comprehensive studies, will be pivotal in averting similar incidents, ensuring safety, and prolonging the longevity of critical infrastructure projects. While the Analytic Hierarchy Process (AHP) is a widely used multi-criteria decision-making technique for assessing geological hazards, including landslides, it is important to consider its performance and limitations to ensure the reliability and accuracy of the resulting susceptibility maps. AHP facilitates the integration of various factors contributing to landslides, such as slope steepness, environmental conditions, geology, and entropy, enabling the creation of a comprehensive decision support system for assessing landslide susceptibility. The accuracy and reliability of susceptibility mapping using AHP heavily depend on the availability and quality of input data. Incomplete or inaccurate data can result in unreliable susceptibility assessments. The mathematical calculations involved in AHP can be complex, particularly when dealing with multiple criteria and large datasets. This complexity may pose challenges in terms of computational resources and time. The static nature of the model may not account for temporal changes in environmental factors, such as climate change or land-use alterations, which can affect the accuracy of long-term predictions. These susceptibility maps are valuable tools for urban planners and policymakers, providing essential

information for making informed decisions regarding land use zoning and development in landslide-prone areas. They also aid in risk assessment, enabling authorities to take proactive measures for risk mitigation and management, such as implementing preventive measures or issuing warnings. In practical application, our approach includes the assessment of the stability of the A1 deviation road, a temporary sinuous road constructed over a steep relief to address the closure of the East tube and ensure traffic flow. The assessment reveals that the deviation is exposed to 23.87% high risk and 52.04% very high risk. Urgent technical solutions are required to ensure the practicability of the A1 highway in its eastern part, including the consolidation of severe cracks in the 113m section. Tracing a new route should also be considered to address these challenges.

7. CONCLUSIONS AND RECOMMENDATIONS

In conclusion, this manuscript presents a comprehensive study on landslide susceptibility mapping and the geological characterization of a specific area. The research employed the AHP method to assess the relative importance of various factors contributing to landslide susceptibility. The integration of multiple causative factors, including lithofacies, slope angle, distance from roads, and terrain elevation, facilitated the construction of a Landslide Susceptibility Index (LSI). The resulting landslide susceptibility map exhibited favorable prediction accuracy, with a commendable overall success rate indicated by an Area Under the Curve (AUC) value of 0.93.

The significance of this work lies in its practical applications for disaster management and land use planning. By identifying areas prone to landslides, decision-makers can implement preventive measures and adopt appropriate land management strategies. The generated landslide susceptibility map provides valuable information for mitigating the risks associated with slope instability, thus contributing to the safety and sustainable development of the studied area.

One of the advantages of the AHP methodology is its ability to consider multiple factors and assign weights to each factor based on their relative importance. This allows for a comprehensive assessment of landslide susceptibility, considering various influential parameters. Additionally, the integration of GIS technology and statistical analysis tools, such as SPSS, enhances the accuracy and efficiency of the mapping process.

However, it is important to acknowledge the limitations of this study. The selection of factors for landslide susceptibility mapping, although guided by key parameters, lacks rigid guidelines and may vary depending on the specific study area. The accuracy of the susceptibility map is also subject to the quality of input data and the assumptions made during the analysis. Therefore, careful consideration should be given to data collection, preprocessing, and validation to ensure reliable results.

Future work in this field could focus on refining the methodology by incorporating additional factors, refining the weightings assigned to existing factors, or applying other probabilistic methods. Advancements in GIS techniques and data availability can further enhance the accuracy and efficiency of landslide susceptibility mapping. Long-term monitoring and validation efforts are crucial to continuously improve the reliability of the models and ensure their effectiveness in real-world applications. Additionally, investigating the temporal dynamics of landslide susceptibility and considering the impact of climate change could provide valuable insights for proactive landslide risk management in a changing environment.

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USE OF AI TOOLS DECLARATION

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

AUTHOR CONTRIBUTIONS

All authors contributed equally to this work. All authors read and approved the final manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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Enhancing Rural Integration into European Agriculture: Rediscovering Sustainable Agri-Food in Romania

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ABSTRACT: One of the factors that threatens the sustainability of rural areas is the hegemonic agro-industrial model with obvious environmental and social impacts which dramatically limits rural life. The study draws attention to the opportunities offered by alternative agri-food systems based on agroecology and food sovereignty as cultural heritage to support sustainable local development. The results of the study demonstrate how the recovery and promotion of traditional ecological knowledge can help increase the capacity of socio-ecological systems to cope with shocks and disruptions and maintain long-term resilience. At the same time, agro-ecological practises allow collective identities to emerge around characteristics of rural space, strengthening local life, focusing on the coevolution of the society-ecosystem of local identity. The case study analyzed in Romania counties shows that rural areas play a critical role in economic and social cohesion, in the resilience of regions and in the contribution of countless services in various local ecosystems, including food production, to their consolidation socio-economic prosperity, the ability to innovate, to achieve a sustainable and inclusive social economy. The types of policies promoted by Romania conceive agro-ecological practices as an intangible collective heritage with a significant potential for transformation towards local sustainability.

KEYWORDS: rural areas, rural tourism, sustainability, food security, Bran-Rucăr corridor

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1. INTRODUCTION

Food and farming have an important role to play in the future of the rural economy, inachieving national net zero targets, and in improving a range of other environmental outcomes. The forecasted 9.1 billion population in 2050 will require an increase in food production for an additional two billion people. There is thus an active debate on new farming practices that could produce more food in a sustainable way. Specially, agroecological practices are agricultural practices aiming to produce significant amounts of food, which valorise in the best way ecological processes and ecosystem services in integrating them as fundamental elements in the development of the practices. Indeed, agroecological practices contribute to improving the sustainability of agroecosystems (Wezel et al. 2014, p.3). Changes will improve the food

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system for people, place and planet and sustainability development can only be achieved through economic and environmental balance (Li et al., 2019). Agroecological approaches are a more holistic way to farm and produce food, integrating nature and societal concerns more coherently than the business-as-usual methods of conventional agriculture. Production techniques pioneered the organic farming and food movement, as well as initiatives based on the principle of food sovereignty including shorter and regionalised food supply systems are core parts of moving towards agroecology. The rural economy has known an increasing improvement during the last years, determining the prosperity of the rural populations, hence farm diversification became necessary in order to achieve good biodiversity and high employment mainly for young people (Chmieliński et al., 2021). The most viable way of farm and rural diversification are traditional products and crafts. Also, traditional food products which has been gaining in popularity among tourists represents a way to increase attractiveness of an agricultural farm offer which has value for the farming in which relates the "contributes to the public awareness of the value of farming in general" (Stotten, 2021). Usually, traditional products are considered healthier, sustainable produced and strongly connected with the cultural heritage of the local communities (Pamukçu et al., 2021, Privitera et al., 2018).

The European Commission (2006) provided the following definition of the term "traditional" related to foods: "Traditional means proven usage in the community market for a time period showing transmission between generations; this time period should be the one generally ascribed as one human generation, at least 25 years" (EU, Council Regulation, 2006). In order to provide a better understanding of traditional food concept the European Food Information Resource Network has developed separate guidelines (Pieniak et al, 2009) regarding the traditional ingredients, composition and traditional type of production and processes (Trichopoulou et al., 2007).

Rural traditional foodstuffs, from agricultural practices to culinary ones are linked to rural tourism activities and represent a pull factor for visiting a particular rural destination (Rachão et al., 2019), hence local food is essential to the success of rural tourism and a means of promoting rural development through traditional cuisine (Stalkos et al., 2021). The gastronomic experiences proven to be an instrinsic connection between food and culture, becaming a way to enhance tourists cultural experience (Horng and Tsai, 2010), thus the traditional food encourage the tourism sector incresing synergies between tourism networks and adapting the offer to the consumer's needs.

Gastronomic tourism generally refers to the origin of a dish as it is connected to a specific location (Green & Dougherty, 2008) and the topic foster social, environmental, territorial and economical cohesion in rural settings (Figueiredo et al., 2021), in order to offer opportunities for the local communities to reinforce and sustain their identities through the promotion of the traditional food products and also events (UNWTO, 2017). The local identities of the communities are also reinforced by farmers' markets, food and drink trails which at local and regional level are important vehicles for sustainable regional development. In order to create a 'sense of place' farmers' markets, producers in the rural sectors and wineries provide motivation and reasons to visit the rural areas mainly by the "the landscape within which they are located" (Hall & Mitchell, 2005, p. 86). The study focuses attention on the issue of what are the opportunities offered by alternative agri-food systems, based on agroecology, as cultural heritage to support sustainable local development. The second part of the article also provides a case study, in rural areas of the Romania that plays a critical role in economic and social cohesion, in the resilience of regions and in the contribution of countless services in various local ecosystems, including food production, to achieve a sustainable and inclusive social economy.

2. LITERATURE REVIEW

The current global food system is associated with a range of challenges including health ones, the climate emergency, poverty, and environmental crises. The EAT-Lancet Commission on healthy diets from sustainable food systems (Willet et al. 2019) identified the production of food as being the most significant cause of environmental change globally, as well as highlighting the overwhelming impacts of unhealthy diets on morbidity and mortality. Similarly, the global call to action in the UN 2030 Agenda for Sustainable

Development recognises food as vital, emphasising the need to '(e)nsure sustainable consumption and production patterns' (Goal 12).

Specially, sustainable agriculture goes beyond simply obtaining food and non-food products, it is also economically sustainable for farmers (who do not use products that have a cost), it respects the environment, it improves the quality of life of both the farmer and the consumer who buys the products obtained from this practice. It also has ethical and moral objectives: to ensure a fair income for the farmer; ensure the health of the farmer and the consumer; implement and preserve soil fertility; safeguard and preserve environmental and landscape resources; promote biodiversity.

The way food is produced, bought, supplied, sold and consumed can be a part of whole system solution to the intertwined challenges of climate, nature and health crises. Food procurement is increasingly recognised as playing an essential part in transforming supply chains and addressing global challenges. 2030 is just here. So many sustainable solutions are integrated and adopted on a regional and national scale to improve human and environmental health but notalwayson wideand global scale.

Agri-food biodiversity and family and small-scale agriculture are in fact endangered worldwide due to industrialization of agriculture, genetic erosion, food transformation, climate change, abandonment of rural areas, migration or the COVID-19 pandemic, but and military conflicts that have forced a global disruption of the supply chain. In order to be as competitive as possible, techniques and plants have been used which aim at increasing yields, but which destroy biodiversity and the very integrity of the territory in which we live.

Consecutive reforms of the Common Agricultural Policy (CAP) have progressively broadened the rationale for rural development policies, from simple support to encouraging its development by promoting agricultural policies, better care and financial support for both qualifications. and the conservation of the environment and the rural space, the improvement of the quality of life, as well as an increasing diversification of rural economy and food produced.

Actually, the concept of food is closely linked to the new role assigned to agriculture in relation to the environment, the territory and the safety and quality of the same. In this development, food is a strategic entry point to national issues as it relates productively to space at all scales, from the intimate one of bodies (Guthman, 2014) to that of global supply chains (Morgan et al., 2006).

In this context, policies and practices nowadays often converge towards a re-territorialisation of the existing food systems (as opposed to the de-territorialisation associated with the place lessness associated with global agro-industrial supply chains), which take new forms. In particular, it is crucial to highlight the role of the relationship between food and the places of its production (local food) within the process of the socio-cultural construction of culinary quality (Barbera et al., 2018).

Although there is growing political, civil society, and academic interest in local food policy, only recently has the importance of sustainable food planning been recognized, a field of planning geared toward finding new paradigms for urban and rural planning that support sustainable and equitable food systems (Marsden & Morley, 2014).In fact, the diffusion of integrated food policies is a recent innovation, aiming to integrate different food dimensions and sectors, consistent with an innovative vision of food and food systems (Morgan, 2013; Coulson & Sonnino, 2019).

Food policies emerged as a relatively autonomous sphere, albeit integrated with agricultural, environmental and other sectoral policies, being implemented at, and impacting different scales: from the international level - with the role of agencies such as the FAO and the WHO; to the EU level with the CAP review process, the proposal for a European Food Policy (De Schutter et al., 2019), the construction of the "From Farm to Fork" strategy and the Food 2030 research programs; till, eventually yet not exhaustively, to the national and regional levels, involved in different ways depending on each context.

The production of food involves a plurality of narratives, extensively explored in the scholarly literature, which addresses a diversity of issues, such as: the image and identity of places (Pollice, 2018); the regional specialization of food production (Morgan et al., 2006); local and tourist development linked to territorial specializations (Hall & Mitchell, 2002) and sustainability (Vodenska, 2020); food-health relations (Neff et al., 2009); deterritorialisation and reterritorialisation of food systems (Wiskerke, 2009); conventional and alternative food networks (Corsi et al., 2018); the multiple meanings of food regions

(Kneafsey, 2010; Nocco, 2021); and challenges of sustainability in its different dimensions (Lang & Barling, 2012).

In this context, the COVID-19 emergency has further pushed existing food systems to their limits (FAO, 2020). The pandemic's global scale has made even more evident the complex multiscalarity of agri-food systems. Moreover, the emergency has brought to the fore some of the intrinsic fragilities of food systems (Hendrickson, 2020), but has also highlighted new potentials for resilience.

3. METHODOLOGY

The research was conducted on the monitoring of a number of 29 localities (6 cities and 23 villages) of the 2 counties (Braşov and Argeş) with entrepreneurship on certified traditional products, based on the working pointby querying data from the National Register of Traditional Products (NRTP) and tourism statistics from the website of the National Institute of Statistics. In the analysis has been included the certified traditional products, not the food products obtained according to the well-known Romanian recipes, even if they are the object of completing the agri-food system in the analyzed area. The research was carried out using the cartographic method by interpreting the data in a visual form such as maps of the two counties using the Arcgis program. Hence, the data obtained from the NRTP site were used by displaying the results obtained.

4. CASE STUDY: BRAŞOV AND ARGEŞ COUNTIES IN ROMANIA

The study area is compound of localities, also villages as Fundata, Şirnea (Braşov county) and Rucăr (Argeş county) that were among the declared experimental tourist villages declared (out of 118 identified and selected localities) since the communist period. Also, Fundata and Şirnea are part of an older typology of tourist villages in Romania of 80's, latter mentioned in many scientific papers for its nice climate and landscapes, and also for tourist resorts and sport practicing.

It is worth drawing the reader's attention to a detail that we consider quite important, precisely in this corridor between the two counties - known as the "Bran-Rucăr corridor" - is concentrated the largest number of producers of traditional products. That is, we argue that apart from the purpose of recreation and relaxation, a significant percentage of tourists opt in favor of spending their holidays within these localities not only because of the existence of a strong base of accommodation units, due to natural resources but also because of traditional products. In order to explain this hypothesis, we opted to produce a questionnaire that was distributed to a number of about 500 respondents. The survey was conducted between April 24 and May 7, 2022. Of this, 214 responses were valid and included in the research.

4. RESULTS AND DISCUSSION

4.1. Traditional products and entrepreneurs - geographical distribution and characteristics

In the Romanian context, a network of entrepreneurs with certified traditional agri-food products had emerged up to the threshold of the COVID-19 pandemic. Thus, in 2018, in the first part of May, on the National Register of Traditional Products (NRTP) on the website of the Ministry of Agriculture and Rural Development were listed 607 certified traditional products, as a result of entrepreneurship in 156 localities (cities and villages, including villages registered as belonging to some cities), being part to the 30 major administrative-territorial units (compared to the total of 42 of Romania) of which 118 villages (75% of the total network of localities). Practically, through the development of the network of entrepreneurs and, at the same time, through the proliferation of the certified traditional products, Romania reformulated its potential of affirmation and recognition at European level. Similar research were approached bu authors as Brochado et al., (2019); Morgan (2013); Morgan et al. (2016); Hall & Mitchell (2005).

The effects of the COVID-19 Pandemic were felt in all sectors of the Romanian economy, mainly in the lifestyles of the population which is why the situation reported in the NRTP of the Ministry's website

stopped on June 23, 2020 (according to Order no. 2013 with subsequent amendments and completions), with a total of 715 traditional products.

This situation came after the modification of the measures to prevent and combat the effects of the COVID-19 pandemic ordered during the state of alert (Decision no. 434 of 28 May 2020). Even though the Covid 19 pandemic was officially declared in Romania as closed and no changes have been reported, the area chosen as a case study is still a representative one for Romania.

Thus, in the analyzed geographical area Brașov-Bran-Rucăr-Dragoslavele, superimposed on Brașov and Argeș counties, 212 products are certified as traditional ones, representing 29.65% of the total country, benefit of the business environment inserted in 29 localities of which 23 villages. In 2018, these two counties sum up 205 products (Brașov-166 and Argeș-39), increased respect to 2014 (Brașov-81 and Argeș-29). According to National Register of Traditional Products (NRTP) it includes almost all categories of certified traditional products, except for the "other" categories such as: meat products; milk products; vegetables fruits; bread, bakery and pastry; drinks, fish. Most of the products are from the first 2 statements, as the area under study is recognized by the age of the occupations related to animal husbandry, especially grazing. The most typical examples of certified traditional products are muttom sausages from Dumbravă, fresh/smoked curd, smoked bacon from "Curtea Brăneană".

These traditional products use local raw materials and do not contain food additives, moreover they present traditional recipes, traditional production and/or processing methods which are distinguished from other similar products belonging to the same category, hence they are listed as food products that provide food safety and increase the tourist attractiveness of the place.

4.2. Tourist localities that guarantee sustainability and food security

Rural tourism is a major factor in maintaining the local and zonal tradition, in supporting and developing entrepreneurship with certified traditional products generated by the tourist flow and accommodation units on the one hand and the tourist potential of the whole area on the other hand. Tourism is present in almost half of the villages with entrepreneurship, most of which belong to Brașov County (see the Figure 1).

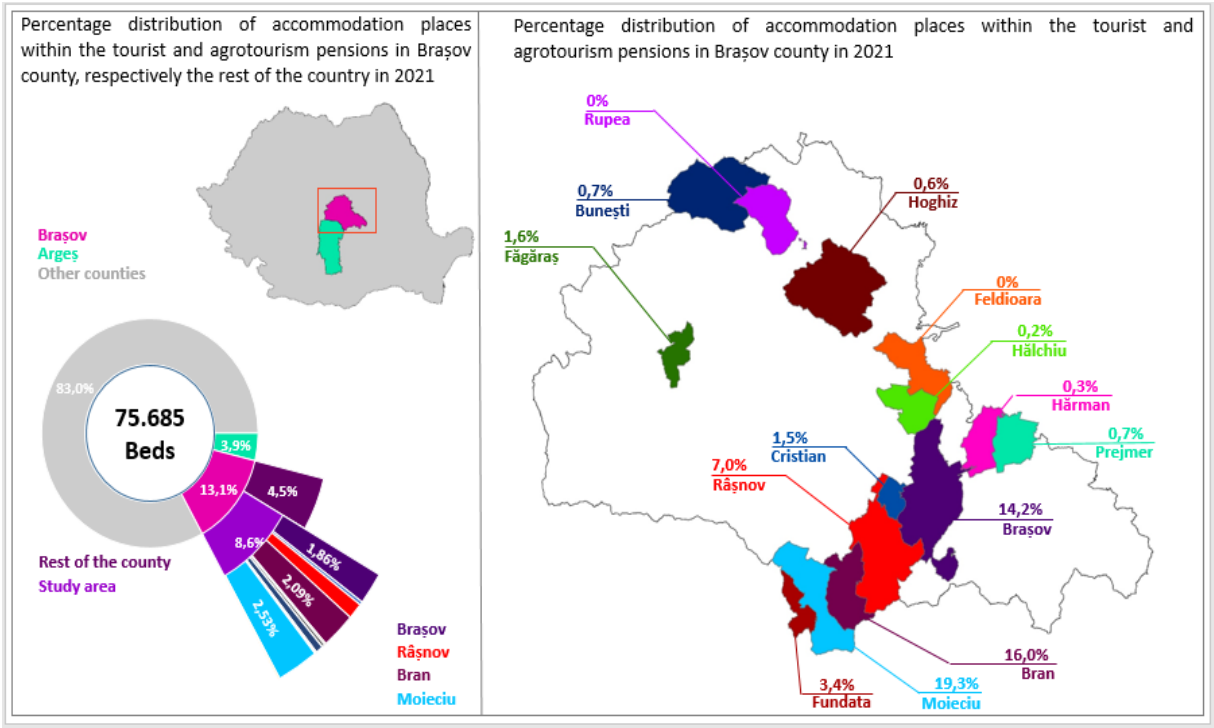

Figure 1. Percentage distribution of accommodation places within the tourist and agrotourism pensions in Brașov county in comparison with the rest of the country in 2021.
Source: Author's own.

