Faculty of Graduate Studies

Institute of Environmental and Water Studies

Measuring water security: A case study from Hebron and Bethlehem cities of Palestine

قياس الأمن المائي: دراسة حالة لمدينتي الخليل وبيت لحم في فلسطين

By:

Omar Jamal Abu Thaher

1195531

Supervisor: Prof. Dr. Issam A. Al-Khatib

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BY:

OMAR JAMAL ABU THAHER

1195531

This thesis was prepared under the main supervision of Prof. Dr. Issam A. Al-Khatib and has been approved by all members of the examination

Prof. Dr. Issam A. Al-Khatib
Chairman of committee ----------------------------

Dr. Ziad Mimi
Member ----------------------------

Dr. Fathi Anayah
Member ----------------------------

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The findings, interpretations and the conclusions expressed in this study do not express the views of Birzeit University, the views of the individual members of the MSc committee or the views of their respective.

Abstract

Water security is a very important issue, especially in the developing world. It is defined by the World Bank as reliable access to water in sufficient quantity and quality to meet human needs, agricultural, and local ecosystem services.

The world suffers from obstacles that contribute to water security problems, including climate change, overpopulation, low income in the developing world, with weak institutional capabilities. This hinders the assistance in adapting to water problems especially in the big dependence on water-based industries, in addition to agriculture. As a result, working on the development of water security is a very important process.

Establishing a mechanism to measure water security is a first step in improving water security and adapting to the problems facing water in Palestine.

This study aims to develop a mechanism for studying and evaluating water security in the cities of Hebron and Bethlehem from Palestine, through a methodology based on dimensions and indicators.

City-scale analysis is very useful for effective water security assessment. The framework contains five dimensions of water security; which are water supply, sanitation, water economy, ecosystem and environmental water security as well as vulnerable populations. These dimensions were adopted with reference to international research to reach an effective assessment of water security in the cities of Hebron and Bethlehem.

The dimensions contain several indicators of water security that have been studied through a number of variables that I linked to the indicators, according to the availability of these variables from official sources and institutions; In order to know the situation of the dimensions of water security in both cities. The result of the study is a water security index in the cities of Hebron and Bethlehem, which enables us to assess and accommodate the water security scale in the two cities. This study may contribute to expanding the scope of this intervention to include other major cities in Palestine.

It was concluded that the cities of Hebron and Bethlehem have dimensions that are not good enough and therefore; the water security index gains a low score which is 2.5 for Hebron and Bethlehem cities; both cities have average benchmarks in terms of water supply dimensions and environmental water security.

The sanitation dimension needs improvement, especially in the absence of water treatment in cities. Moreover, the two cities perform very poorly in terms of water economy due to the high percentage of non-revenue water, low water bill collection, and high water prices.

I recommend immediate intervention from the Palestinian municipalities and government in addition to the participation of the private sector and stakeholders to work together towards improving the dimensions of water security, especially in the shade of Israeli occupation; With the need to make agreements for the equitable distribution of water, and the development of water treatment capabilities, in addition to increase awareness among citizens and institutional bodies as well.

ملخص الرسالة بالعربية

يعتبر الأمن المائي من القضايا فائقة الأهمية وبشكل خاص في دول العالم النامي؛ والذي عرفه البنك الدولي على أنه وصول موثوق إلى المياه بكميات ونوعية كافيتين لتلبية الاحتياجات البشرية، والزراعية، وخدمات النظم البيئية المحلية.

يعاني العالم من عقبات تساهم في مشاكل الأمن المائي، ومنها التغير المناخي، الدخل المنخفض في دول العالم النامي، مع الإمكانيات المؤسسية الضعيفة، فهذا يعيق المساعدة في التكيف مع مشكلات المياه في ظل الاعتماد الكبير على الصناعات القائمة على المياه، بالإضافة إلى الزراعة. نتيجة لذلك، فإن العمل على تطوير الأمن المائي يعتبر عملية مهمة جدا.

يمثل إنشاء آلية لقياس الأمن المائي خطوة أولى في تحسين الأمن المائي والتكيف مع المشكلات التي تواجه المياه في فلسطين. تهدف هذه الدراسة إلى تطوير آلية لدراسة وتقييم الأمن المائي في مدينتي الخليل وبيت لحم من فلسطين، وذلك من خلال منهجية قائمة على الأبعاد والمؤشرات.

إن التحليلات على مستوى المدن ونطاقها تعتبر مفيدة للغاية للوصول إلى الأمن المائي الفعال. يحتوى إطار الدراسة على خمسة أبعاد للأمن المائي؛ وهي إمدادات المياه، الصرف الصحي، الاقتصاد المائي، النظام البيئي وأمن المياه البيئية بالإضافة الى السكان

تم اعتماد هذه الأبعاد بالرجوع الى أبحاث عالمية للوصول الى تقييم فعال للأمن المائي في مدينتي الخليل وبيت لحم. تحتوي الأبعاد على عدة مؤشرات للأمن المائي تمت دراستها من خلال عدد من المتغيرات التي قمت بربطها بالمؤشرات، وذلك حسب توفر هذه المتغيرات من المصادر والمؤسسات الرسمية؛ وذلك لمعرفة حالة أبعاد الأمن المائي في كلتا المدينتين.

نتيجة الدراسة هي مؤشر للأمن المائي (water security index) في مدينتي الخليل وبيت لحم، والذي يمكننا من تقييم و استيعاب سلم الأمن المائي بالمدينتين. قد تساهم هذه الدراسة في توسيع نطاق هذا التدخل ليشمل مدناً رئيسة أخرى في فلسطين.

تم التوصل إلى أن مدينتي الخليل وبيت لحم لديهما أبعاد ليست جيدة بما فيه الكفاية وبالتالي؛ فإن مؤشر الأمن المائي حصل على تقييم منخفض وهو 2.5 في كلتا المدينتين؛ مدينتي الخليل وبيت لحم لديهما مقاييس متوسطة من حيث أبعاد إمدادات المياه والأمن المائي البيئي. يحتاج بُعد الصرف الصحي إلى تحسين خاصة في ظل غياب معالجة المياه في المدن. علاوة على ذلك، فإن أداء المدينتين سيئ للغاية فيما يتعلق بالاقتصاد المائي بسبب ارتفاع نسبة المياه غير المدرة للدخل (الفاقد)، وانخفاض نسبة تحصيل فواتير المياه، وارتفاع أسعار المياه.

نوصي بتدخلاً فوريا من البلديات والحكومة الفلسطينية بالإضافة الى مشاركة القطاع الخاص وأصحاب المصالح للعمل معا نحو تحسين أبعاد الأمن المائي، وخاصة في ظل الإحتلال الإسرائيلي؛ مع ضرورة إجراء اتفاقيات للتوزيع العادل للمياه، وتطوير إمكانيات معالجة المياه بالإضافة الى نشر الوعي بين المواطنين والجهات المؤسسية أيضا.

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List of Acronyms

ARIJ	Applied Research Institute - Jerusalem
IIASA	International Institute forApplied System Analysis
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water ResourcesManagement
JWC	Joint Water Committee
MOA	Ministry of Agriculture
NRW	Non-Revenue Water
OECD	Organization for Economic Co-operation and Development
OPT	Occupied Palestinian Territory
PARC	Palestinian Agricultural Development Association
PCBS	Palestinian Central Bureau of Statistics
PMD	Palestinian Metrological Department
ppt	Parts per Thousand
PWA	Palestinian Water Authority
SDGs	Sustainable Development Goals
UNCCD	United Nations Convention to Combat Desertification
WBWD	West Bank Water Department
WHO	World Health Organization
WSI	Water Security Index
WSSA	Water Supply and Sewage Authority

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Chapter One: Introduction

This chapter begins with a general overview of the study, followed by the research problem and goals, the research questions, significance of the study and the thesis outline.

1.1 Background

People's access to clean, cheap drinking water in adequate amounts to satisfy their demands for home use, food production, and subsistence is becoming increasingly important in talks on freshwater supply (The United Nations World Water Development, 2021) . A well-managed risk of water-related disasters is a key component of water security, defined by the World Bank as reliable access to water in sufficient quantity and quality for human needs, small-scale farming, and local ecosystem services. (Lautze et al., 2012). Many cultures' water security is in danger. These dangers have a direct influence on getting enough water in appropriate amounts and quality to fulfill basic demands (Gari et al., 2018). Climate change is often cited as a key contributor to water scarcity, there are other pressing issues to address, such as providing and managing water supply services, in order to keep up with the rising demand for resources due to an expanding population. The most serious short-term challenges including a lack of political dependency which will make it difficult for people to get water, and insufficient water resource management. Access, quality, dangers, and quantity are all aspects that are linked to water security. (Nyiwul, 2021).