Tourists find in these places almost everything they need: relaxation, a healthy natural mountain environment, healthy food with ancient origins and ideas, a good hospitality, convenient distance to the place of residence or even for a weekend.

According to statistical data (NIS, 2022), in 2010 tourist and agro-tourism represented about 12.4% of all accommodation available at country level. During the last decade, the number of these touristic units has experienced a steady growth rate, which has led to the doubling of the number of pensions as well as their expansion in various parts of Romania. Thus, in 2021, tourist and agrotourism held a share of the market of just over 25%. Due to the strategic positioning, to a wide range of tourist resources both natural and anthropogenic, but also to the human resource with an extremely wide openness to tourism, Brasov county was one of the most important poles of tourist attraction at national level. Every 12th place of accommodation in Romania is located in Brasov county. Things change even more when we talk about the touristic and agrotourism, the percentage of such accommodation types in the county being even bigger, that is, every 7th place of accommodation in such units for receiving tourists is located in Brașov county.

The most important clusters for the development of this form of tourism can be considered 4 localities: Brașov city, Râșnov city, Bran and Moieciu localities, which amount to over 56% of the total accommodation places of this type in the county. On the other hand, we are obliged to mention that the number of these accommodation units is increasing at a constant pace in other localities in the county, Făgăraș or Fundata representing two notable examples (Figure 1).

Although it has a significant number of producers of traditional products, it being a neighbor of Brasov and having at its disposal a range of similar natural resources, unfortunately, Arges county cannot be proud of the same results in terms of tourism as its neighbor in the North-West. The number of pensions in Argeș represents only the third part of Brașov county's, that's about 31.6%. Therefore, it is no wonder that in some localities these types of accommodation units are completely missing (Figure 2). In 2021, the analyzed localities made available to tourists a number of 1,064 accommodation places, the largest number being in comuna Rucăr (369 seats), Câmpulung (271 seats) and Curtea de Argeș (269 seats), equivalent to 25.7% of the total places available in the agritourism at county level.

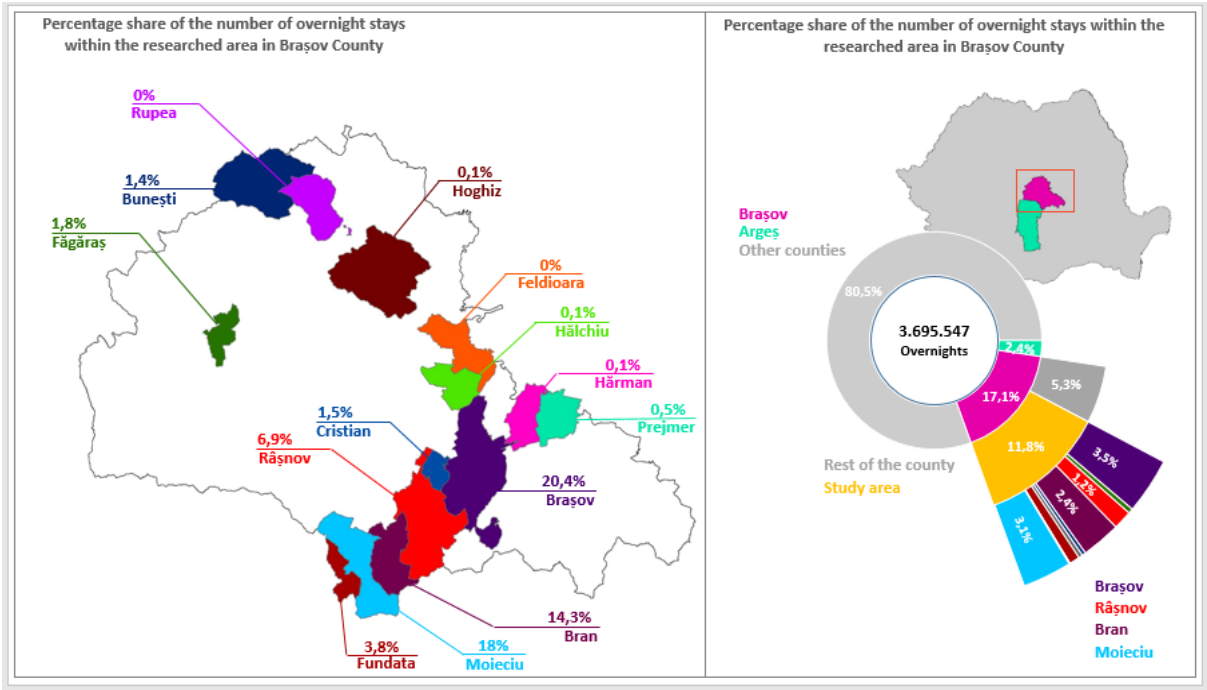

Figure 2. Percentage share of the number of overnight stays within the researched area in Brașov county in comparison with the rest of the country in 2021.
Source: Author's own.

The average countrywide medium stays in 2021 was about 2.22 nights. Both counties recorded an average number of overnight stays of 1.87 nights, Brașov being rated better in the preferences of tourists where the number of arrivals at touristic and agrotourism sites was 322,203 arrivals and 631,381 overnight stays, that is about 1.96 nights/tourist. Unfortunately, Argeș had fewer arrivals (61,633) and

87,902 overnight stays, which makes the duration of the nights spent in the accommodation units there to be 1.43 nights.

In the image above (Figure 2) we can see that within Brașov county almost 70% of the number of overnight stays is owned by the same localities that were mentioned when we talked about accommodation capacity. These are Brașov (20.4%), Râșnov (6.9%), Bran (14.3%) and Moieciu (18%).

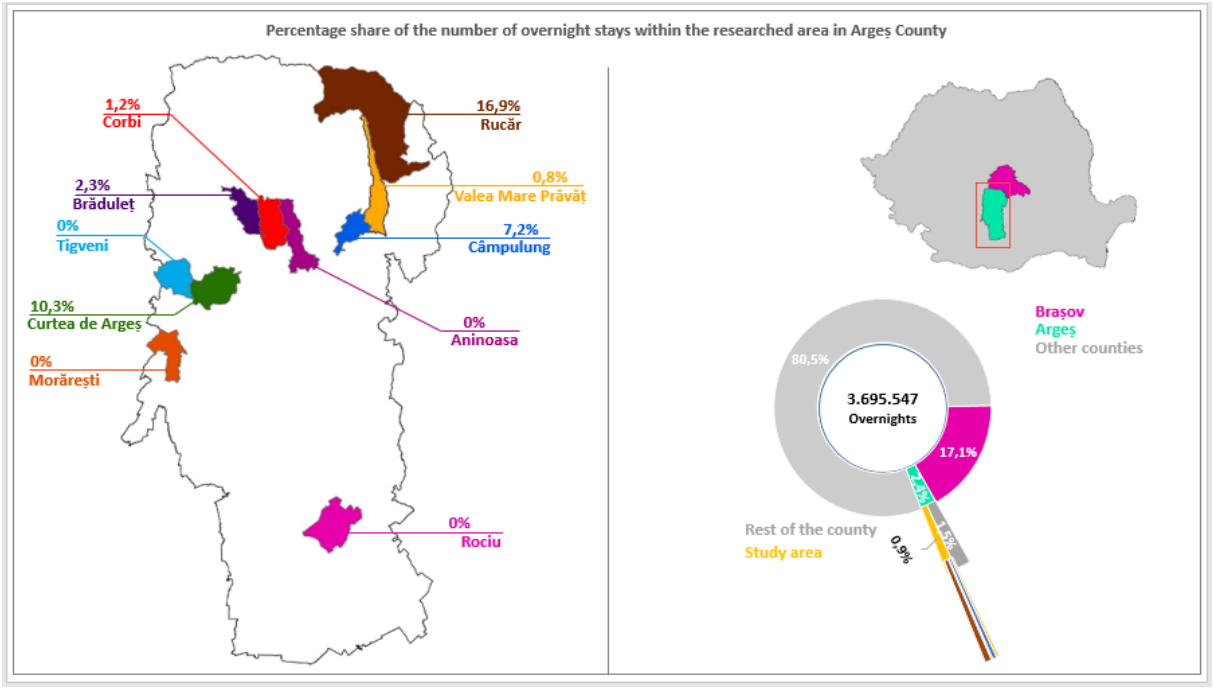

Figure 3. Percentage distribution of accommodation places within the tourist and agrotourism pensions in Argeș county in comparison with the rest of the country in 2021.
Source: Author's own.

Firstly, respondents were asked to indicate where they come from (Figure 3). The answers were divided into four categories: from Brașov; Transylvania, but other than Brașov; Romania but elsewhere than Transylvania; and abroad (Figure 4).

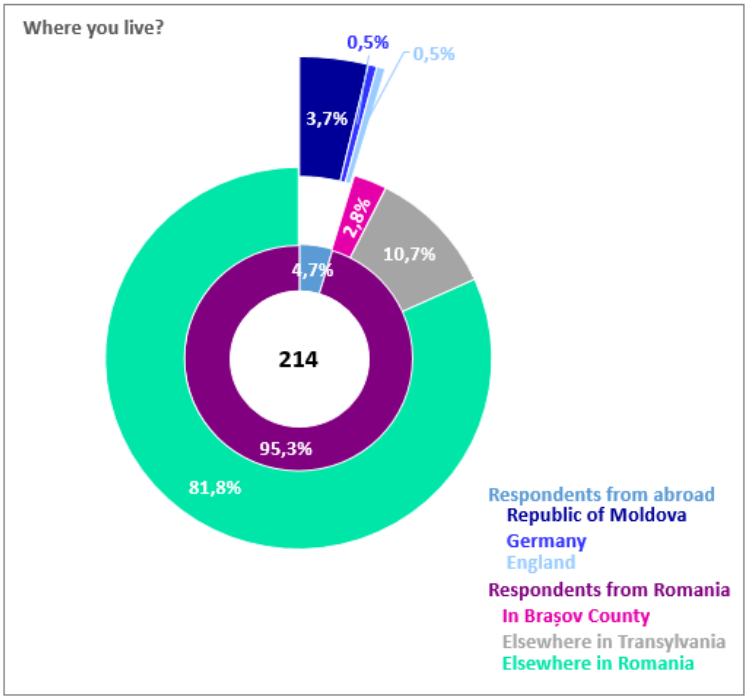

Figure 4. Geographical distribution of respondents.
Source: Author's own.

The age and sex of the respondents is quite varied, the majority (32.3%) are included in the group of those aged between 20 and 29, and it includes part of iGeneration as well as part of Millennials. The majority of respondents have a university degree (87.4%) being followed by people with secondary education. Most (49.1%) are unmarried. The average monthly income of the majority (44.9%) is between 300 and 900 euros, while 40.2% have a monthly income of more than 900 euros. The rest (15%) have incomes below 300 euros per month. The majority (84.1%) visited Brașov county repeatedly, 6.5% were once and 6.1% were twice. Only 3.3% have never visited this county. A 7.7% of respondents see in the local cuisine a reason to visit the county while the majority (26.5%) consider that the landscape is the main asset of the county. The image below (Figure 5) better shows the motivations for which the tourists visit this county. One of the questions was addressed to the respondents in order to identify the defining elements for the cuisine of the Brașov region (including the Rucăr-Bran corridor), hence almost every third person (30.9%) thinks that traditional cuisine is that element. Every fourth person (23%) believes that hospitality and the quality of services provided on the spot are another defining element (Figure 5).

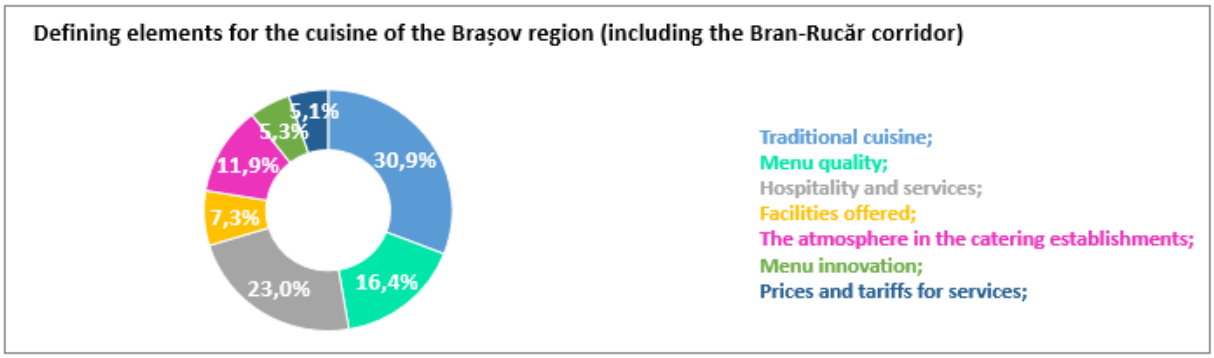

Figure 5. Defining elements for the cuisine of the Brașov region (including the Bran-Rucăr corridor).
Source: Author's own.

When asked if they consider that the products that follow a traditional recipe are of a better quality than the products that do not fall into this category, 67.8% of the respondents had an affirmative answer, 14% a negative answer and 18.2% they abstained. The survey participants were asked to tell us about how often they consume traditional products. Therefore, 36% of them said that the frequency of consumption of these products is several times a week, and 12.6% consume them daily. The detailed situation of these answers can be seen in the image below (Figure 6).

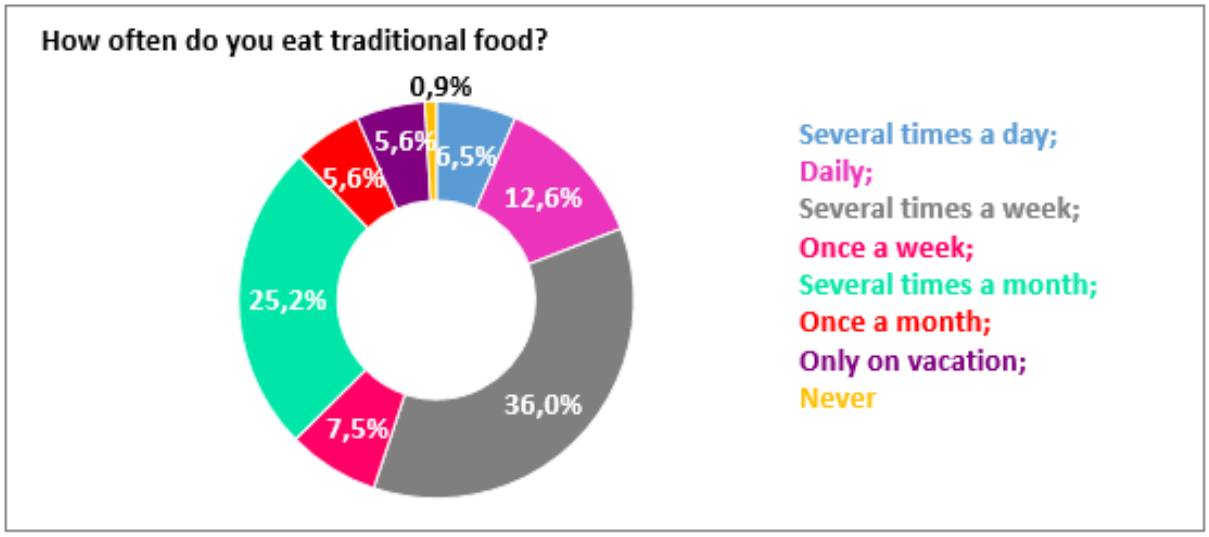

Figure 6. The frequency of consumption of traditional products by respondents.
Source: Author's own.

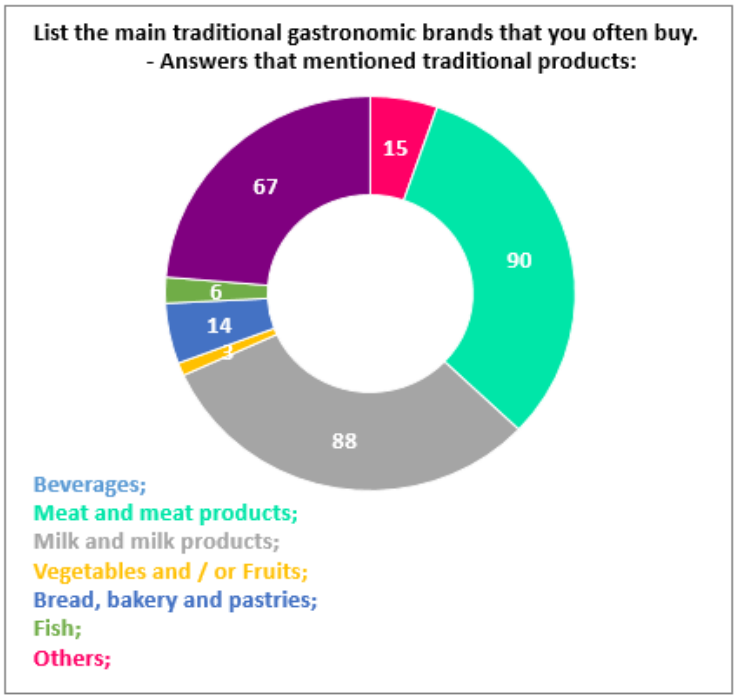

Figure 6.1. List of the main traditional gastronomic brands that you often buy
Source: Author's own.

The answers were categorized as follows: traditional products, almost all traditional food products (Figure 6.1) recognized by Ministry of Agriculture and Sustainable Development (MADR) were taken into account; producers - a significant percentage used the option of naming a specific producer (e.g: Napolact, Matache Măcelaru - famous processor for the production of several meat specialties or Sergiana); localities brand names as Pleșcoi; Bran; Sibiu or Doftana Valley, generic answers as Transylvanian dishes or brands from Bucovina region. Due to the fact that the most common answer was those that mentioned traditional products, for a better representation of these answers we decided to analyze the respective variants (Figure 6.2).

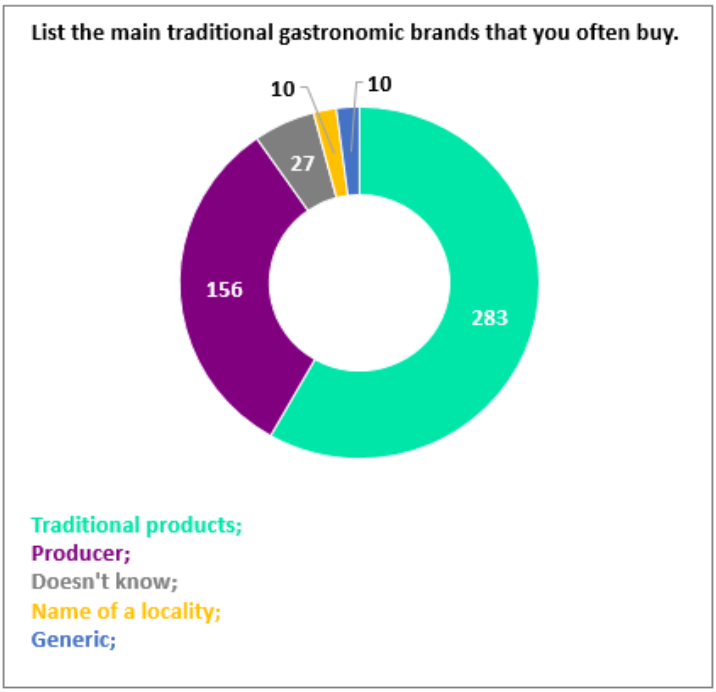

Figure 6.2. Distribution of products grouped by categories according to NRTP.
Source: Author's own.

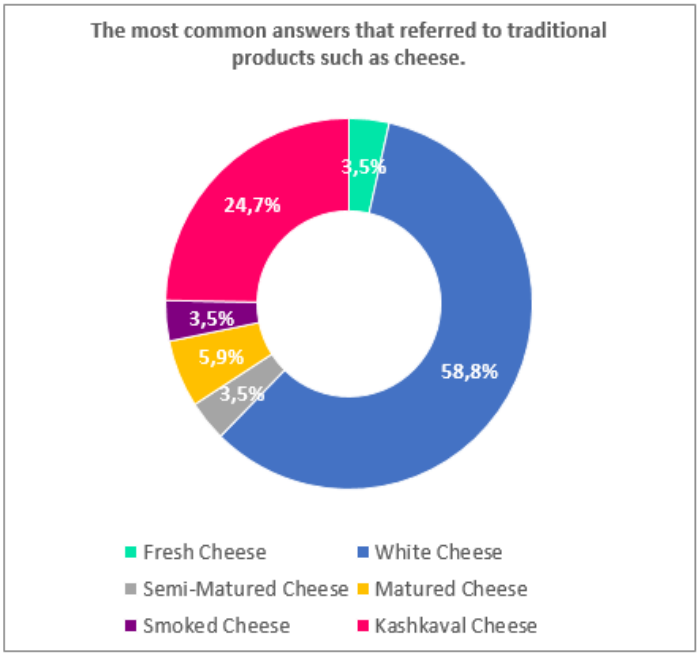

Figure 6.3. The most common answers to cheese.
Source: Author's own.

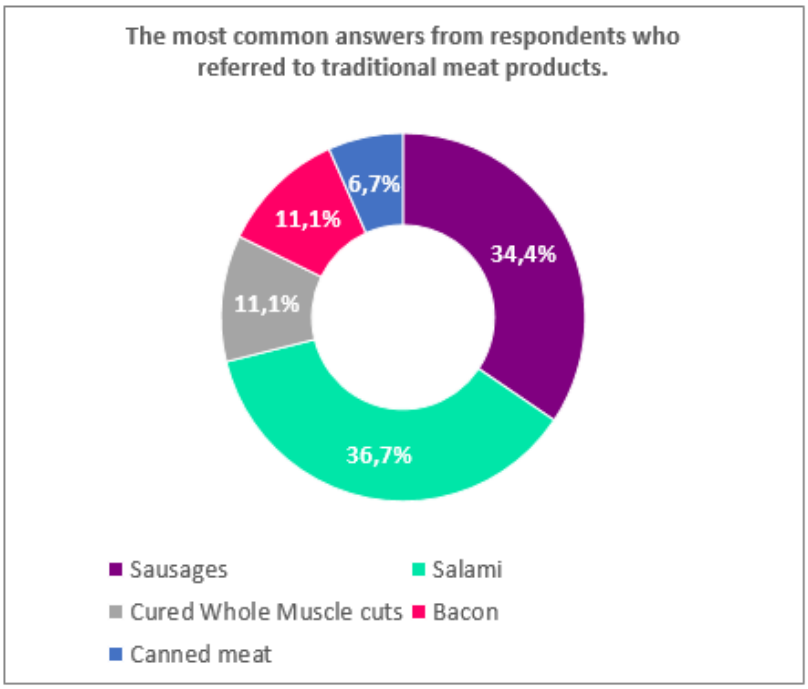

Figure 6.4. The percentage distribution of answers mentioning meat products and their derivatives.
Source: Author's own.

Among the products that were most often mentioned we can list some of these that are part of the PDO category (PGI) such as: Sibiu Salami, Magiun de Topoloveni, Rucăr Cheese, Pleşcoi Sausages, Telemeaua or Smoked Bacon. Cheeses are mentioned quite often (31.1%), and their geography goes far from the researched area and is spread throughout Romania (Figure 6.3). Thus, the respondents gladly mentioned the Ibăneşti, Trascău, Fundata, Horezu, Colţeşti and Mărginimea Sibiului region of cheeses. At the same time, other specific products were mentioned such as: Caşul, Urda, Brânza de Burduf and Caşcaveaua or Caşcavalul de Moeciu.

The most common answers are those that mention sausages and meat dishes (31.8%), they have a wide range of products that respondents remembered (Figure 6.4). Sausages, like cheeses come from

various parts of Romania, so we can meet: Ghiudem-ul tătăresc, Cârnații Ardelenești, Moldovenești, Pleșcoi or Babic de Buzău. It is interesting because a large part of the respondents does not necessarily consider that the traditional product must have a brand behind it, for many, this kind of products are already brands, not of some commercial entities but of the Romanian people.

Among the most popular dishes we can find sarmale; soups - Transylvania, bean or belly to fish brine or bulzul - interpreted by various ways of preparation, such as the variety of Bulzul de Bran or the one with Burduf cheese (Figure 6.5).

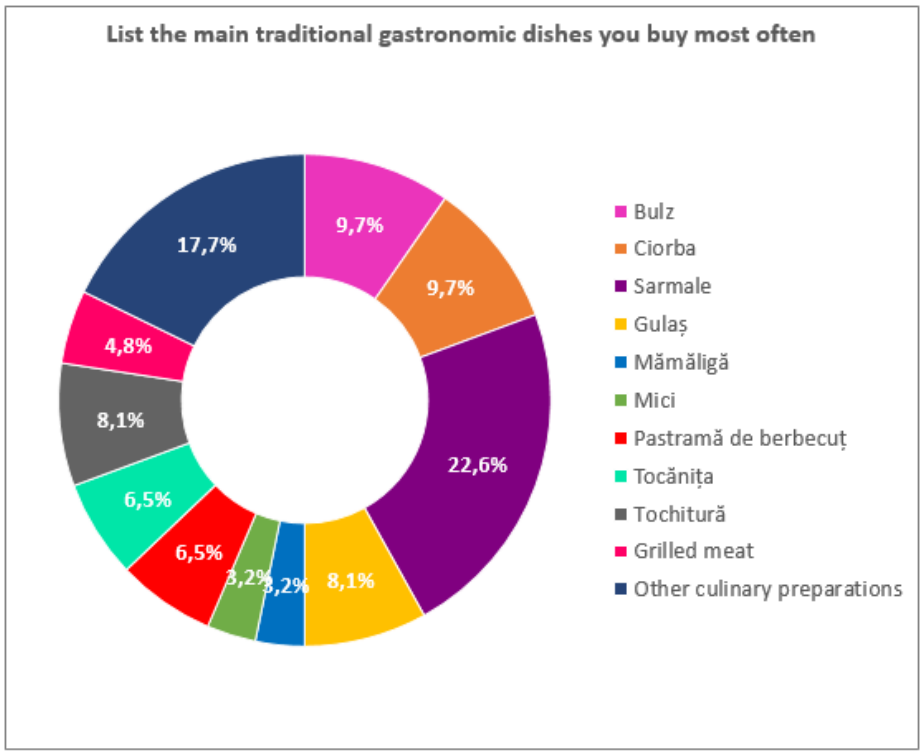

Figure 6.5. Food (preparations) cooked according to the traditional recipes mentioned by the respondents.
Source: Author's own.

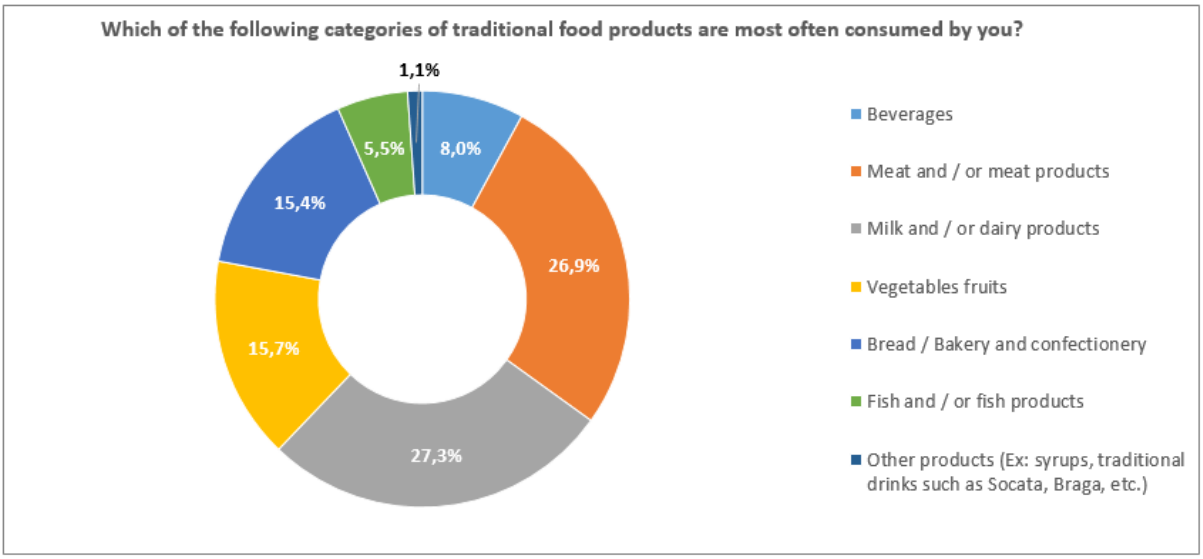

Figure 7. Frequency of consumption of traditional products according to their category.
Source: Author's own.

Respondents were asked to tell us which products are most often consumed by them, so we can see that among the leaders are dairy and meat products (27.3% and 26.9%, respectively). Fruits and

vegetables rank third in the consumption list (15.7%), which indicates that most do not have a high interest in health. More details can be seen in the image below (Figure 7).

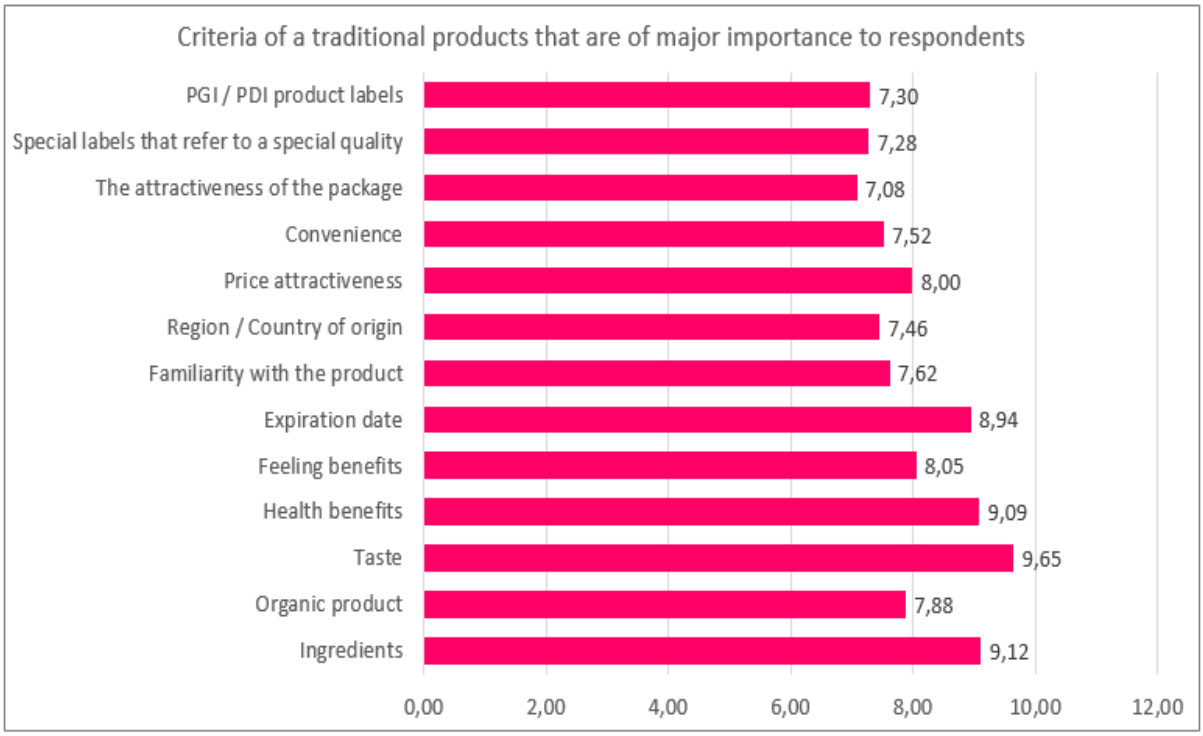

Figure 8. Important criteria for traditional products from the respondents' point of view.
Source: Author's own.

When participants were asked to express their opinion on the quality of public catering services an overwhelming majority (97%) said they were very satisfied or only satisfied with this, with negative responses representing only 3 % (Figure 8).

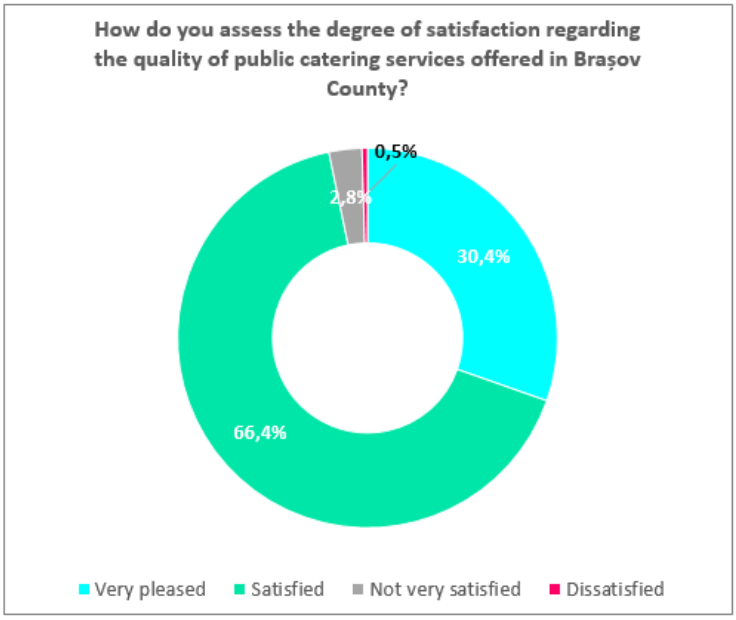

Figure 9. The level of satisfaction regarding the quality of public catering services in Brașov county.
Source: Author's own.

The next question that the people participating in the survey were asked to answer was the quality of the gastronomic events organized in Brașov county, hence the majority were satisfied (66.4%) and the next one related to the level of satisfaction of the respondents regarding the quality of the gastronomic events organized in Brașov county (Figure 9).

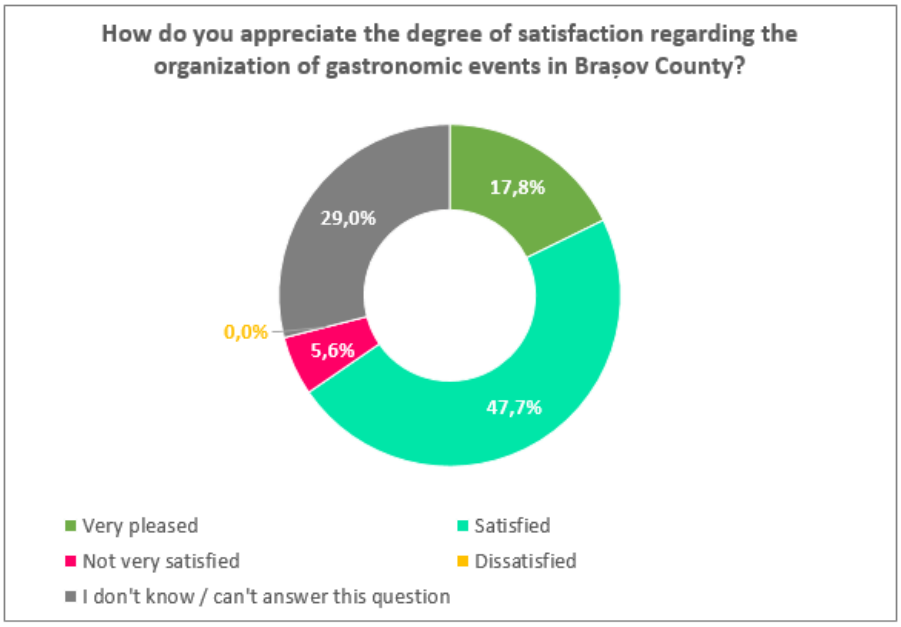

Figure 10. The level of satisfaction of the respondents regarding the quality of the gastronomic events organized in Brașov county.
Source: Author's own.

Most of the respondents are consumers of traditional products from the researched area (Brașov county, implicitly Bran-Rucăr Corridor) and from other parts of Romania. All participants in the survey, regardless of age, seem to be interested in gastronomic tourism (Figure 10) and want to participate in various cultural events aimed at promoting certain elements of local and traditional cuisine. Their interest is motivated not only by the natural or anthropic aspects of the tourist destinations but also by the aspect of the local cuisine and the gastronomic culture of the visited region.

5. CONCLUSIONS

The values of the tourist indicators (accommodation units and tourist flow) during the COVID-19 pandemic period, in 2020 and 2021, express the attractiveness of the beauty of the rural landscape springing from the collective biography of the human-nature relationship.

Judging by the high and diversified number of certified traditional products of the entrepreneurs of the Brașov-Bran-Rucăr-Dragoslavele area in the 10 tourist villages, located in an exceptional natural setting, the daily meals of the tourists can be ensured for the most partor even only from the existing fund of certified traditional products. The situation reached highlights the power of influence of the tradition in the area with healthier lifestyles and the existence of an adequate framework in the development of culinary tourism. Even if some are high altitude villages, advances in information technology, internet, mobile telephony, etc. have been an important way in the development of tourism for this area.

Therefore, the successful rural communities have been able to create the right mix of business for tourism including adequate accommodation and catering facilities. They have also developed quality tourist attractions by organizing special events, with greater impact such as gastronomic festivals (with traditional products, some certified), plus all kinds of outdoor activities thus making tourists to stay longer, return to this area and to promote the area through social channels (Facebook, WhatsApp, etc.) and through live speeches when returning to the places of residence. The tourist attractions of these villages throughout the COVID-19 pandemic, some like Bran, Moieciu, Fundata with priority places in the whole network of villages and with accommodation units and tourist flow of the area, but also throughout

the countryexpress the rediscovery by tourists of the rural world, away from the noise of cities, with accommodation in smaller reception units than hotels.

Compared to the big urban centers as Bucharest, Ploieşti, Târgovişte, Buzău, Brăila, Galaţi, Braşov, Sibiu, the receiving villages in the studied area have an advantage due to their geographical location, being up to about 3-4 hours away driving from big cities, which means that these cities will continue to fuel and resize the flow of tourism.

Future recommendations for this type of research would be the expansion of the study area and the addition of more data in this regard (i.e from questionnaire or interview methods), as well as the combination of several research methods to obtain more exhaustive results. The work also has limitations in that it is limited to only two counties of Romania and only deals with a certain subject from the perspective of agritourism.

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USE OF AI TOOLS DECLARATION

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

AUTHOR CONTRIBUTIONS

All authors contributed equally to this work. All authors read and approved the final manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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Regional Aspects of Water Use and Management in the Republic of Moldova

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ABSTRACT: Water is the most important environmental factor that has a direct influence on the health of the population and the development of society. There is a clear need to establish the supply of the population with sufficient quantities of drinking water as a priority direction in state policy and actions for the health of the population in relation to the environment, in the context of sustainable management of water resources. Although, currently, the national balance of water reserves - water consumption in the Republic of Moldova is adequate in relation to the available resources, in the context of climate aridity and inefficient management of water consumption, this balance may be affected in the future. This research aims to analyze the dynamics and particularities of water resource abstraction and use in regional aspect, highlighting the branch structure and some limiting factors in determining the correct volume of water used. In the period 2003-2022 analyzed in this study, several periods with a maximum volume of water use (years 2007, 2009, 2020 and 2022) were highlighted as a result of droughts that affected the whole country. In all 6 development regions, most of the water used is abstracted from surface sources (85%). At district level, especially in rural localities, water use from underground sources, including wells and springs, predominates as a result of reduced access to public water supply systems. About 75% of the total volume of water used is attributed to technological uses. On the right side of the Dniester River, water is predominantly used for domestic (48%) and agricultural (38%) purposes.

KEYWORDS: Development Region, water use, technological, agriculture, household, Republic of Moldova

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1. INTRODUCTION

At present, the consequences of climate change have already been felt in the Republic of Moldova, being one of the factors that triggered the process of water scarcity in some regions of the country. In addition, a number of non-climatic factors (increased pollution, development of industry and agriculture, etc.) are exacerbating the adverse effects of climate change on water resources, and the development of the national economy is also increasing demand for water. In this context, in order to develop and effectively implement policies and actions for the sustainable use and management of water resources, and to forecast water requirements in relation to available water resources, a comprehensive analysis of the specifics of water abstraction and use is needed. The research hypothesis is the insufficient knowledge of the aspects of water resources use and management, thus making it impossible to rationally exploit and protect them, which made it necessary to carry out this study, which provides a comprehensive scientific foundation of the current problem - water resources use and sustainable management, taking into account regional characteristics.