Water resource management is essential for many fundamental requirements, including drinking water, home water services, sanitation, environmental demands, agricultural production, energy generation, and industrial activities.

A lack of water resources owing to climate or geography, as well as unsustainable usage or overexploitation, may all contribute to water insecurity. When there is a shortage of access to water resources, or when pollution and natural pollution make it impossible for people to get to them, they may have economic value. The poor world is particularly hard hit by water shortages and security issues. During the last century, water consumption across the world grew six-fold. 40% of the world's population lives in locations where there is a high demand for water (International Institute for Applied System Analysis (IIASA), 2020). Because Palestine lacks control over its water resources, it is confronting a serious water problem. Palestine's average daily water consumption in 2000 was 55 liters per capita per day, or 55 percent of the WHO's minimum requirement of 100 liters per cubic meter (Zahra, 2001). According to international standards, the water supply for the Palestinian people is insufficient (Zahra, 2001).

When compared to the WHO minimum criteria of 100 liters per capita per day., Palestine's average water usage is low, and the Palestinian people's water supply is insufficient by international standards. Water supplies in Hebron and Bethlehem are limited, and in danger. Hebron and Bethlehem's water resources are mostly transboundary, and no agreement has yet been achieved on a "fair and equitable allocation" of water resources between Palestinians and Israelis (FAO, 2015).

The 2030 Agenda for Sustainable Development includes water (Goal 6) and climate change (Goal 13) goals since it is widely acknowledged that tackling climate change problems necessitates better water security. For policymakers all over the world, creating a water-safe community is a top priority. Water security has received more attention in recent years. Quantifying water security is the first step toward improving it. Water security has been studied, defined, and framed in a variety of ways by a number of scholars and institutions (Jensen and Wu, 2018; Cook and Bakker, 2012).

Generally speaking, most of the studies are conducted at a national level. A national water security evaluation may be a major indicator for local water security. Although national water security may be considered safe, but it may not be so on a city level. Despite the fact that national research generates significant and helpful data. It is also possible that national level evaluations may not be fit for use at the local level, so assessing water security at the local level (city scale) using national evaluations is a basic problem; so, city scale water security assessment should be studied (Cook and Bakker, 2012).

1.2 Research Problem

Many water-related concerns confront Hebron and Bethlehem cities, including an increased danger of floods, torrential formations, drifts, water shortages, and drinking water quality. Also, there is a conflict over water especially due to the increased population and lack of water independence because of the Israeli occupation. Hebron and Bethlehem have a high percentage of Non-Revenue Water, in addition to reliance on imported water with the absence of effective water treatment.

1.3 Research Objectives

The main objectives of our research are:

- To set a mechanism for studying and evaluating water security in the cities of Hebron and Bethlehem from Palestine by calculating the water security index , through a methodology based on dimensions and indicators.
- Determine water related dimensions that need improvement. .
- Provide recommendations that may be implemented to raise the water security index, and thus better water security at all dimensions in the cities of Hebron and Bethlehem.

1.4 Research Questions

The main research question this research aims to answer is:

➢ How secure is the water system in Hebron and Bethlehem cities in Palestine?

Other questions which this research aims to answer are:

1. How much is the water security index in the Hebron and Bethlehem districts?
2. How are the researched dimensions of water security doing and do they require improvement?
3. How has the Israeli occupation affected the water security of Palestine?
4. What are the effective solutions to raise the water security index in Hebron and Bethlehem?

1.5 Significance of the Study

This research will make a significant contribution to the discussion and assessment of the water situation in the Hebron and Bethlehem districts. It may help to alleviate water shortages and enhance water security in a variety of ways. The findings of this study may contribute to future research in this field and for neighboring cities.

1.6 Thesis Outline

This thesis is subdivided into six main chapters. Chapter one is the introduction, the main aim of the introduction is to show the importance and objectives of this thesis, overview for water security. Chapter two presents the literature review of the subject. Chapter three describes the study area which is Hebron and Bethlehem cities in Palestine . Chapter four clarifies the approach and methodology used in this study. Chapter five discusses the data, analysis and results. Chapter six presents the conclusions and recommendations.

Chapter Two: Literature Review

A literature review was done to get a better knowledge of the many aspects and components of water security, as well as approaches for evaluating and assessing scales. The following sections provide an overview of the literature pertinent to our study.