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In the Republic of Moldova, the most important water resources are surface waters, which are mainly represented by the transboundary rivers Dniester and Prut, which border the country to the west and east, respectively, and groundwater, with inland rivers being of only local importance. Even though the volumes of the main rivers are considerable, their use is limited due to several factors, such as depletion of water resources, long distance from the main rivers, declining water quality, etc (Bacal et al., 2022). On average, 85% of the water abstracted in the Republic of Moldova is from surface sources, this share being largely conditioned by the Cuciurgan Thermal Power Plant in the Transnistrian Development Region (DR), which abstracts more than 550 million m^3 of water from surface sources or 65% of the total volume of water abstracted in Moldova (849 million m^3) (Burduja & Bacal, 2022). However, most localities, especially rural ones, use predominantly groundwater. According to Van der Gun (2021), groundwater resources, at present, are not used sustainably, both due to natural factors and human activities, suggesting that options for restoring sustainability under favourable groundwater governance conditions should be identified. Transnistrian DR uses 85% of the total volume of water used in Moldova, of which more than 80% is for technological needs, which determines the branch structure of water use as a whole.

At the regional level, and in special at the district level, the specificities of water abstraction and use differ according to the natural conditions and the socio-economic situation. In this context, the aim of this research is to identify and analyse regional peculiarities of water resources use and management. The main topics covered in the paper are: 1) general characterization of water resources at regional level; 2) highlighting the sources of water abstraction; 3) analysing the dynamics of water abstraction and use; 4) highlighting the branch structure of water use at regional level; 5) carrying out SWOT analysis of water resources use.

2. LITERATURE REVIEWS

The water use is the aspect of water resources science that is best associated with human activity. The study of water use is essential for understanding human impacts on water resources and for assessing whether available surface and groundwater supplies are and will be adequate to meet future needs (National Research Council of USA, 2004).

The management and use of water resources in the Republic of Moldova is regulated by several legislative and normative acts: the Water Law No. 272 of 23.12.2011, the Law No. 440-XIII of 27 April 1995 on water, rivers and water basins protection strips, the Law No. 272 of 10 February 1999 on drinking water, the Government Decision No. 619 of 16 August 1994 "On the regulation of relations in the field of water management and rational use of water resources in the Republic of Moldova" (Burduja & Bacal, 2022).

There are many papers dealing with water resources in the Republic of Moldova, but most often them deal with water quality or hydrological aspects. A review of research in the field of water resources use and management has revealed that most often only certain aspects of water resources are addressed. In the Republic of Moldova there is already valuable research on: a) environmental protection management by Bacal P. (2010); b) surface water resources - Bejenaru & Melniciuc (2020), Cazac et al., (2010), Boboc & Bejan (2019), Jeleapov & Burduja (2020), and groundwater - Iurciuc (2017). The authors of this paper conducted research on the economic and geographical aspects of water abstraction and use at the level of country (Bacal & Burduja, 2018) , development regions (Burduja & Bacal, 2022; Burduja et al., 2020), as well as river basins (Bacal & Burduja, 2019, 2022). Economic analysis of water resources use is also included in the management plans of the Danube-Prut-Black Sea hydrographic district (Bejan et al., 2017), the Dniester hydrographic basin district (Governmental Decision of the Republic of Moldova no. 814, 2017), including the Prut, Camenca and Botna hydrographic basins (Bejan et al., 2016, 2019, 2020). Despite the existence of many valuable researches, at present, the researches on water resources assessment, use and management are rather fragmented and these aspects have not been studied as a whole, which also required the present study. Most often, only aspects of water quantity and quality are addressed, and water use and management are only superficially investigated.

An important aspect in the efficient valorisation of water resources is good water management. As a science, water management has developed with the complexity of problems related to the development of water users, changing climatic influences on water resources, and the timing and frequency of hydrological

droughts and floods. According to specialists Hâncu & Nițescu (2016), the rational use of water resources includes their integral use and the protection of their quality, thus ensuring the sustainable development of society, they also point out that water management is already becoming a kind of branch of economy. There are numerous works elaborated by Romanian researchers (Băloiu, 1971; Giurma, 2000) that approach water management from both quantitative and qualitative points of view, these studies representing an example, but also a good informational support in the analysis and appreciation of water management in the Republic of Moldova.

A great deal of effort is being made by experts in the field to raise awareness among the general public, decision-makers and the scientific community at large of the importance of a thorough understanding of water use (Caminola et al., 2023), and the factors that determine water consumption (Grespan et al., 2022). Water authorities face the challenge of ensuring that there is enough water to meet demand in the face of droughts, population growth and predictions of reduced supply due to climate change. To develop effective household demand management programmes, water managers need to understand the factors that influence household water use (Jorgensen et al., 2009). Reducing demand by improving water use efficiency requires understanding how water is used and how water savings can be achieved. In terms of water use and economic analysis of water use, in 2018 a group of researchers Aznar-Sánchez et al. (2018) conducted a survey of work in the field of economic analysis of water use, highlighting the evolution of research in this area globally.

In water consumption management an important role is played by water metering through public water supply systems. Access of the population to public water supply systems plays an important role both in knowing how water is used and in protecting water resources, so it is necessary for the population to understand the importance of water consumption monitoring meters. In this context, Madias et al. (2022), assessed and highlighted the extent to which consumers' perceived knowledge of water use influences their intention to adopt smart water meters, which provide very accurate data on the amount of water used in a household, concluding that informing the population has a positive impact on their understanding of the need for water use to be metered. In the Republic of Moldova, papers have already been developed addressing issues of the status and use of public supply systems (Bacal et al., 2022).

3. STUDY AREA

The Republic of Moldova is a landlocked country in Eastern Europe, bordered by Romania to the west and Ukraine to the north, east, and south. The capital city is Chișinău. The country spans a total of 33,483 km^2 and has a population of approximately 2.5 million. According to the Law no. 438 of 28.12.2006 on regional development, Development Region (DR) is the functional territorial unit that represents the framework for planning, evaluation and implementation of regional development policy. The Republic of Moldova comprises 6 development regions: North, Centre, Chișinău municipality, South, ATU Găgăuzia and Transnistria. From here arose the need for this study on the analysis of regional peculiarities of water resources use.

The Northern Region overlaps with the Northern Development Region and comprises 11 districts as well as the Bălți municipality. The Northern DR occupies >30% of the total area of the Republic of Moldova. The present population is 909 thousand inhabitants, including 127 thousand inhabitants - in Bălți municipality (National Bureau of Statistics, 2023). Most of the Northern DR (Dondușeni, Soroca, Drochia, Florești, Sângerei districts and Bălți municipality) lies within the boundaries of the Răut hydrographic basin (HB), while the western districts of the region are located in the Prut HB (Bacal et al., 2022).

The Central Region includes 13 districts that make up the Central DR, as well as the Chișinău municipality. The total area of the Central Region is 11.2 thousand km^2 or 33% of the total area of the Republic, with Chișinău municipality occupying 568 km^2. The population of the Central Region is ≈1.8 million inhabitants or about ½ of the total population of the Republic of Moldova, including 779 thousand in Chișinău municipality (National Bureau of Statistics, 2023). Districts in the central and eastern part of the region lie within the boundaries of the Dniester River basin and its tributaries, including the Răut hydrographic basin - Telenești and Orhei districts, Bâc HB - Călărași, Strășeni and Chișinău municipalities, Botna HB - Ialoveni district. Most of the territory of Ungheni, Nisporeni and Hâncești districts lies within the boundaries of Prut HB. And the eastern part of Hâncești rayon lies in the Cogâlnic river basin, which flows into the Black Sea.

The Southern Region of the Republic of Moldova covers an area of 9.2 thousand km^2, including the Southern DR - 7.4 thousand km^2 (22%) and the ATU Găgăuzia - 1.8 thousand km^2 (5.5%). The population of the Southern Region is 643 thousand inhabitants (21%), including the Southern DR - 494 thousand (17%) and ATU Găgăuzia - 150 thousand (4.8%) (National Bureau of Statistics, 2023). The Southern Region is part of the Danube-Black Sea Hydrographic Space, including the basins of the Ialpug (ATU Găgăuzia, Cantemir and Cahul districts), Cogâlnic (Cimişlia, Basarabeasca and Cauşeni districts), Sărata and Hadjider rivers (Căuşeni and Ştefan-Vodă districts). In the Dniester basin are the localities of the Ştefan-Vodă district situated in the Dniester River meadow, as well as most of the localities of the Căuşeni district situated in the basin of the Botna river, a tributary of the Dniester. In the Prut River basin is located the localities of the Leova district, as well as the localities of the Cantemir and Cahul districts located in the river basin.

The Transnistrian DR includes the districts of Râbniţa, Dubăsari, Grigoriopol and Slobozia, as well as the Tiraspol municipality. The unrecognised authorities of the breakaway region also control territories on the right side of the Dniester, including the Tighina municipality (Bender) and 6 communes in its vicinity. Therefore, the actual area of the Transnistrian DR is 4.2 thousand km^2 and the population 465 thousand. Thus, the share of the Transnistrian DR in the area and population of the Republic of Moldova is only 12% (Burduja & Bacal, 2022).

4. RESEARCH METHODS AND DATA

The scientific study's starting point was the analysis of existing studies related to the proposed research topic, thus placing this work at the interface of several scientific directions, which determined its complexity and importance. In general, the most commonly used methods were: statistical (for the assessment of water resources, accumulation and processing of statistical data on water abstraction and use, analysis of water supply systems and non-centralised water supply sources); comparative (for highlighting the peculiarities of water resources distribution, spatial and branch analysis of the volume of water abstracted and used); analytical (for the assessment of water resources and water abstraction and use systems, establishment of cause-effect relationships).

SWOT analysis method was applied to identify and discuss problems and opportunities related to water resources use and management. This method also allowed a comprehensive analysis of the current situation of water resources use and management, defining problems requiring the involvement of responsible institutions in the implementation of policies to improve the situation in this field.

The cartographic method is one of the basic methods in geographic research and is used in this study to spatially represent the weight of water abstraction sources and water use categories using ArcMap software.

Primary data can be used to determine water use through direct measurements, but due to the complexity and large study area secondary data was used. The acquisition of secondary data involves evaluation of the compilation and analysis of measured or estimated data submitted by water users to state agencies. In the present study, secondary data on water use was used, which is mirrored in the annual statistical reports obtained from the relevant authorities in the given area. The generalisation of these statistical data allowed a comprehensive analysis of several indicators directly related to water use and their dynamic management in order to highlight trends and evolution of these indicators. The period 2003-2022 was selected for the study, this being justified by the fact that in 2003 the Republic of Moldova returned to the Soviet system of administrative division into districts (32 districts, 13 municipalities and two recognized autonomous territorial units: ATU Găgăuzia and Transnistrian DR).

The information base included a series of statistical data from 2003 to 2022, which were selected, systematised and thoroughly processed from the annual reports on water management indices. The main data sources were: 1) Annual Reports of the Water Agency of Moldova (2003-2022); 2) Annual Reports of the Environmental Agencies and Inspectorates (2018-2021); 3) Reports of the National Bureau of Statistics (2022, 2023); 4) Reports of the State Hydrometeorological Service (SHS) (1977-2022).

5. RESULT AND DISCUTIONS

5.1. Water resources

Surface water resources. The hydrographic network of the Republic of Moldova consists of 4 drainage basins (Figure 1): the Dniester River, which accounts for 57% of the surface area; the Prut River, with about 24%; and the basins of the rivers flowing into the Danube and Black Sea, with 19%. The analysis of the water runoff balance on the territory of the Republic of Moldova during the period 1977-2022, showed a decreasing trend in the volume of runoff. The years 2011 to 2022 are classified as dry years. Since 2011, the volume of runoff on the territory of the Republic of Moldova has not been within the multi-year norm (State Hydrometeorological Service, 2019). All these years had runoff volume less than 2-3 km^3, and in 2016 the hydrological drought reached a record; the runoff volume was equal to 6.86 km^3 of water, which is almost half of the multi-year norm of 11.87 km^3; 2022 was an also a dry year, the runoff volume was only 7.32 km^3. Although, according to the available data (years 1977-2022) of the State Meteorological Service, the lowest volume of runoff was recorded in 2016, while the lowest amount of precipitation was recorded in 1990 and 2022 (13.0 km^2).

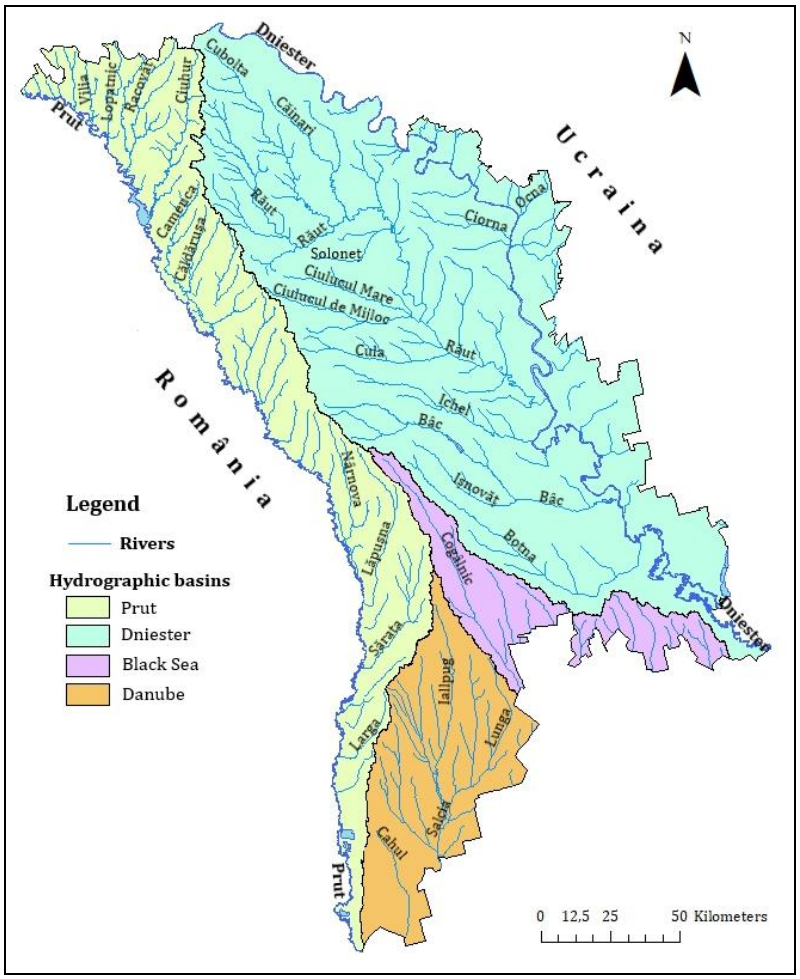


Figure 1. Hydrographic basins and main rivers of the Republic of Moldova.

The main surface water resources of the Northern DR are the Prut and Dniester rivers, which represent the eastern and western borders of the region. Within the boundaries of this region, the length of the Dniester River is 194 km and the basin area is 6,087 km^2, and the length of the Prut River is 232 km and the basin area is 3,964 km^2 (Jeleapov & Burduja, 2020). 36 rivers flow through the Northern DR. The Central DR has 57 watercourses stretching over a length of 1,955 km. The most significant surface water resources are available in the districts bordering the Dniester and Prut rivers. The river network of the Southern DR includes the Prut River basin, sectors of the Ialpug and Dniester rivers and the basins of the smaller Cogâlnic, Botna, Salcia, Cahul, Sărata and Hadjider rivers. Surface resources in the ATU Găgăuzia are limited, and most of the territory is in the Ialpug river basin (Figure 1).

At present, according to data from the Inspectorate for Environmental Protection (2021), there are 4,275 natural lakes and artificial basins in the Republic of Moldova with an area of about 43.1 thousand ha,

located and built on their courses and beds. About 57% or 2437 of the lakes are located in the Northern DR. More than ½ (52%) are allocated for fish farming, 1,660 lakes or 39% are allocated for general use. Only 6% are allocated for irrigation and only 139 lakes for recreation.

Groundwater resources. The renewable groundwater reserves of the Republic of Moldova are estimated at 3.478 million m^3/day. According to the State Balance of Reserves on 01.01.2020, the total number of approved natural mineral water reservoirs on the territory of the Republic of Moldova is 68 reservoirs (Bejan et al., 2017). The Northern Region has groundwater resources from 4 aquifer horizons, but the region's water supply is from the Badenian-Sarmatian Aquifer Complex and the Alluvial-Deluvial Aquifer Horizon. Exploitable groundwater reserves in the Northern DR represent only 17% of the total exploited groundwater reserves in the Republic. Most reserves are in Bălți municipality (89.3 thousand m^3/day) and in Râșcani (33.6 thousand m^3/day) and Fălești (28.1 thousand m^3/day) districts. The localities of the Central DR are also supplied with water mainly from the Badenian-Sarmatian aquifer complex and the Alluvial-Deluvial aquifer horizon. The Central Region has about 2/3 of the total groundwater reserves exploited in the country. The richest groundwater reserves are located in the districts bordering the Dniester River (Anenii Noi - 346.7 thousand m^3/day, Criuleni - 219.5 thousand m^3/day and Dubăsari - 200.2 thousand m^3/day). In the Southern Region groundwater supply is predominantly from the Alluvial-Deluvial aquifer and the Badenian-Sarmatian aquifer complex, but the available reserves are much lower - only 14.5% of the total of the Republic. The most important groundwater reserves are in Căușeni (57.9 thousand m^3/day) and Ștefan Vodă (51.6 thousand m^3/day) districts. On the territory of the Transnistrian DR are registered 76 underground water deposits from 4 aquifers (Burduja & Bacal, 2022).

5.2. Regional particularities of water resources abstraction

5.2.1. Water pumping stations and boreholes

Water pumping stations are a set of constructions, installations and machinery, which are used to bring water up to the required level of use. According to the National Bureau of Statistics, there are 1750 water pumping stations in the Republic of Moldova, including 1125 stations (64%) in rural areas and 615 stations (36%) in urban areas (Burduja & Bacal, 2022).

In Northern DR water is supplied by 350 pumping stations, of which about 230 stations (≈2/3 of the total number) are located in rural areas. Most stations are operated in the larger districts of the region, with a higher access of the population to public aqueducts, especially in rural areas, including Sângerei (67), Fălești (40), Râșcani (36) and Florești (32) districts. However, only about ¼ of the design capacity of these stations is used, which is explained by the advanced degree of wear and deterioration, and the significant reduction of water consumption in agriculture and industry.

In the Central Region there are about 850 water pumping stations or ≈50% of the total number in the Republic. There are about 650 water pumping stations in the districts of the Central DR, which is 37% of the total number in the Republic of Moldova (excluding the Transnistrian DR). The maximum number of pumping stations is found in the districts with the richest surface and groundwater resources, including Orhei (124), Telenești (87), Anenii Noi (86) and Criuleni (56).

In the Southern Region there are 562 (32%) water pumping stations, including 422 stations in the Southern DR and 140 stations in the ATU Găgăuzia. In rural areas ≈70% of the total number of water pumping stations in the region are located, including ≈80% in the Southern DR and 50% in ATU Găgăuzia. Most pumping stations are in districts with the maximum number of localities connected to public aqueducts, including Căușeni (91), Cimișlia (82). Cahul (80) and Ștefan Vodă (60).

Boreholes. According to data from the Inspectorate for Environmental Protection, there are 4970 boreholes on the territory of the Republic, of which only 53% are exploited. About 40-50% of the remaining boreholes are abandoned and remain without legal ownership. Most non-operated boreholes are located in the Northern DR, where they constitute 62% of the total number (1381) of boreholes in the Republic of Moldova (excluding the Transnistrian DR). In the Northern DR, most boreholes are located in the districts of Sângerei (183) and Râșcani (178). In the districts of Ocnița, Dondușeni, Drochia and Soroca, the share of non-operated boreholes exceeding 70% of the total number. The presence of a large number of non-operational boreholes indicate not only the inadequate quality of water resources, which prevents their use, but also the fact that their location was not correctly determined in time, depending on

several criteria. In the Central Region there are 2,166 boreholes, of which 1,693 are located in the districts of the region. About 62% of the total number are exploited. In the Southern Region, 1,423 boreholes were monitored in 2020, of which only 53% are exploited. Most boreholes are located in the ATU Găgăuzia (327) and the district of Căușeni (234). The Southern Region of the country is noted for the presence of the most exploited boreholes for domestic and curative purposes.

5.2.2. Wells and springs

Wells are extremely important to all societies. In many places wells provide a reliable and ample supply of water for home uses, irrigation, and industries. Where surface water is scarce, such as in deserts, people couldn't survive and thrive without groundwater, and people use wells to get at underground water (U.S. Geological Survey, 2018). In the Republic of Moldova, in 2018, more than 176 thousand wells were monitored by the Inspectorate for Environmental Protection. In the Northern DR there are about 107 thousand wells or 61% of the total number, of which most are concentrated in Edineț (15,898), Briceni (14,587) and Drochia (12,879) districts. In the Central Region there are 50.3 thousand wells or 28% of the total number of wells in the Republic. Most wells are located in Strășeni (6,911), Ungheni (6,112) and Orhei (5,485) districts. 18.7 thousand wells are located in the Southern Region, most of them in Leova (3,975), Căușeni (6,112) and ATU Găgăuzia (3,176) districts. In general, about 85% of the total number of wells are installed, but the situation by regions is different, in the Southern Region it is only 49%. Although the majority of wells and springs are arranged, they often do not meet sanitary and ecological standards. Official data are also influenced by the work of the environmental and health authorities in recording and monitoring springs and wells (Burduja & Bacal, 2022).

In the Republic of Moldova, 2,966 springs were monitored in 2018, 41.5% and 39% respectively were located in the Central and Northern Region, and only 234 springs in the Southern Region due to limited groundwater reserves in this region.

5.2.3. Volume of water abstracted in regional profile

The volume of water abstracted and used is conditioned by the water demand, the water resources available from surface and groundwater sources, and the technical and economic capacities for water abstraction, transport, treatment and use for various socio-economic activities (Bacal & Burduja, 2022). According to the data of the Water Agency of Moldova, in the analyzed period (2003-2022), the total volume of abstracted water was, on average, 849 million m^3, including 719 million m^3 (85%) - from surface sources and 130 million m^3 (15%) - from groundwater (Table 1, Figure 3).

Table 1. Volume and share of water abstraction by source and region.

TAU	**Average of years 2003-2022**							**2022**						
	total			**from surface**		**underground**		**total**			**from surface**		**underground**	
	million m^3	%		million m^3	%	million m^3	%	million m^3	%		million m^3	%	million m^3	%
North DR	**34,3**	**4.0[1]**	**21[2]**	**14,8**	**43[3]**	**19,5**	**57**	**36**	**4.3**	**23**	**18,7**	**52**	**17,2**	**48**
Soroca	10,2	1.2	6.4	9,0	88	1,2	12	15,3	1.8	10	14,4	94	0,9	5.9
Central DR	27,1	3.2	17	8,8	32	18,2	68	35,2	4.2	5	15	43	20,2	57
Chișinău	79,4	9.4	50	74,7	94	4,7	5.9	68,6	8.1	43	65,5	95	3,1	4.5
Central R.	107	12,5	67	83,6	78	23	22	104	12	65	80,5	77	23,3	22
Southern DR	15,4	1.8	9.6	6,5	42	8,8	57	15,7	1.9	10	6,3	40	9,4	60
Găgăuzia	3,7	0.4	2.3	0,4	10	3,3	89	4,1	0.5	3	0	0	4,1	100
Southern R	19,1	2.2	12	6,9	36	12,2	64	19,8	2.3	12	6,3	32	13,5	68
Dniester river right side	**160**	**19**	**100**	**105**	**66**	**54,7**	**34**	**160**	**19**	**100**	**106**	**66**	**54**	**34**
Transnistrian DR	**689**	**81**	**100**	**614**	**89**	**75,2**	**11**	**685**	**81**	**100**	**610**	**89**	**75,1**	**11**

[1] Share (%) of total volume of water abstracted in the Republic of Moldova, including Transnistrian DR

[2] Share of regions and municipalities in the total volume of water abstracted on the left and right sides of the Dniester river

[3] Share of surface sources in the total volume of water abstracted in the respective regions and municipalities.

Dnestrovsc	555	65,4	81	553	99,6	1,8	0.3	555	66	81	553	99,6	1,9	0,3
Tiraspol	26,7	3.1	3.9	1,3	4.9	25,4	95	26,7	3,2	3.9	1,3	4.9	25,4	95
Bender	24,1	2.8	3.5	0,45	1.9	23,7	98	24,1	2,9	3.5	0,49	2.0	23,6	98
Râbnița	14,6	1.7	2.1	7,7	53	6,9	47	10,7	1,3	1.6	3,8	36	6,9	64
Total RM	**849**	100		**719**	**85**	**130**	**15**	**845**	**100**		**716**	**85**	**129**	**15**

Source: Elaborated by the author according to data from the Annual Reports of the Water Agency of Moldova

More than 80% (689 million m³) of the total volume of water abstracted in the Republic comes from enterprises in the Transnistrian Development Region, including the Tighina municipality. The maximum volume of water in the Transnistrian DR is abstracted at the Dnestrovsc Thermo-Electric Power Station (555 million m³ or 81%), as well as in the cities of Tiraspol (26.7 million m³), Bender (24.1 million m³) and Râbnița (14.6 million m³). In the Transnistrian DR, from surface sources, are abstracted 614 million m3 of water or 90% of the total volume of water abstracted in this region, including 553 mil. m³ of water abstracted from the Dniester Liman for technology processes (water cooling) at the Dnestrovsc. Also, in the Transnistrian DR, on average 75.2 million m³ of water or 58% of the volume of water abstracted from groundwater sources in the Republic of Moldova is abstracted from underground sources (Table 1) and only 11% of the total volume of water abstracted in the region.

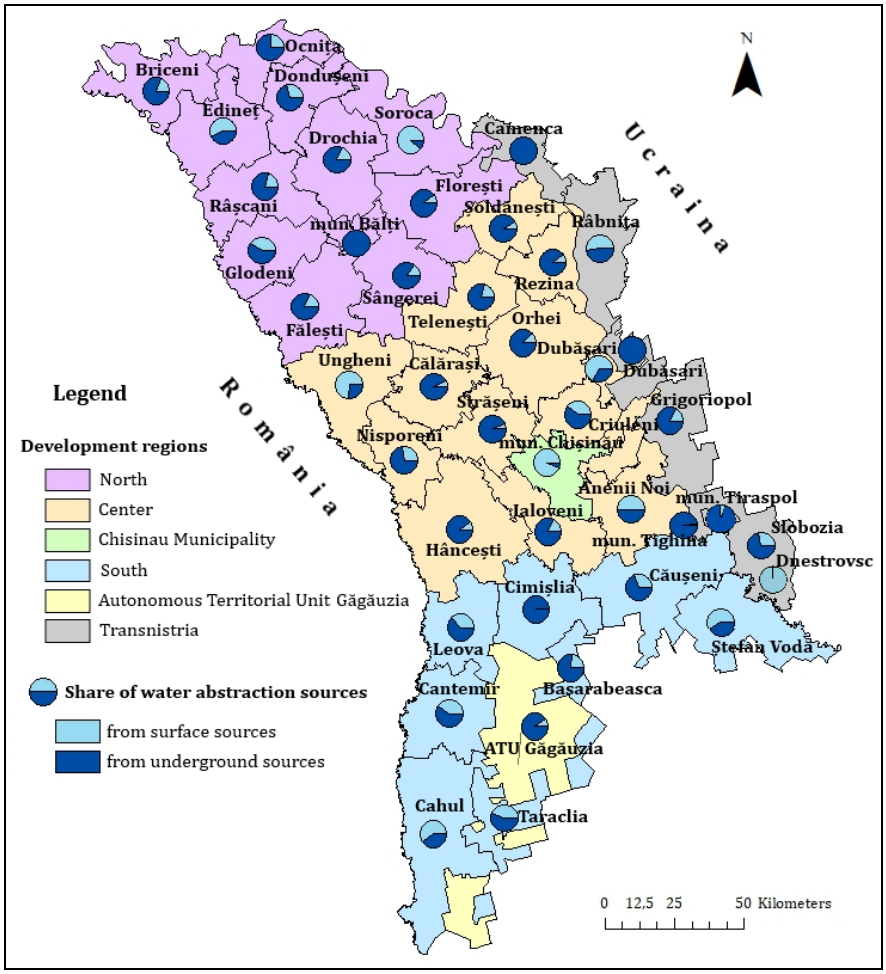
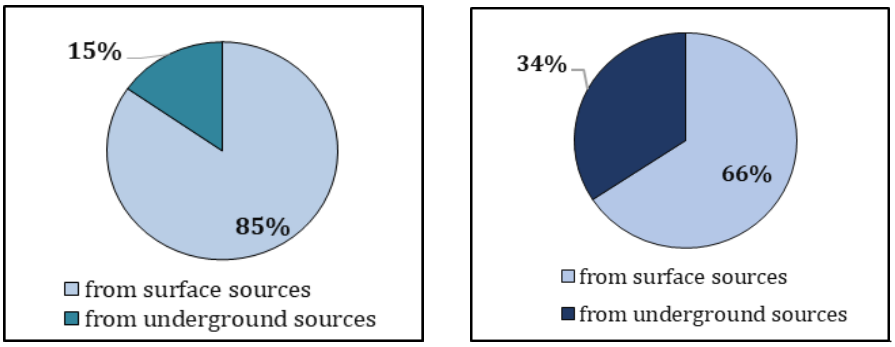


Figure 2. Share of water abstraction sources in the Republic of Moldova, average of years 2003-2022.
Source: Elaborated by the author according to data from the Annual Reports of the Water Agency of Moldova.

On the right side of the Dniester River, an average of 160 million m³ were captured, including in the Chișinău municipality - 79.4 million m³ (50%), in the Northern DR - 34.3 million m³ (21%), in the Central DR - 27.1 million m³ (17%), in the Southern Region - 19.1 million m³ (17%) and in the Southern Region - 19.1 million m³ (20%), of which in the Southern DR districts - 15.4 mil. m³ (10%) and in ATU Găgăuzia - 3.7 mil. m³ (2.3%). 105 mil. m³ or ≈ 2/3 of the total volume was captured from surface sources on average. At the

same time, more than 70% (74.7 mil. m3) of water from surface sources in the right side of the Dniester River was captured at the Vadul lui Vodă station in Chișinău municipality, 14.8 (14%) in the Northern DR, 8.8 mil. m³ in the Central DR (8%) and 6.9 mil. m3 (6%) in the Southern Region. On average, 54.7 million m³ or more than 1/3 (34%) of the total volume of water abstracted in the right side of the Dniester River was abstracted from underground sources. Underground sources predominate in the Central DR with more than 2/3 (67%) of the total volume of water abstracted and in the Southern Region with 64%, including in the Southern DR with 57% and in ATU Găgăuzia with 89% of the total volume of water abstracted.



(a) **(b)**

Figure 3. Share of water abstraction sources in the Republic of Moldova total (**a**) and without Transnistrian DR (**b**).

Source: Elaborated by the author according to data from the Annual Reports of the Water Agency of Moldova.

In the Northern DR, an average of 34.3 million m³ was abstracted, which represents 4% of the total volume of water abstracted in the Republic and 21% on the right side of the Dniester River, of which about 14.6 million m³is abstracted from surface sources. The predominant share (87%) of surface sources in the Soroca district is largely due to water pumping stations operated by ÎS Acva Nord in the city of Soroca. An average of 19.5 million m³ or 57% of the total volume of water abstracted in the region was abstracted from underground sources. Underground sources predominate by far in the Bălți municipality and in 9 of the 11 districts of the region, and the maximum share (≥80%) is found in the Bălți municipality (≈100%), as well as in the districts of Drochia, Florești and Fălești (Figure 2).

In the Central DR, an average of 27.1 million m³ was abstracted, which is 3% of the total volume of water abstracted in the Republic and 17% on the right side of the Dniester River. Maximum volumes of water were also abstracted in districts with direct access to the Dniester and Prut rivers, including Anenii Noi (4.2 million m³), Orhei (3.9 million m³) and Ungheni (3.2 million m³). An average of 8.8 million m³ or 32% of the total volume of water abstracted in the region was abstracted from surface sources. Surface sources predominate only in the riparian districts. From underground sources 68% of the total volume of water abstracted in the region was abstracted.

In the Chișinău municipality, an average of 79.4 million m³ were abstracted, which represents 9.4% of the total volume of water abstracted in the Republic and 50% in the right side of the Dniester River. From surface sources, an average of 74.7 million m³ or 71% of the surface water abstracted on the right side of the Dniester River was abstracted and 94% of the total volume of water abstracted.

In the years 1990-2002, as a result of the deep social and economic crisis, which affected in particular agricultural and industrial enterprises, there was a more than fourfold reduction in the total volume of water abstracted, or from about 4 billion m³ to about 900 million m³, including the volume of water abstracted from surface sources - 4.4 times (from 3.6 billion m3 to about 730 million m³). Due to the significant decrease in state control in the field of natural resource use and protection, the record of the volume of water abstracted and used, especially in agriculture and mining is of a formal nature. In addition, a large part of the rural population, especially in the Northern DR, is supplied from wells and springs and the water used is not subject to recording and treatment (Burduja & Bacal, 2022).

In the period 2003-2022, the total volume of abstracted water has an oscillating evolution (Figure 4), marked both by the economic evolution and meteo-climatic peculiarities, as well as by the evolution of data from the Transnistrian DR. At the same time, the data of the Moldovan Water Agency for the cities of the region are almost identical throughout the period analyzed, except for the the Râbnița city. This would

not correspond to reality, if we take into account the reduction in the volume of industrial and agricultural production and the number of population. At the same time, according to data from the Tiraspol Statistical Service, the total volume of water abstracted after 2010 is much higher than indicated in the reports of the Water Agency of Moldova, including 958 million m³ in 2010, 861 million m³ in 2015 and 923 million m³ in 2019. In this context, it is necessary for the Chișinău and Tiraspol authorities responsible for water resources management to develop a common platform of the Water Information System, coordination and implementation of measures for sustainable development and protection of water resources (Burduja & Bacal, 2022).

The negative trend is due to the reduction in the volume of water abstracted in the Southern DR (1.3 times). At the same time, the volume of water abstracted in the Central DR increased by 34%, due to the faster expansion of rural public aqueducts and the partial restoration of irrigation systems in the districts bordering the Dniester River. A multiple reduction in the volume of water abstracted was observed in the Bălti municipality (due to the connection to the Soroca-Bălți aqueduct in 2006), as well as in the Căușeni (-60%) and Edineț (2.0 times) districts.

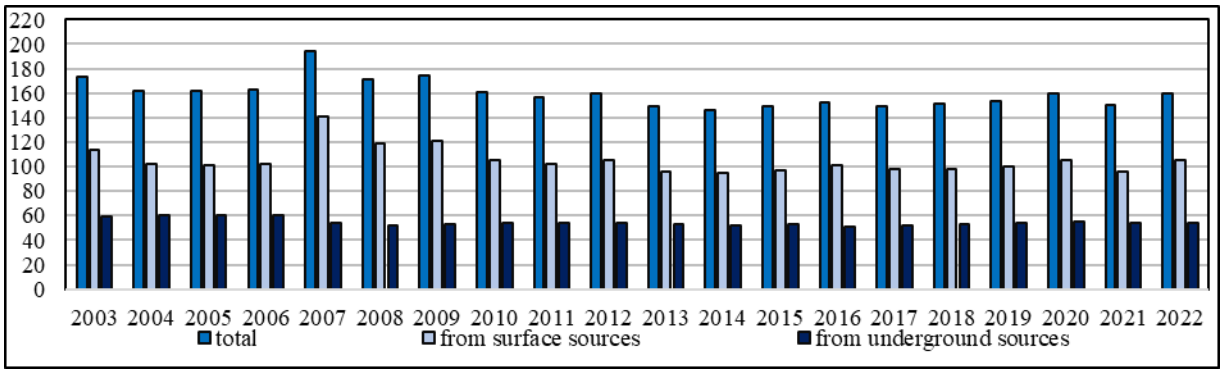


Figure 4. Dynamics of water abstraction volume in total and by abstraction source in the Republic of Moldova (without Transnistrian DR), in million m³.

Source: Elaborated by the author according to data from the Annual Reports of the Water Agency of Moldova.

The dynamics of the volume of water abstracted from surface sources is similar to that of the total volume of water abstracted, with a general downward trend of 7%, which is due to the Chișinău municipality (by ≈1.2 times or by ≈15.1 million m³) and the Southern Region (by 2 times or by 6.2 million m³). At the same time, the significant increase in the volume of water abstracted from surface sources is recorded in the Northern DR (by 1.8 times) and the Central DR (by 1.5 times), which is due, as mentioned, to the increase in the volume of water abstracted by the Northern Acva State , the increase in water abstraction and distribution capacities at large export-oriented agricultural enterprises, as well as the restoration of irrigation systems in the districts bordering the Dniester river in the Central RD, due to the exploitation of the opportunities offered by the "Compact" Programme for the rehabilitation of irrigated land.

In 2022, 845 million m³ of water were abstracted, including 686 million m³ in the Transnistrian DR. 160 million m³ were abstracted on the right side of the Dniester River, of which 68.6 million m³ (43%) in the Chișinău municipality, 36 million m³ (22%) in the Northern DR, 35.2 million m³ (22%) in the Central DR, 15.7 million m³ (10%) in the Southern DR and 4.0 million m³ in ATU Găgăuzia (2.5%). From surface sources, 715 million m³ or 85% of the total volume was captured. The share of surface sources in the total volume of water abstracted from surface sources in the year 2022 has higher values compared to the average of the analyzed period, due to the increase in the volume of water used for irrigation. In the Southern DR, the share of surface sources is 3% lower than the period average. 130 million m³ or only 15% of the total volume was abstracted from underground sources.

5.3. Regional and branch peculiarities of water resources use

During the period under review, the total volume of water used in the Republic of Moldova averaged 785 million m³, of which 670 million m³ (85%) in the Transnistrian DR. Similar to the volume of abstracted

water, the maximum volume of water used in the Transnistrian DR is in the city of Dnestrovsc (555 million m³), of which 99.5% is used at the Dnestrovsc Thermo-Electric Power Station for technological cooling processes, as well as in the cities of Tiraspol and Bender (about 22 million m³ each), Râbnița (13.4 million m³).

On the right side of the Dniester River, an average of 116 million m3 were used, including 50.2 million m³ (43%) in the Chișinău municipality, 25.1 million m³ (22%) in the Central Region, 24.2 million m³ (21%) in the Northern Region, and 16.1 million m³ (14%) in the Southern Region (Table 2).

Table 2. Volume and share of water use by regions and use categories (average years 2003-2022).

TAU	Total			Household		Technological		Agriculture					
								Total		Regular irrigation		Other	
	million m³	%	%	million m³	%	million m³	%	million m³	%	million m³	%	million m³	%
Northen DR	24,2	3.1	21	6,7	27	3,3	14	14,2	59	3,9	16	10,2	42
Soroca	5,1	0.6	4.4	3,4	67	1,5	29	0,17	3.3	0,007	0	0,16	3
Central DR	25,1	3.2	22	4,8	19	1,3	5.2	18,4	75	5,8	23	12,9	51
Chișinău	50,2	6.4	43	41	82	8,5	17	0,56	1.1	0,2	0	0,33	1
Central R.	75,3	9.6	65	46	61	9,7	13	18,9	25	6	8.0	13,2	18
Southern DR	13,6	1.7	12	2,8	21	0,7	5.1	9,9	73	3,3	24	6,6	49
Găgăuzia	2,6	0.3	2	0,9	35	0,12	4.6	1,4	53	0,2	7.7	1,1	42
Southern R	16,1	2.1	14	3,8	24	0,8	4.8	11,3	70	3,5	22	7,7	48
Dniester river right side	**116**	**14.7**	**100**	**56**	**48**	**13,8**	**12**	**44,4**	**38**	**13,5**	**12**	**31,2**	**27**
Transnistrian DR	**670**	**85.3**	**100**	**60**	**9,0**	**568**	**85**	**39,6**	**5.9**	**32,8**	**4.9**	**6,8**	**1**
Dnestrovsc	555	70.7	83	2,7	0.5	553	100	0	0	0	0	0	0
Tiraspol	22,1	2.8	3.3	18,6	84	3,5	16	0	0	0	0	0	0
Bender	21,6	2.8	3.2	19,9	92	1,7	7.9	0,04	0	0,04	0	0	0
Râbnița	13,4	1.7	2.0	10,7	80	2,9	22	0	0	0	0	0	0
Total RM	**785**	100		**116**	15	**582**	74	**84**	**11**	**46**	5.9	**37,9**	4.8

Source: Elaborated by the author according to data from the Annual Reports of the Water Agency of Moldova.