2.1 Water Security

The WHO defines water security as a country's ability to meet its basic human needs and manage risk of water-related disasters (Lautze et al., 2012). Water security is at the center of the battle for long-term development, growth, and poverty reduction - especially in developing nations. It is also a source of worry for many of the world's poorest countries today (Grey et al., 2007).

Water have great economic value of any ecological function. A popular index for analyzing and managing water resources that are the result of a variety of natural and human-made factors is water security (Zhang et al., 2021).

Similar to water resource assessments, the mobility of ecosystem services is based on the link between regional supply and demand and statistically examines the interplay of ecosystem services across areas. Water provision service flow capacity has the potential to connect ecosystem service activities across areas, so that regional management and decision-making are more easily applicable (Zhang et al., 2021).

The Arab area is one of the world's most arid, and climate change is anticipated to exacerbate future strains on already precious water supplies (IPCC, 2021). Climate change has been highlighted as one of the primary obstacles to sustainable development and as a major danger to water security in the area by the Arab strategy (IPCC, 2021). The direct consequences of climate change are extensive and involve various fields and sectors of development in all of its forms and kinds, although the nature of these effects varies by country (IPCC, 2021). Floods, storms, and severe hurricanes are among the effects of the seas and oceans on coastal regions, as are pollution, water advancement, and encroachment (IPCC, 2021).

2.2 The 2030 Global Agenda Dedicated Goals for Water

In the 2030 Agenda for Sustainable Development, there are 17 main Sustainable Development Goals (SDGs) that all of the goals are based on. These are natural, and they should be done with the idea of indivisibility in mind (Bennich et al., 2020). However, the 2030 Agenda does not give specific examples of how indivisibility works, how the SDGs work together, or how to measure how these connections work out in the real world (Bennich et al., 2020).

The field of SDG interaction studies is growing quickly, but there isn't yet a clear consensus on what it implies to take an integrative view of the SDGs. This is what the field is trying to help (Bennich et al., 2020).

2.2.1 SDG 6

Ensure access to water and sanitation for all.

Water extraction in the industrial sector accounts for around one-fifth of world water use; agriculture and its supply networks account for the other two-thirds (FAO, 2017). Water solutions are increasingly being assessed, controlled, and used by a growing number of enterprises (FAO, 2017).

There will be no major progress toward achieving SDG 6 unless there is precise data on the present situation and what needs to change in order to maintain water. We can monitor and evaluate progress and speed up action to accomplish SDG 6 using the world's biggest corporate water dataset (Disclosure insight action, 2021).

2.2.2 SDG 13

Take urgent action to combat climate and its impacts

For global warming to stay at 1.5°C or below and the worst consequences of climate change to be avoided, scientists believe that greenhouse gas emissions must peak quickly and then be reduced to zero by 2050, or sooner (Disclosure insight action, 2021). Improving corporate understanding of environmental consequences by monitoring impacts of climate change is crucial to effectively controlling carbon and climate hazardous situations (Disclosure insight action, 2021).

2.3 Creating a Water Secure Society

Science and society alike are concerned about the safety of our water supply and demand. There is a rapidly developing literature on water security from the standpoint of risk science and management. Definitions and indicators of water security reveal unsolved methodological difficulties. When it comes to identifying and measuring the water security of an area and keeping track of indications like exposure to hazardous substances and sensitivity to water-related risks, risk concepts have been frequently employed. These metrics and indices must be examined across several socioeconomic levels to establish threshold levels of risk associated with water-related issues. Water security indicators reflect a broad variety of threats and vulnerabilities depending on geography and political-economic conditions. We need a strong commitment from researchers, governments, development agencies, and politicians to ensure water security. Risk reduction and trade-off management in water-related organizations and infrastructure are captured by pathways to water security (Garrick et al., 2014).

The following elements of creating a water secure society may include an evaluation process for the water sector (Mukheibir, 2008):

- Important water challenges and issues facing the country that may affect activities or those that may cause direct risks, such as droughts, floods, and torrents.
- Social and economic development that may affect water needs, such as growth (urban, foreign trade, and state policies with regard to food security).
- Socio-economic aspects related to water use, such as user behavior and the expected impacts of water demand management. Water is needed to maintain the ecosystem (including water quantity and quality).
- The state of surface and groundwater resources, whether in terms of quantity or quality, and the state of the elements fundamental to the hydrological cycle.
- Alternative water sources, such as desalination, reuse of cleansed wastewater, and irrigation drainage, to become more commonplace.