On average, 24.2 million m³ were used in the Northern DR, which represents 3.1% of the total volume of water abstracted in the Republic of Moldova and 21% in the right side of the Dniester River (Table 2). The maximum volume of water was used in the larger districts, namely in Edineț (2.4 million m³), Soroca (2.4 million m³ of water), Briceni and Florești (2.1 million m³ each). An average volume of water is also used in Drochia and Râșcani districts (1.9 million m³ each), which have more extensive functional aqueducts and higher water consumption. The minimum volume is recorded in smaller districts, including Dondușeni (928 thousand m³), Glodeni and Ocnița (1.2 million m³ each).

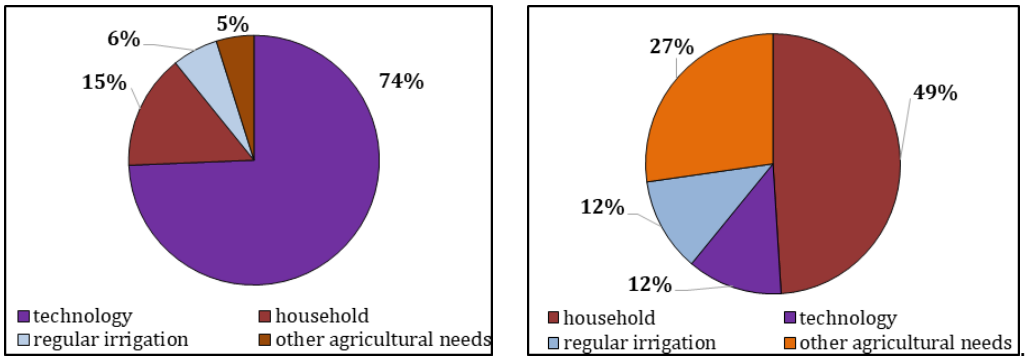
In the Central DR, an average of 25.1 million m³ or 3.2% of the total volume of water used in the Republic was used and 17% in the right side of the Dniester River. Maximum volumes of water were used in Anenii Noi (3.8 million m³), Orhei (3.4 million m³) and Ungheni (2.7 million m³) districts. An average volume of water is used in Ialoveni (2.3 million m³) and Criuleni (2.2 million m³) districts. The minimum volume of water used is also recorded in districts with smaller size, smaller urban and industrial centres and lower irrigation capacities, including in the Șoldănești (832 thousand m³), Nisporeni (1 million m³), Rezina and Călărași (1.1 million m³ each) districts.

In the Chișinău municipality an average of 50.2 million m³ was used, which represents only 6.4% of the total volume of water used in the Republic of Moldova and 43% of the water used on the right side of the Dniester River, and in the Bălți municipality - 5.1 million m³ (5%).

In the Southern Region an average of 16.2 million m³ of water was used, or 14% of the total volume of water used in the right side of the Dniester River (table 2), including in the districts of Southern DR - 13.6 million m³ (12%) and in ATU Găgăuzia - 2.6 million m³ (2%). The maximum volume of water used is recorded in the districts with direct access to the Dniester and Prut rivers, including Cahul (3.1 million m³), Ștefan Vodă (2.5 million m³) and Căușeni (2.4 million m³) and in ATU Găgăuzia with a higher

level of urbanisation and access to public aqueducts. The minimum volume was used in Basarabeasca (761 thousand m^3), Leova (1.1 million m^3) and Cantemir (1.2 million m^3) districts.

If we also take into consideration the official data available from the Transnistrian DR, then ≈¾ (582 million m^3) of the total volume of water used in the Republic of Moldova is used for technological (industrial) purposes. About 15% or 116 million m^3 is used for domestic purposes, and only 11% or 84 million m^3 is used in agriculture, of which 46.1 million m^3 (6%) for irrigation (Figure 5.a). In the Transnistrian DR, an average of 568 million m^3 or 85% of the total volume is used for technological purposes, 60 million m^3 (9%) for domestic purposes and 39.6 million m^3 (6%) for agricultural purposes, including 32.8 million m^3 (5%) for irrigation.



(a) **(b)**

Figure 5. Share of water use categories in the Republic of Moldova total (**a**) and without Transnistrian DR (**b**).
Source: Elaborated by the author according to data from the Annual Reports of the Water Agency of Moldova.

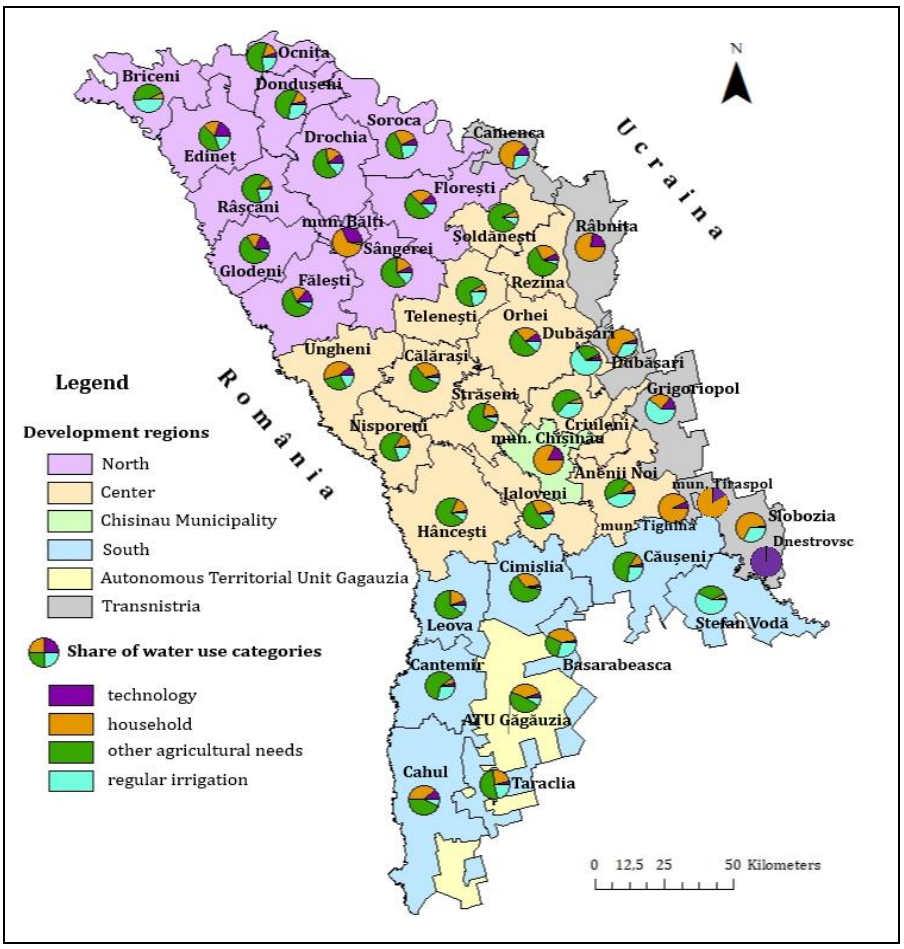


Figure 6. Share of water use categories in the Republic of Moldova, average of 2003 - 2022 years.
Source: Elaborated by the author according to data from the Annual Reports of the Water Agency of Moldova.

Excluding the Transnistrian DR, approximately ≈1/2 (56 million m^3) of the total volume of water was used for domestic purposes (Figure 5.b). This is conditioned by Chişinău, where 41 million m^3 of water or about 73% of the total volume of water used for domestic purposes in the right side of the Dniester River was used for domestic purposes. In agriculture, an average of 44.4 million m^3 of water or 38% of the total volume was used, including 13.5 million m^3 (12%) for irrigation and 13.8 million m^3 (12%) for industrial purposes. At the same time, in most of the districts on the right side of the Dniester River more than ¾ of the total volume was used for agricultural purposes.

In the Chişinău municipality (Figure 6), more than 80% was used for domestic purposes, 17% (8.5 million m^3) for technological purposes and only 1.1% (560 thousand m^3) of the total volume for agricultural purposes. In Bălţi, about 2/3 (3.4 million m^3) of water was used for domestic purposes, 31% (1.5 million m^3) for technological purposes and only 3% (163 thousand m^3) for agricultural purposes.

5.3.1. Water use for technological needs

Water consumption for technological (industrial) purposes is conditioned by the size and number of urban and industrial centres, water consumption in main industrial enterprises. Thus, of the 582 million m^3 of water used for industrial purposes, 98% is used by enterprises in the Transnistrian DR (table 2), including 553 million m^3 (80%) at the Dnestrovsc Thermoelectric Power Station only, which determines the detached predominance of technological uses in the Republic of Moldova, despite its agrarian character. In addition, according to the data of the Statistical Service of the Tiraspol authorities, in 2019, ≈300 million m^3 more was used for technological purposes than the amount reported by the Water Agency of Moldova. A high consumption of technological water is also observed in industrial enterprises in the cities of Tiraspol (3.5 million m^3), Râbniţa (3.0 million m^3) and Bender (1.7 million m^3), which have a higher level of industrialization and water consumption than the cities on the right bank of the Dniester. This is due to geostrategic planning during the Soviet period and the concentration of the most important heavy industry enterprises (electro-energy, steel, machine building) - in Transnistria.

On the right side of the Dniester River, the maximum volume of water used for technological purposes is recorded in Chişinău - 8.5 million m^3 or 62% of the total volume of industrial water used on the right side of the Dniester River. In the Northern DR, an average of 3.3 million m^3 (24%) was used for technological purposes, of which ≈ ½ - in the Bălţi municipality, which has a higher level of industrialization compared to the Central and Southern DR. An average level of water consumption for technological purposes is recorded in districts with medium-sized urban and industrial centers, including Edineţ (484 thousand m^3), Floreşti (244 thousand m^3) and Făleşti (211 thousand m^3) in the Northern DR, Orhei (339 thousand m^3) and Ungheni (319 thousand m^3) in the Central DR, Cahul (369 thousand m^3) in the Southern DR.

5.3.2. Water use for domestic purposes

In the period 2003-2022, an average of 116 million m^3 or about 15% of the total volume was used for domestic purposes. Domestic water consumption is conditioned by the size and number of urban centers and rural settlements with extensive metered water supplies and the number of population with access to public water supplies. In addition, in the generalised reports of the Water Agency of Moldova, water delivered to households by urban water supply companies is frequently attributed to domestic use, while the volume of water distributed by municipalities and other various categories of operators of public water supply systems in rural areas is frequently attributed to agricultural use. This considerably reduces (up to 20-30%) the share of domestic water use in the districts of the Republic. In the Transnistrian DR, an average of about 60 million m^3 was used for domestic purposes, which represents more than ½ (52%) of the volume of water used for these purposes in the Republic of Moldova and only 9% of the total volume of water used in the region. The maximum consumption for domestic purposes in this region is in the cities of Bender (19.9 million m^3), Tiraspol (18.6 million m^3) and Râbniţa (10.7 million m^3).

According to the data of the Water Agency of Moldova, an average of 56 million m^3 or 48% of the volume of water used for domestic purposes in the Republic of Moldova was used on the right side of the Dniester River. In Chişinău municipality, an average of 41.1 million m^3 of water was used for domestic purposes, which represents ≈3/4 of the total volume of domestic water used in the right side of the Dniester River and 82% of the total volume of water used in the capital, in the North DR - 6.7 million m^3

(12% and, correspondingly 27%), including in Bălți - 3.4 million m^3 (or 2/3 of the total volume), in Central DR - 4.8 million m^3 (8% and correspondingly 19%), in Southern DR - 2.8 million m^3 (5% and correspondingly 21%), and in ATU Găgăuzia - ≈930 thousand m^3 (2% and correspondingly 35%). Also, a large volume of water for domestic purposes was used in districts with larger urban centers, including Ungheni and Cahul (1.1 million m^3 each) and with higher distribution and consumption capacities of drinking water abstracted from the Prut River (Burduja & Bacal, 2022).

The highest share of water used for domestic purposes is found in the Chișinău (82%), Bălți (67%), Bender (92%) and Tiraspol (84%) municipalities. A high share (<30%) is found in the Ungheni and Cahul districts, with larger urban centres, as well as in the Călărași and Camenca districts, which have seaside resorts with high water consumption. In most of the districts (17 out of 32), the share of domestic uses is on average 15-30%, and the volume of water used for these purposes shows a marked upward trend. At the same time, if we add the volume of water distributed by rural public aqueducts usually allocated to agricultural uses, then the share of water used for domestic purposes in many districts will increase by up to 20-30%.

5.3.3. Water use for agricultural purposes

For agricultural purposes, an average of 84 million m^3 was used, which represents only 11% of the total volume of water used in the Republic, including 46.3 million m^3 (5.9%) - for irrigation. Despite a much lower share compared to industrial and domestic uses, agriculture predominates in the consumption of water resources in 4 out of the 6 development regions of the Republic, except for the Chișinău municipality and Transnistrian DR. The volume of water used in agriculture is conditioned by the availability of surface water resources, the density of the hydrographic network, the length and flow of watercourses, the level of water use in agriculture and the water use capacities of farmers. The maximum water consumption in agriculture is found in the districts, which have large capacities for distribution and use of water abstracted from the Dniester and Prut riverbeds, as well as from reservoirs used for irrigation. Also important is the presence of large agricultural households, which practice intensive technologies, including high water consumption and meeting current domestic and foreign market requirements.

In the Transnistrian DR, despite a much smaller share (12%) of the total surface area, an average of 39.6 million m^3 or 47% of the total volume of water used for agricultural purposes in the RM and only 6% of the total volume of water used in the region was used for agricultural purposes, due to the predominance of industrial uses. The maximum consumption of water in agriculture is observed in Grigoriopol (2.6 million m^3), Dubăsari (1.2 million m^3) and Slobozia (923 thousand m^3) districts, where the absolute majority of irrigated land and irrigation systems are concentrated, both those inherited from the Soviet period and those recently built by large agricultural companies.

On the right side of the Dniester River, an average of 44.8 thousand m^3 was used in agriculture, which represents 53% of the total volume of water used in agriculture in the Republic of Moldova (figure 5.b), including 18.8 thousand m^3 (42%) in the Central DR, 14.2 thousand m^3 (32%) in the Northern DR, 9.9 thousand m^3 (22%) in the Southern DR, 1.4 thousand m^3 (3%) in ATU Găgăuzia and 572 thousand m^3 (1.1%) - in the Chișinău municipality.

In the Northern DR, an average of 59% of the total volume of water used in the region was used for agriculture. The maximum consumption of water in agriculture is observed in Briceni (1.9 million m^3), Râșcani and Soroca (about 1.6 million m^3 each), Edineț (1.5 million m^3). The maximum share (≥80%) of agriculture is found in Briceni (91%), Râșcani (87%), Dondușeni (82%) and Ocnița (81%) districts, where large agricultural enterprises operate, and consumption for domestic purposes is lower, due to the population's lesser access to public aqueducts. In Drochia and Sângerei districts, ¾ of the total volume of water used for agriculture is used, while in the remaining districts it constitutes 60-70% due to the higher consumption of water for domestic and industrial purposes in the urban localities of these districts.

In the Central DR, an average of 18.8 million m^3 of water, or about ¾ of the total volume of water in the region, which has a pronounced agricultural and rural character, was used for agricultural purposes. The maximum volume of water used for agricultural purposes is recorded in Anenii Noi (3.0 million m3), Orhei (2.2 million m^3), Criuleni (2.1 million m^3) and Dubasari (1.9 million m^3) districts. An

average water consumption in agriculture is observed in the districts bordering the Prut River with larger areas - Hincesti (1.5 million m^3) and Ungheni (1.2 million m^3), as well as in Ialoveni district (1.5 million m^3). Minimum consumption is observed in smaller districts, such as Rezina (745 thousand m^3), Şoldăneşti (765 thousand m^3) and Nisporeni (840 thousand m^3). The maximum share (≥90%) of agriculture is found in Criuleni, Dubasari, Teleneşti districts. In the districts of Hincesti and Nisporeni more than 80% of the total volume of water used is allocated to agriculture.

In the Southern DR, on average about 10 million m^3 of water or ≈¾ of the total volume of water in the region, which has the most pronounced agrarian and rural character, was used for agricultural purposes. Therefore, the maximum volume of water used for agricultural purposes is recorded in the districts bordering the Dniester River: Ştefan Vodă (2.3 million m^3) and Căuşeni (2.0 million m^3), as well as in the large Cahul district (1.6 million m^3) located near the Galaţi city, where a large part of the agricultural production is delivered. Minimum water consumption in agriculture is found in Basarabeasca (445 thousand m^3), Cimişlia (701 thousand m^3) and Leova (781 thousand m^3). The maximum share (≥80%) of agriculture is in the districts of Ştefan Vodă, Căuşeni and Cantemir, and the minimum share in the districts of Cahul (52%) and Basarabeasca (67%) and is due to the higher consumption of water for domestic and industrial purposes in their urban centres. In ATU Găgăuzia, an average of 1.4 million m^3 or only 3% of the total volume of water used for agricultural purposes in right side of the Dniester River and 53% of the total volume of water used in the region was used for agricultural purposes. The lower share of agriculture is explained by higher consumption for domestic purposes, due to higher access to public aqueducts. The highest water consumption is registered in the large agricultural enterprises with a complex profile in the region, in the Association of Irrigation Water Users of Vulcăneşti and in the vineyards.

On average 46.3 million m^3 or ≈6% of the total volume of water used was used for regular irrigation, including 32.8 million m^3 in the Transnistrian DR and 13.5 million m^3 in the right side of the Dniester River (figure 5.a), of which 5.8 million m^3 (41%) in the Central DR, 3.9 million m^3 (30%) in the Northern DR, 3.3 million m^3 (25%) in the Southern DR, 221 thousand m^3 (1.6%) in ATU Găgăuzia and 241 thousand m3 (1.6%) in Chişinău municipality.

The maximum share of water used for irrigation in the total volume is recorded in the riverside districts on both sides of the Dniester on the sectors between the Dubasari Reservoir and the mouth of the Dniester River, including Grigoriopol and Ştefan Vodă districts (60% each), Dubasari (63% on the right side and 33% on the left side of the Dniester), Anenii Noi (40%) and Criuleni (33%). The maximum share of water used for irrigation is also attested in Briceni (≈50%) and Ungheni districts, where the largest capacities for pumping and distributing water from the Prut River for irrigation were concentrated. In most of the northern districts there is an average share (15-30%) of water used for irrigation, which is due to the more pronounced agrarian character in the Northern DR. In addition, in recent years, there has been a frequent demand from efficient agricultural enterprises for water from the Dniester and Prut rivers in order to meet the growing demands of the external market in CIS countries and the Middle East. In most of the central and southern districts, especially in the western part, a low share of water used for irrigation is observed, due both to the relatively large distance from Dniester River and the unsatisfactory condition of most reservoirs (Burduja & Bacal, 2022).

In the Transnistrian DR, an average of 32.8 million m^3 or only ≈5% of the total volume of water used in the region was used for irrigation. The maximum volume of water used for irrigation is recorded in the districts located downstream of the Dubăsari Reservoir, including Grigoriopol (2.6 million m^3), Dubăsari (1.2 million m^3) and Slobozia (920 thousand m^3). Unlike on the right side of the Dniester River, most of the water abstraction and pumping stations for irrigation have been preserved and subject to much stricter monitoring, and with affordable investments can be rehabilitated.

On the right side of the Dniester River, an average of 13.5 million m^3 or only 12% of the total volume of water used for irrigation was used. The small volume of water used for irrigation is conditioned by natural conditions and the possibilities of using water for irrigation.

In the Northern RD, an average of 3.9 million m^3 of water, or 16% of the total volume of water used in the region, was used for irrigation. The maximum water consumption for irrigation purposes, according to the Inspectorate for Environmental Protection, is recorded at: Technological Irrigation

Stations and Associations of Water Users for Irrigation in Briceni, Drochia (220 thousand m³), Edineţ (166 thousand m³) districts, agricultural enterprises practicing intensive agricultural techniques and oriented to internal and external commercial networks, including "Climăuţeanu Agro" (500 thousand m³)and Agropanfil (162 thousand m³) enterprises, SA "Alfa-Nistru" (513 thousand m³) from Soroca district, SRL „Dimazcom Nord" (112 thousand m³) and from Drochia district, SRL„Vardan Agro" (137 thousand m³) and SRL„Vapricom" (63 thousand m³) from Râşcani district; Vladisvaleo Ltd. (155 thousand m³), "Danulschii" Company (42.4 thousand m³) from Glodeni district.

In the Central RD, an average of 5.8 million m³ or 23% of the total volume of water used was used for irrigation. A maximum volume was used at: Technological Irrigation Stations and Associations of Water Users for Irrigation in Anenii Noi (830 thousand m³), Dubasari (580 thousand m³), Criuleni (530 thousand m³), Ungheni (410 thousand m³) districts; large and medium agricultural enterprises SRL Lobi Logistic (62 thousand m³), in Teleneşti district; SRL "Octama" (363 thousand m³), SRL„Gorobica-Agro" (67,1 thousand m³) and SRL "Işcomagro" (55,6 thousand m³) from Criuleni rayon, IS „Serele Moldovei" (236 thousand m³) and CAP Basarabia (75, 4 thousand m³) from Anenii Noi district, GŢ Urîtu Semion (29,7 thousand m³) from Dubăsari district, SA "Minjir Agro" (83 thousand m³), SRL "Vitis-Vinifera" (61,2 thousand m³) from Hânceşti district.

In the Southern DR, an average of 3.4 million m³ of water or 25% of the total volume of water used in the region was used for irrigation. The maximum consumption of water for irrigation purposes is recorded at: the Technological Irrigation Stations in Ştefan Vodă district (1.1 mil. m³) and Vulcanesti (352 thousand m³); Associations of Water Users for Irrigation in Căuşeni, Cahul and Leova districts; large agricultural enterprises with a complex profile SA„Nistru-Olăneşti" (234 thousand m³) from the district of Ştefan Vodă, SRL Baimaclia agro (106 thousand m³) and SRL Hagimus agro (37,5 thousand m³) from the district of Căuşeni, CAP "Ciobalaccia" (218 thousand m³) and CAP "Glia" (134 thousand m³) from the district of Cantemir, SRL Sadac-Agro (264 thousand m³) from the district of Basarabeasca.

5.3.4. Dynamics of the volume of water used

In the years 2003-2022, similar to the abstracted water, the total volume of water used shows an oscillating evolution against a general negative trend (Figure 7). In the years 2003-2006, on the right side of the Dniester River a reduction is observed, which is more pronounced in the volume of water used for domestic purposes in the Chişinău municipality and for agricultural uses - in the Southern Region, due to the decommissioning of state irrigation systems, bankruptcy and reduction of industrial production, etc. In the years 2008-2014, there is a general negative trend, which is manifested in all categories of water use and in all regions.

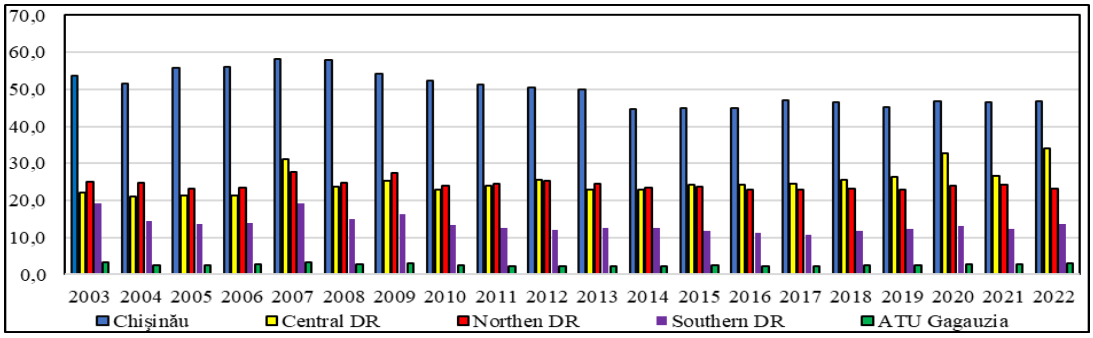


Figure 7. Dynamics of water use in the Republic of Moldova by development regions, in million m³.
Source: Elaborated by the author according to data from the Annual Reports of the Water Agency of Moldova.

In the years 2015-2022, the volume of water used shows a positive dynamic, with the maximum growth rates in the Central DR (Figure 7), due to the partial restoration of irrigation systems in the riparian districts, especially through the Compact Program, and the massive consumption of water in irrigation in 2020 and 2022 which were quite dry. In 2022, due to drought and lack of rainfall, the total volume of water used in Moldova was 789 million m³, or about 9 million m³ more than in 2021. On the right side of the Dniester River 120 million m³ were used, of which 46.7 million m³ (39%) - in Chişinău

municipality, 34 million m³ (28%) - in the Central DR, 23.3 million m³ (20%) - in the Northern DR, 13.5 million m³ (11%) - in the Southern DR and 2.9 million m³ (2%) - in ATU Găgăuzia.

In the Northern DR, during the period 2003-2022, there is also an oscillating evolution, and the total volume of water used in 2022 is 1.8 million m³ less than in 2003. The reduction of the total volume of water used is observed in the Bălți municipality (by 11%) and in 6 of the 11 districts of the region, being caused by the decrease of industrial water uses. The increase of the total volume of water used is recorded in Soroca (1.6 times), Florești (+27%), Drochia (+17%) districts, where there is a faster expansion of rural public aqueducts and a more active revival of agro-industrial enterprises.

In the Central DR, the maximum reduction in the total volume of water used in 2008-2014 is recorded in Dubasari (3.0 times), Anenii Noi (1.9 times), Hincesti (1.8 times), Nisporeni (1.7 times). At the same time, water consumption increased in Strășeni (+25%), Telenești (+11%) and Călărași (+9%) districts, due to the increase in water abstraction capacities of large agricultural enterprises near Chișinău and Bălți. In the Central DR, in the years 2015-2022 (except 2021), there is a significant increase (by 35%) in the volume of water used, due to increased demand and massive consumption of water in irrigation in 2020 and 2022. The positive dynamics is recorded in all districts of the region, except in the district of Șoldănești. The maximum increase is recorded in Dubasari (2.1 times), Nisporeni (1.9 times), Criuleni (1.8 times) and Anenii Noi (1.6 times) districts. In 2022, 7.3 million tons of water were used in the districts. m3 more water was used in 2022 than in 2021, and it is almost exclusively due to the increase in the volume of water used for irrigation, as a result of the very low amount of precipitation in 2022, with the most significant increase in the districts bordering the Dniester River such as Criuleni (+2.6 mil. m³), Anenii Noi (+2.1 mil. m³) and Dubăsari (1.5 mil. m³).

In the Southern Region (Southern DR and ATU Găgăuzia) there is a maximum reduction (by 30%) in the total volume of water used, caused by the massive deterioration and decommissioning of centralized irrigation systems, the significant decrease in production volumes and the bankruptcy of many agricultural and agro-industrial enterprises, the application of the Russian embargo (since 2006) on Moldovan agricultural products. Negative dynamics are observed in all districts except Cimișlia. The biggest decrease in the volume of water used, by about 50%, is observed in the Basarabeasca, Taraclia and Cantemir districts (by about 50%). Also, a reduction of more than 60% in the volume of water used is recorded in the district of Căușeni (by 2015), which is due to the gradual disconnection of the pumping station in Bender, the massive deterioration of the other pumping stations in the area (Leuntea, Chircaiești, Căușeni) and the hydrotechnical installations for water distribution for irrigation.

In the Southern DR and ATU Găgăuzia, the total volume of water used in 2015-2022 increased by 17%, and the positive dynamics is recorded in 5 out of 8 districts of the Southern DR, including ATU Găgăuzia. The maximum increase is observed in Leova (+80%), Taraclia (+39%) and Căușeni (+36%) districts. In 2022, 1.3 million m³ of water were used more than in 2021, which is due to the increase in the volume of water used in the Southern DR, especially for irrigation, due to insufficient rainfall this year.

The maximum volume of water used for technological purposes was reached at the end of the 1980s (about 2.5 billion m3) and decreased by 2002 to about 600 million m³. If we take into account the data of the AAM concerning the Transnistrian DR as well, then in the period 2003-2014 the volume of water used for these purposes is almost constant. At the same time, in the right side of the Dniester River, in the period 2003-2016 there is a constant negative dynamic.

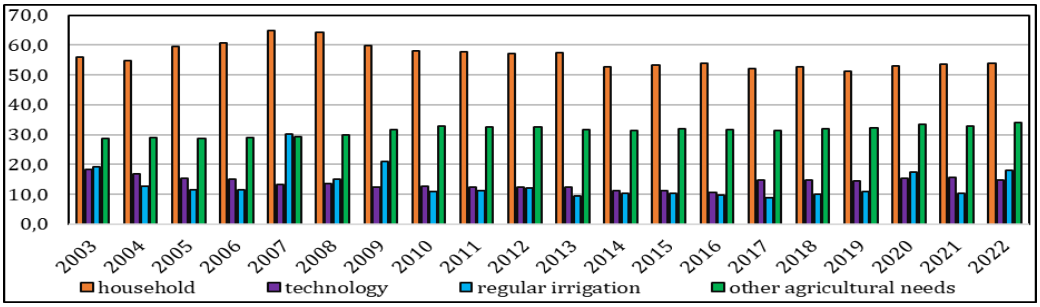


Figure 8. Dynamics of water use by use category, in million m³.

Source: Elaborated by the author according to data from the Annual Reports of the Water Agency of Moldova.

Overall, the total volume of water used for technological purposes on the right side of the Dniester River has decreased by about 20% or from 18.4 million m^3 to 14.8 million m^3. This dynamic is to a large extent due to the significant reduction of industrial water uses in the Northern DR (2.6 times), especially in the Bălți municipality (4 times). The significant reduction of water volume is registered in the districts where several industrial enterprises have stopped or significantly reduced their production activity, especially sugar factories, wine factories, meat processing enterprises, dairy factories, etc. The negative trend is also due to the modernisation of many enterprises, especially wine factories, meat and milk processing centers.

In recent years (2016-2022), there has been a significant increase (≈1.3 times from 10.5 million m^3 to 14.8 million m^3) in the volume of water for technological uses on the right side of the Dniester River. This dynamic is mainly due to the increase in the volume of water for industry in the municipality. The positive trend is not only due to the increase in the volume of industrial production, as a result of the implementation of the Association Agreement with the EU, but also to the increase in the level of statistical recording and reporting of water consumption.

According to the data of the Water Agency of Moldova, the total volume of water used for *domestic purposes* has a weakly oscillating evolution, conditioned both by almost constant data from the Transnistrian DR (with the exception of the city of Râbnița), as well as by the quantity and regime of atmospheric precipitation, the evolution of the socio-economic situation. At the same time, on the right side of the Dniester River, there is a general negative development. At the beginning of the period analysed (2003-2007), there was a significant increase of 16% in the volume of water used for domestic purposes (Figure 8), including 19% (8.1 million m^3) in the Chișinău municipality and 15% (610 thousand m^3) in the Central DR.

In the years 2008-2019, there is a sharp downward trend (1.4 times or from 64.8 million m^3 to 51.4 million m^3), caused by the decrease in the volume of domestic water in the Chișinău municipality (from 50.5 million m^3 to 34.5 million m^3). In the years 2020-2022, the positive dynamics is recorded throughout the country, especially in the small districts. The positive dynamics are due to the expansion of public water supply systems and the increase in metered water consumption.

According to data from the Water Agency of Moldova, the volume of *water used in agriculture* shows a fluctuating but generally negative trend, which was more intense in 2003-2006 and 2010-2013.
In 2003-2006, the volume of water used for agriculture in the right side of the Dniester River decreased on average by 1.3 times (by 7.5 million m^3), with the maximum reduction in the Southern DR (by 1.7 times) and in ATU Găgăuzia (by 1.4 times). At the same time, the positive dynamics are recorded in most of the central districts (7 out of 13), in Soroca and Fălești districts of the Northern DR, and the maximum increase is recorded in Dubasari (+30%), Călărași and Nisporeni (+20%). In the period 2008-2017 there is a significant reduction (more than 1.6 times) in the volume of water used in agriculture, interrupted in 2009. The highest rates of reduction are observed in the Southern DR (by 2.2 or from 15.5 million m^3 to 7.2 million m^3) and in ATU Găgăuzia (by 1.8 times or from 2.0 million m^3 to 1.2 million m^3). In the years 2017-2022, the positive dynamics are recorded in all development regions on the right side of the Dniester River, including in the Central DR - 1.5 times and in the Southern DR - 1.3 times.

In 2022, the total volume of water used in the Republic of Moldova was 788 million m^3 or about 8 million m^3 more than in 2021, which is due to the precipitation deficit and increased water consumption, especially for irrigation. On the right side of the Dniester River, 120 million m^3 were used, of which 46.7 million m^3 (39%) - in the Chișinău municipality, 34 million m^3 (28%) - in the Central DR, 23.3 million m^3 (20%) - in the Northern DR, 13.5 million m^3 (11%) - in the Southern DR and 2.9 million m^3 (2%) - in ATU Găgăuzia. As a result of the significant reduction in the volume of water used in the Chișinău municipality, the share of the respective regions is lower compared to the average for the period under analysis, and the share of the Central DR is higher.

5.4. Public water supply systems

The number and length of public aqueducts are conditioned by the size of the districts and municipalities, the number and size of the component localities, which have extensive functional aqueducts, the available water reserves and the technical and financial capacities for their exploitation, as well as the territorial organization of the public water supply services. Thus, in 2021, 1,365 public water

supply systems were registered, including 633 (46%) - in the Central DR, 335 (25%) - in the Southern and Northern DR, 41 (3.0%) - in the ATU Găgăuzia and 21 (1.5%) - in Chişinău municipality.

The maximum number of public water supply systems is recorded in Orhei (98), Teleneşti (87), Anenii Noi (78) districts in Central DR; Cimişlia (68), Cahul (65), Căuşeni (63) in Southern DR. The minimum number is observed in Chişinău municipality (21), as well as in small peripheral districts such as Dubasari (11), Leova and Basarabeasca (16 each), Taraclia (17) and Nisporeni (19). The rural environment is by far predominant, with 95% of the total number (Burduja & Bacal, 2022) .

The total length of public aqueducts was 16.4 thousand km, including in the Central DR - 5.8 thousand km, in the Northern DR - 4.1 thousand km, in the Southern DR - 3.6 thousand km, 2.0 thousand km - in mun. Chişinău and 970 km - in ATU Găgăuzia. The maximum length of public aqueducts is recorded in the districts of Orhei (842 km), Hânceşti (662 km), Anenii Noi (593 km) in the Central DR; Floreşti (564 km) and Sângerei (507 km) in the Northern DR; Căuşeni (714 km) and Cahul (706 km) in the Southern DR. The minimum length is in Bălţi municipality (273 km), as well as in districts with a small number of localities connected to public aqueducts, including Ocniţa (67.7 km), Donduşeni (156 km), Şoldăneşti (169 km), Dubăsari (203 km), Briceni (214 km), Basarabeasca (216 km).

As a result of the rapid expansion of the public water supply network, currently about 2.3 million people or 2/3 (69%) of the total population in the Republic of Moldova (excluding the Transnistrian DR) have access to public water supply systems, including 1.3 million people or 93% - from urban areas and 990 thousand people or 52% - from rural areas.

In the Northern DR have access to public water supply systems 454 thousand people or 51% of the population present, of which 83% in urban areas and only 34% in rural areas. The Northern DR has the lowest level of access to public water supplies, especially in rural areas. The highest access is in Bălţi municipality (84%), Râşcani (74%) and Sângerei (60%) districts, and the minimum in Ocniţa (17%), Briceni (25%) and Donduşeni (32%) districts. In urban areas, the number of people connected to public aqueducts is directly proportional to the size of the population. Thus, the maximum number of people connected to the aqueduct is recorded in Bălţi (104 thousand), Soroca (31.8 thousand) and Făleşti (15.7 thousand). The cities of Bălţi, Floreşti, Făleşti, Râşcani, Sângerei have the highest access to public aqueducts, and the lowest access - Ocniţa (47%) and Donduşeni (52%). In rural areas, the highest level of access is in Râşcani (66%) and Sângerei (53%), and the lowest in Ocniţa (0%), Briceni (15%), Soroca (22%) and Donduşeni (27%), the lowest in the whole country.

In the Central DR there are 579 thousand people or 60% of the population present in the public aqueducts, including 159 thousand (90%) in urban areas and 420 thousand (52%) - in rural areas. The maximum access of the population to public aqueducts is in Ialoveni (83%), Anenii Noi (78%) and Orhei (70%) districts, and the minimum access - in Şoldăneşti (29%) and Străşeni (38%) districts. Full access to public aqueducts is observed in the cities of Orhei, Călăraşi, Ialoveni, Criuleni, and minimum access - in the cities of Teleneşti (50%) and Străşeni (71%). In rural areas the highest degree of access is observed in the districts of Ialoveni (79%) and Anenii Noi (76%), and minimum access - in the districts of Şoldăneşti (18%), Străşeni (27%) and Hancesti (40%).

In the Chişinău municipality, 766 thousand people or 97% of the total population are connected to the public aqueducts, including ≈100% in urban areas and 78% in rural areas.

About 70% (350 thousand people) of the population of the Southern DR has access to public water supply systems, including 88% (113 thousand) - in urban areas and 66% - in rural areas. The highest access is in Basarabeasca (95%), Căuşeni (87%), Ştefan Vodă (82%) and Cimişlia (81%), and the lowest - in Leova (26%) and Cantemir (53%). In rural areas, the highest degree of access is recorded in Basarabeasca (92%), Căuşeni (86%), Ştefan Vodă (81%) and Cimişlia (72%) districts, and the minimum access - in Leova (26%), Cantemir (50%) and Taraclia (58%) districts. In ATU Găgăuzia, the degree of access of the population to public aqueducts is quite high, being connected 123 thousand people or 82% of the total population (Burduja & Bacal, 2022).

5.5. SWOT analysis of water resources use in the Republic of Moldova

Although the SWOT analysis of water resources use in the Republic of Moldova identified several weaknesses and risks, there are a number of strengths and opportunities for the development and management of this area, which are listed in Table 3.

Table 3. SWOT analysis of water resources use in the Republic of Moldova.

Strengths	Weaknesses
- Sufficient water resources; - Presence of main aqueducts (Vadul lui Voda-Chișinău, Soroca-Bălți-Sângerei, Prut-Fălești, Prut-Edineț); - Good practices in the development of irrigation systems by UAI supported by the Compact Programme, especially in the riparian districts downstream of the Dubasari reservoir; - Significant increase in access to public aqueducts, particularly in rural localities in Central and Southern DR; - The majority of pumping stations of water supply companies are operational; - Water supply to the population is a main thrust of regional and local strategies and programmes and a priority of the Regional Development Agencies; - The presence of wells and springs with a high water flow is a valuable source of water, especially for the rural population.	- Insufficient technical and economic capacity to exploit surface water resources; - Advanced state of wear of previously built irrigation systems and slow expansion of new centralised irrigation systems; - Significant increase in maintenance costs of irrigation systems; - Reduced access to public aqueducts in rural localities in Northern DR and some central districts; - Underfunding of the SWA sector, in particular the sources of co-financing of SWA projects; - A good part of the pumping stations of irrigation systems and agricultural and industrial enterprises built during the Soviet period are out of use, being damaged or massively worn out; - The large number of unused wells and their advanced wear and tear; - High level of water pollution of wells and springs.
Opportunities	**Threats**
- Increase the number of water pumping stations and ensure the proper functioning of existing ones; - Siting new boreholes according to water requirements; - Implementation of measures for the development of public water supply systems stipulated in the Regional Development Strategies and the Regional Sectoral Programme in this field; - Extension of the water supply network in the rural area of the region by attracting foreign investments in the context of accession to the European Union; - The liquidation or conservation of exploited wells will contribute significantly to water protection; - Adequate implementation of Regional Water Supply and Sanitation Programmes; - Optimised systems for reporting, monitoring and evaluation of water resources use performance.	- Accelerating climate change; - Significant population decline, accelerated ageing, particularly in rural areas; - Unused artesian wells are frequently not conserved and cause groundwater pollution; - Acute shortage of financial resources to implement planned measures and actions; - Increased negative socio-economic effects resulting from the operation of hydropower complexes on the Dniester and Prut rivers; - Major dependence on external sources of funding for projects in the field of water resources development and protection; - Reluctance of Local Public Authorities to regionalize water supply and sanitation services.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The main water resources are located in the Dniester hydrographic basin district, where the river network is much denser. The most significant surface water resources are available in the districts

bordering the Dniester and Prut rivers, and underground - in the districts of the central part of the country bordering the Dniester river. The groundwater of the Badenian-Sarmatian aquifer complex is used most intensively, due to its distribution throughout the whole territory of the Republic and the better quality of the water, as well as the more available waters of the Alluvial-Deluvial aquifer.

Due to the limited access to public aqueducts, non-centralised sources (lakes, wells and springs) play an important role in water supply, especially in rural areas. Although the water in most wells and springs does not meet quality requirements, it is widely used for drinking purposes, which directly affects the health and quality of life of the population.