2.4 How to Measure Water Security

Adapting to changing conditions, such as climate change, necessitates securing and enhancing water security. To improve water security, we must first establish a method for measuring water security. After that, it's time to assess whether or not the little incremental changes are making a difference. An indicator-based technique should be used in order to build a framework for assessing water security. In order to achieve water security improvements, the framework should be created as a city-level study. The method's goal is to stimulate the implementation of real-world water security measures (Babel et al., 2020).

There are many different ways to look at water security, and one of them is to look at how much water there is, how easy it is to get to, how cheap it is, and how good it is to drink in the city. Sanitation and health are two other types of water security dimensions, and they can be used to measure things like how many people in a city have access to better drainage systems and how clean they are as a whole. Some studies also look at the water economy, which includes things like how much water is used and how much money is invested in the area being studied. Another dimension that may be there is the environment and ecosystem, which looks at how natural water bodies are doing. Similarly, how society and government work together should be used to assess leadership behavior and widespread support for freshwater supplies (Khan et al., 2020).

There are some indicators or advices that should take place in the Arab region (Sayed, 2004), such as:

1- Education for inhabitants and general awareness.
2- New conservation technologies development.
3- Wastewater that should be recycled.
4- Irrigation and agricultural water use to be improved.
5- Rainwater collection as a method of collecting rainwater.
6- Partnerships and community governance.

2.5 Global Threat to Human Water Security

In order to safeguard freshwater resources across the globe, it is necessary to identify dangers at many levels of scale, from the global to the local. Water security risk affects over 80 percent of the world's population. High levels of stress may be mitigated in wealthier countries without dealing with the root causes, while poorer nations remain susceptible. There has been little to no effort to protect the habitats linked to 65 percent of our continent's discharge. For the sake of human and freshwater biodiversity, the cumulative threat paradigm helps prioritize policy and management solutions to this catastrophe. There is a strong emphasis on minimizing dangers at their source rather than just dealing with symptoms, which may be expensive (Vörösmarty et al., 2010).

Changes in climate, population, land use and urbanization have all put pressure on water supplies, making them scarcer. Consequently, understanding the long-term viability and security of water supplies is essential. A framework for quantifying global human water hazards, as well as how to employ an indicator-based method to assess water usage sustainability at regional and global scales must be developed. This means that after we estimated the human water threat with both global and local datasets, and if it started showing that the index for global data was close to the index for regional data, we could look at many different aspects of the index with local datasets, which have a good spatial and temporal resolution. The objective is to anticipate water security or sustainability and find forecasts using existing indicator datasets. However, this would require regionally defined connections between water security and similar indicators (Kim et al., 2018).

2.6 Scale of assessment of water security

Traditionally, water resource assessments have looked at the physical balance of water in terms of how much water comes in and how much goes out. National and local studies have looked into how much water there is in a basin so that basin-wide master plans can be made about how much water each place needs. New ideas about water management in the 1990s were based on sustainability, but now there is also a question about integrity that needs to be talked about more. Integrated Water Resources Management (IWRM) is a type of work that includes both vertical and horizontal dimensions. The concept of integrity can be used to describe both of these types of projects. Horizontal integrity is made up of all the people who work in different fields and sectors. Vertical integrity is made up of various management levels, from the local to the national level. An important part of the IWRM water planning process is the assessment of integrated water resources, which takes into account not only the physical water balance, but also how water affects economic and social sub - systems in terms of its contribution to social well-being, economic production, and job creation, among other things. It also cares about how water use affects the environment, especially pollution that is released into the environment. As such, an integrated water management assessment is comprehensive as well as strategic, based on environmental, social, and financial factors that affect long-term viability. It is important to arrange the indicators in a way that makes sense to the people who are looking at them. There are tools called analytic frameworks that can connect indicators from different fields so that may figure out how water affects the environment, social, and economic sectors, as well as how those sectors affect the state of the water resources and the risks that are associated with it. All over the place, from the farm to the city to the national level, we can use this scale (Mahdavi et al., 2019).