The volume of water abstracted and used is determined by the available water resources and the demand for water, as well as the capacities for water abstraction, transport and use. More than 80% (689 million m^3) of the total volume of water abstracted in the Republic comes from sources in the Transnistrian DR. On the right side of the Dniester River about ½ (79 million m^3) of the water is abstracted in the municipality of Transnistria. Chișinău, 21% - in the Northern DR, 17% - in the Central DR and 12% - in the Southern Region. About 85% of the abstracted water comes from surface sources, of which 553 million m^3 (65%) are abstracted from the Dniester riverbed and used at the Dnestrovsc Thermo-Electric Power Station, and only 20% (144 million m^3) - from the Dniester riverbed. Surface sources are predominantly used to supply water to urban and industrial centres, as well as large agricultural enterprises for irrigation. The majority of localities are supplied mainly from underground sources. The maximum share of surface sources is found in the cities of Dnestrovsc, Chișinău, as well as in the districts of Soroca, Edineț, Ungheni, Cahul, Dubasari and Ștefan Vodă, with extensive systems of water abstraction and distribution from the Dniester and Prut rivers.

If we also take into consideration official data from the Transnistrian DR, then ≈¾ (582 million m^3) of the total volume of water used in the Republic of Moldova is for technological purposes. About 15% or 116 million m^3 is used for domestic purposes, and only 11% or ≈84 million m^3 is used for agriculture, of which 46 million m^3 (6%) for irrigation. On the right side of the Dniester River, domestic uses prevail in the municipalities of Chișinău (82%) and Bălți (66%), and in the districts - agricultural uses.

The use of water for other agricultural needs is predominant in most districts, except for Dubasari, Anenii Noi, Ștefan Vodă and Briceni, where water use for irrigation is predominant, and Ungheni, Cahul and Basarabeasca, where domestic uses are predominant. The high share of non-irrigated agriculture is conditioned both by the pronounced agrarian and rural specificity of the districts and by the frequent allocation by the Water Agency of Moldova of water delivered by public rural water supply systems to agricultural use.

In the years 2003-2022, the total volume of water abstracted and used shows an oscillating evolution, based on a general negative trend, which is more pronounced for water abstracted from surface sources and used for domestic purposes in Chișinău municipality and for agricultural purposes - in the South Region. In the years 2007 and 2020, 2022, as a result of strong droughts, there is a maximum consumption of water. In the years 2015-2022, there is a positive dynamic, which is due to the restoration of some irrigation systems, but also to the increase in metered water consumption due to the significant expansion of rural public aqueducts.

Currently about 2.2 million people or ≈70% of the present population (excluding the Transnistrian DR) has access to centralized water supply systems, including 94% - urban and 53% - rural. At the same time, there is still limited access to public aqueducts in rural localities in the Northern and Central DR.

6.2. Recommendations

Considering the availability and quality of water resources, it is recommended to expand the capacities of water abstraction, treatment and distribution of water from the Dniester and Prut Rivers and allocated for domestic and agricultural uses, including irrigation of fields near the house. In this context, it is imperative to declare the main aqueducts as national security objectives and to apply rigorous control over their condition and operation.

As a result of the high proportion of non-operated boreholes, it is necessary to create a regulation on the location of new boreholes, based on environmental, social and technical-economic criteria, and to

conserve the non-operated ones correctly. In order to minimise the negative impact on the health of the population, permanent sanitary and ecological monitoring of wells, springs and lakes is essential. An important aspect in the efficient management of water resources is the extension of public water supply systems, especially in rural localities in the Northern and Central DR, to ensure planned access of the population to quality water, but also to monitor the consumption of water resources.

It is necessary to create and properly manage an Integrated Water Resources Information System to eliminate inconsistencies between different sources and databases. To this end, it is imperative that the public authorities responsible for water resources management in Chişinău (Republic of Moldova) and Tiraspol (Transnistrian DR) should create common platforms for reporting water use data, coordination and implementation of measures in the field of sustainable water resources development and management.

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USE OF AI TOOLS DECLARATION

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

AUTHOR CONTRIBUTIONS

All authors contributed equally to this work. All authors read and approved the final manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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6. **CONCLUSIONS** (Cambria, 10pt, Bold. Spacing: Before 12pt; After 6pt. Line spacing: At least; At 13pt) It should provide a neat summary and possible directions of future research. The checklist:

- Does this part include the general summary of the article, its results and findings?
- Does this part include implications and recommendations for practice?
- Does this part include research limitations?
- Does this part include suggestions for future research? (Cambria, 10pt, Normal).

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REFERENCES: (Cambria, 10pt, Bold. Spacing: Before 12pt; After 6pt. Line spacing: At least; At 13pt) The list of references should be complete and accurate. For each work shown in the list of references, there must be a reference in the text.

Beginning with Volume 5, Issue 1 / 2023, the citation of authors in the text will follow the 7th edition of the APA style (American Psychological Association), instead of the previously used Vancouver style.

Citations in the text and the list of references should follow the referencing style used by the American Psychological Association, the latest version of the APA Publication Manual (i.e., APA 7), which released in October 2019. Details concerning this referencing style can be found at **http://www.library.cornell.edu/resrch/citmanage/apa**. Authors can also use citation machine at **http://citationmachine.net/**

References should be arranged first alphabetically and then further sorted chronologically if necessary. More than one reference from the same author(s) in the same year must be identified by the letters "a", "b", "c", etc., placed after the year of publication.

In every article there should be at least 20 references and majority of references have to be from SCOPUS/Web of Science. The authors should concentrate on the references to publications for recent years.

Authors are required to complete the reference in a list of literature used with DOI (Digital Object Identifier) if it has been assigned to the publication. To search for the DOI, please visit: **http://www.crossref.org/guestquery/**

- ***In-text citations:*** The citation of authors in the text will follow the 7th edition of the APA style.

Every use of information from other sources must be cited in the text so that it is clear that external material has been used. For every in-text citation, there should be a full citation in the reference list and vice versa. In APA style, in-text citations are placed within sentences and paragraphs so that it is clear what and whose data or information is being quoted or paraphrased.

If the author is already mentioned in the main text then the year should follow the name within parentheses.

- Research by Posea (2005) and Ielenicz (2003) supports…

If the author's name is not mentioned in the main text then the surname and year should be inserted, in parentheses, after the relevant text. Multiple citations should be separated by semicolon and follow alphabetical order.

- The petrographic composition of the massif explains this type of relief (Ielenicz, 2003; Posea, 2005).

If three or fewer authors are cited from the same citation then all should be listed. If four or more authors are part of the citation then 'et al.' should follow the first author's name.

- (Ielenicz, Comanescu & Nedelea, 2010)
- (Ielenicz et al., 2008)

If multipe sources are used from the same author and the same year, then a lowercase letter, starting from 'a', should be placed after the year.

- (Ielenicz, 2003a; Ielenicz, 2003b)

If you are directly quoting from a work, you will need to include the author, year of publication, and page number for the reference (preceded by "p." for a single page and "pp." for a span of multiple pages, with the page numbers separated by an en dash).

You can introduce the quotation with a signal phrase that includes the author's last name followed by the date of publication in parentheses.

- According to Ielenicz (2003), "quoted text" (p. 199).
- Ielenicz (2003) found "quoted text" (pp. 199-202).

If you do not include the author's name in the text of the sentence, place the author's last name, the year of publication, and the page number in parentheses after the quotation.

- The author stated, "quoted text" (Ielenicz, 2003, p. 199), but he did not offer an explanation as to why.

Authors with the Same Last Name: To prevent confusion, use first initials with the last names.

- (D. Privitera, 2004; A.C. Privitera, 2019)

The names of groups that serve as authors (corporate authors) are usually written out each time they appear in a text reference.

- (European Environment Agency [EEA], 2018)

When appropriate, the names of some corporate authors are spelled out in the first reference and abbreviated in all subsequent citations. The general rule for abbreviating in this manner is to supply enough information in the text citation for a reader to locate its source in the Reference List without difficulty.

- (EEA, 2018)

If the name of the group first appears in the narrative, put the abbreviation, a comma, and the year for the citation in parentheses after it.

- The European Environment Agency (EEA, 2023) state that extreme weather threat makes climate change adaptation a top priority.

When a paper has no author, use the first two or three words of the paper's title (using the first few words of the reference list entry, usually the title) as your text reference, capitalizing each word. Place the title in quotation marks if it refers to an article, chapter of a book, or Web page. Italicize the title if it refers to a book, periodical, brochure, or report.

- On climate change ("Climate and Weather", 2010) …
- Guide to Hydrological Practices (2008)

Please do not include URLs in parenthetical citations.

(Cambria, 10pt, Normal).

- ***Reference list***: References follow the 7th edition of the APA style, which includes a dedicated section to the citation of electronic resources.

We strongly recommend the use of reference management software such as Mendeley or Zotero. The official APA style manual can be purchased through their website. (Cambria, 9pt, Normal, Idendation, Special: Hanging; By: 1cm; Line spacing: Single).

Triple-check your references details and their correspondence with the in-text citation. Be aware that despite doing our best to remediate possible issues, authors are responsible for the accuracy of references.

Some examples of references in APA style (7th edition) are included below.

Book with one author:

Fennell, D. (2008). *Ecotourism.* Third edition. Routledge.

Book with two authors:

Jones, R., & Shaw, B.J. (2007). *Geographies of Australian Heritages: Loving a Sunburnt Country?* Routledge. https://doi.org/10.4324/9781351157520

Book with more than two authors:

Carter, T., Harvey, D., Jones, R., & Robertson, I. (Eds.). (2019). *Creating Heritage: Unrecognised Pasts and Rejected Futures*. Routledge. https://doi.org/10.4324/9781351168526

Journal article with DOI:

Leimgruber, W. (2021). Tourism in Switzerland – How can the future be? *Research in Globalization, 3*, Article 100058. https://doi.org/10.1016/j.resglo.2021.100058

Journal article without DOI (when DOI is not available):

Ianos, I., Sirodoev, I., & Pascariu, G. (2012). Land-use conflicts and environmental policies in two post-socialist urban agglomerations: Bucharest and Chişinău. *Carpathian Journal of Earth and Environmental Sciences, 7*(4), 125–136. https://www.cjees.ro/viewTopic.php?topicId=276

Journal article with an article number or eLocator:

Ivona, A., Rinella, A., Rinella, F., Epifani, F., & Nocco, S. (2021). Resilient Rural Areas and Tourism Development Paths: A Comparison of Case Studies. *Sustainability, 13*(6), Article 3022. https://doi.org/10.3390/su13063022

Article in a magazine or newspaper:

Benabent Fernández de Córdoba, M., & Mata Olmo, R. (2007, July 13). El futuro de la geografía. *El País.* https://elpais.com/diario/2007/07/13/opinion/1184277607_850215.html

Edited book:

Yang, P. (Ed.) 2018. *Cases on Green Energy and Sustainable Development.* IGI Global.

Chapter in an edited book:

Privitera, D., Štetić, S., Baran, T., & Nedelcu, A. (2019). Food, Rural Heritage, and Tourism in the Local Economy: Case Studies in Serbia, Romania, Italy, and Turkey. In J. V. Andrei, J. Subic, A. Grubor & D. Privitera (Eds.), *Handbook of Research on Agricultural Policy, Rural Development, and Entrepreneurship in Contemporary Economies* (pp.189-219). IGI Global. DOI: 10.4018/978-1-5225-9837-4.ch010

Conference proceedings (published):

García Palomares, J. C., Gutiérrez Puebla, J., Romanillos Arroyo, G., & Salas-Olmedo, H. (2016). Patrones espaciales de concentración de turistas en Madrid a partir de datos geolocalizados de redes sociales: Panoramio y Twitter. In *Aplicaciones de las Tecnologías de la Información Geográfica (TIG) para el desarrollo económico sostenible* (pp. 131-139). Actas del XVII Congreso Nacional de Tecnologías de Información Geográfica. Málaga, June 29-30 and July 1. http://congresotig2016.uma.es/downloads/separadas/lt1/García%20Palomares.pdf

Working paper (more than twenty authors):

De Stefano, L., Urquijo Reguera, J., Acácio, V., Andreu, J., Assimacopolus, D., Bifulco, C., De Carli, A., De Paoli, L., Dias, S., Gad, F., Haro Monteagudo, D., Kampragou, E., Keller, C., Lekkas, D., Manoli, E., Massarutto, A., Miguel Ayala, L., Musolino, D., Paredes Arquiola, J., … Wolters, W. (2012). *Policy and drought responses–Case Study scale* (Technical report no. 4). DROUGHT-R&SPI project. http://www.isa.ulisboa.pt/ceabn/uploads/docs/projectos/drought/DROUGHT_TR_4.pdf

Webpage or piece of online content:

Vasile Loghin – Geographical Works. *Volcano Island. Geological, geomorphological and volcanological features*.

https://vasileloghin.files.wordpress.com/2015/02/insula-vulcano-cu-foto-final.pdf

Facebook page:

American Association of Geographers - Home [Facebook page]. Facebook. Retrieved September 19, 2022 from https://www.facebook.com/geographers

Non-English references should contain, at the end, additional explanation in which language it was written. If the article contains English summary it should be mentioned. For example:

Grahovac, M., Pivac, T. & Nedelcu, A. (2018). Značaj internet prezentacije za razvoj vinskog turizma Banata(Srpski i Rumunski Banat), *SINTEZA 2017, International Scientific Conference on Information Technology and Data Related Research.* (in Serbian with English abstract & summary)

Dinu, M. (2002). *Geografia turismului [Tourism Geography]*. Editura Didactică şi Pedagogică. (in Romanian)

Language and Text

Foreign concepts, proper nouns, names of institutions etc.

If the article discusses foreign institutions or businesses, the original name should be provided in parentheses. Foreign terms and phrases should be set in italics and followed by an English translation enclosed in parentheses; for example, *griko* (the good food).

Spelling

Submissions must be made in English. Authors are welcome to use American or British spellings as long as they are used consistently throughout the whole of the submission.

- colour (UK) *vs.* color (US)

When referring to proper nouns and normal institutional titles, the official, original spelling must be used.

- World Health Organization, *NOT* World Health Organisation

Grammar

American or English grammar rules may be used as long as they are used consistently and match the spelling format (see above). For instance, you may use a serial comma or not.

- red, white, and blue *OR* red, white and blue

Authors not proficient in English should have their manuscripts checked before submission by a competent or native English speaker. Presenting your work in a well-structured manuscript and in well-written English gives it its best chance for editors and reviewers to understand it and evaluate it fairly.

Font

The font used should be commonly available and in an easily readable size. This may be changed during the typesetting process.

Underlined text should be avoided whenever possible.

The use of bold or italicised text to emphasise a point is permitted, although it should be restricted to minimal occurrences to maximise its impact.

Lists

Use bullet points to denote a list without a hierarchy or order of value. If the list indicates a specific sequence then a numbered list must be used.

Lists should be used sparingly to maximise their impact.

Acronyms and Abbreviations

Except for units' measurement, abbreviations are strongly discouraged. With abbreviations, the crucial goal is to ensure that the reader – particularly one who may not be fully familiar with the topic or context being addressed – is able to follow along. Spell out almost all acronyms on first use, indicating the acronym in parentheses immediately thereafter. Use the acronym for all subsequent references.

- Research completed by the International Geographical Union (IGU) shows …

A number of abbreviations are so common that they do not require the full text on the first instance of use. Examples of these can be found **here**.

Abbreviations should usually be in capital letters without full stops.

- USA, *NOT* U.S.A.

Common examples from Latin do not follow this rule, should be lower case and can include full stops.

- e.g., i.e., etc.

Use of footnotes/endnotes

Use endnotes rather than footnotes (we refer to these as 'Notes' in the online publication). These will appear at the end of the main text, before 'References'.

Notes should be used only where crucial, clarifying information needs to be conveyed.

Avoid using notes for the purposes of referencing; use in-text citations instead.

Symbols

Symbols are permitted within the main text and datasets as long as they are commonly in use or an explanatory definition is included on their first usage.

Hyphenation, em and en dashes

For guidelines on hyphenation, please refer to an authoritative style guide, such as The Chicago Manual of Style (16th ed.) (US English) or Oxford's New Hart's Rules (UK English). Be consistent in your style of hyphenation.

Em dashes should be used sparingly. If they are present they should denote emphasis, change of thought or interruption to the main sentence; em dashes can replace commas, parentheses, colons or semicolons.

En dashes can be used to replace 'to' when indicating a range. No space should surround the dash.

- 10–25 years *OR* pp. 10–65

Numbers

For numbers zero to nine please spell the whole words. Use figures for numbers 10 or higher. We are happy for authors to use either words or numbers to represent large whole numbers (i.e. one million or 1,000,000) as long as the usage is consistent throughout the text.

If the sentence includes a series of numbers then figures must be used in each instance.

- Thermal springs were found in the north of Bucharest at depths of 100, 175, and 230 m.

If the number appears as part of a dataset, in conjunction with a symbol or as part of a table then a figure must be used.

- This study confirmed that 7% of…

If a sentence starts with a number it must be spelt, or the sentence should be re-written so that it no longer starts with the number.

- Fifteen examples were found to exist… *RE-WRITTEN*: The result showed that 15 examples existed…

Do not use a comma for a decimal place.

- 2.56 *NOT* 2,56

For numbers that are less than one a '0' must precede the decimal point.

- 0.29 *NOT* .29

Units of measurement

Symbols following a figure to denote a unit of measurement must be taken from the latest **SI brochure**.

Formulae

Formulae must be proofed carefully by the author. Editors will not edit formulae. If special software has been used to create formulae, the way it is laid out is the way it will appear in the publication.

Tables

Tables must be created using a word processor's table function, not tabbed text.

Tables should be included in the manuscript. The final layout will place the tables as close to their first citation as possible.

All tables must be cited within the main text and numbered with Arabic numerals in consecutive order (e.g. Table 1, Table 2, etc.).

Each table must have an accompanying descriptive title. This should clearly and concisely summarise the content and/or use of the table. A short additional table legend is optional to offer a further description of the table.

The title should be above the table (font 10pt) and the source of the data below (font 10pt).

Example:

Table 1. This is a table. Tables should be placed in the main text near to the first time they are cited

Year	Number of foreign tourists (millions)	Foreign currency cashing (USD billions)	Cashing increase compared to 1950
1950	25,3	2,1	-
1990	410,4	300,4	143,0
2010	940,0	919,0	437,6
2013	1, 087,0	1, 159,0	551,9

Source: UNWTO, 2015.

Tables should not include:

- Rotated text
- Images
- Vertical and Diagonal lines
- Multiple parts (e.g. 'Table 1a' and 'Table 1b'). These should either be merged into one table, or separated into 'Table 1' and 'Table 2'.

NOTE: *If there are more columns than can be fitted on a single page, then the table will be placed horizontally on the page. If it still cannot be fitted horizontally on a page, the table will be broken into two.*

Figures

All photographs, maps and graphs have to be named as Figure. The figures have to be enclosed in the text, in their order of appearance and should be numbered consecutively using Arabic numbers. The title (font 10pt) has to be below the figure. All figures (photographs and maps) have to be submitted as a separate file. All graphs have to be submitted as a separate file in MS Excel format with all the data needed for making the graph. The file should be named as the number of the figure in the main text. Example: Figure 1, Figure 2, etc. If a figure has been previously published, acknowledge the original source. Example:

(a) **(b)**

Figure 1. This is a figure. Schemes follow the same formatting. If there are multiple panels, they should be listed as: (**a**) Description of what is contained in the first panel; (**b**) Description of what is contained in the second panel. Figures should be placed in the main text near to the first time they are cited. A caption on a single line should be centered.
Source: Adrian Nedelcu (2014).

Figure 1. Sardinia. La Pelosa beach with marine abrasion forms.
Source: Adrian Nedelcu (2019).

NOTE: *All figures must be uploaded separately as supplementary files during the submission process, if possible in colour and at a resolution of at least 300dpi. Each file should not be more than 20MB. Standard formats accepted are: JPG, TIFF, GIF and PNG. For line drawings, please provide the original vector file (e.g. .ai or .eps).*

Reviewer Suggestions

During the submission process, please suggest three potential reviewers with the appropriate expertise to review the manuscript. The editors will not necessarily approach these referees. Please provide detailed contact information (address, phone, e-mail address). The proposed referees should neither be current collaborators of the co-authors nor have published with any of the co-authors of the manuscript within the last five years. Proposed reviewers should be from different institutions to the authors. You may suggest reviewers from among the authors that you frequently cite in your paper.

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