It takes a multi-factor system with several moving pieces to ensure the security of water resources. Therefore, in order to keep track of regional water resource security, a comprehensive set of evaluation indicators that are in line with regional water resource features must be developed. An independent, systematic, and representative indicator system is used to divide water resource security into several subsystems. These include a subsystem for monitoring and assessing the quality and quantity of the water supply, a subsystem for monitoring and assessing the impact of water shortages on engineering, a subsystem for monitoring and assessing the vulnerability of water resource storage, and so forth. It is safest for regional water resources to be in a safe condition when all of the subsystems are in a secure state (Yin et al., 2020).

2.7 Indicators Developed for National Scale of Assessment of Water Security

There is a propensity for disciplines to focus on a variety of scales. Watershed sizes in hydrology may vary from regional to national, while social scientists often study at the community level. National scales are typical in development research, a meta-analysis of water security is difficult and confounding. Assessments of national water security may conceal major variations in local security (Cook and Bakker, 2012).

In order to have a complete view of the situation, it is important to undertake water security assessments at the local level rather than at the national level. On the national level water security may exist, but on the local level the reality may be very different. Water security may be studied at the subnational level, but not at the national level due to the difficulty of doing so. It is not entirely successful to localize water security indices using national scale evaluations. Some indicators produced for the global level may not be adequate for the local size (Vörösmarty et al., 2010).

It is recommended that national water security frameworks be built on the United Nations comprehensive water's and multidisciplinary definition of water security, which includes all viewpoints and aspects. IWRM is a technique and a useful framework for attaining water security and linking water to society that is employed in the majority of national water policies. When it comes to water management issues, uncertainty, and complexity, IWRM implementation has been criticized for failing to give full answers (Phillis et al., 2017).

It is common for benchmarking systems to use dimensions to measure different aspects of a city's performance. These dimensions are broken down into different indicators like productivity; infrastructure development; quality of life; equity; social inclusion; environmental sustainability; as well as local planning and legislation. Compare or study guidelines among both sustainable and unsustainable thresholds by converting indicators to values in [1 - 5] as (Khan., et al) mentioned in his study for Pakistan’s Capital Islamabad in 2019, and then averaging them to get the overall and dimensional indexes, which are then used to compare or study standards (Habitat, 2015).

2.8 Water Security Assessment at City Scale

It is vital to conduct local studies in order to put the concept into effect, since improving water security often necessitates a "up from the bottom" approach. In order to fill knowledge for managing water security, city scale analysis aims to create and implement a methodology for analyzing water security at the city level. Given that water does not respect administrative borders (Zhu and Chang, 2020).

A city-scale framework is created to encourage practical water security interventions. It can be used as a small tool for comparison, especially for nearby cities. The unique conditions of the city will intervene to choose the variables that lead us to a result of the indicators that branch from the water security dimensions to reach the result of the water security index. Water security index is the result of the framework, which is scaled from one as the worst conditions to five which indicates that the water security is at the best conditions (Vörösmarty et al., 2010).

The ability of the city-scale analysis to be generic while capturing site-specific elements is one of its distinguishing features. This aspect is divided into two parts (Dimensions and indicators) which is the framework's generic component, which can be applied to any research for evaluating water security for different cities. This essentially implies that all cities should use the compatible or defined dimensions and indicators. Site-specific conditions and data may alter the framework's second part (variables). The consequence is that a city may choose the optimal metric to measure a certain indicator. A flood damage variable, for example, may be measured in a variety of ways. The city is free to choose the most important variable for their situation. As a result, one of the framework's underlying principles is that using all potential variables we can measure the indicator equally well (Babel et al., 2020).

2.9 Elements of Water Security

Water security has been highlighted in a number of studies. So that everyone may have a healthy and productive life while also preserving and enriching the natural environment (Siwar et al., 2014). There are three elements of water security which are water Access, water safety and water affordability as discussed below (Siwar et al., 2014):

1- **Water access**: Water security begins with access to water. It indicates that safe drinking water should be available to everyone. For example, if just part of the year's water is accessible or if water quality is impaired at certain points in the year, such as when it rains, water security is hard to attain. Throughout the year, a water supply must be able to offer appropriate amounts and quality of water. When a community's water supply is unreliable, it has significant health and economic effects. Every house, business, healthcare facility, and public area must have access to water services as well. It is also necessary to secure long-term accessibility (Gerlak et al., 2018).

2- **Water safety:** Water safety is the second aspect of water security. A sufficient amount of water must be available to meet all of the household's personal and domestic needs. Water, on the other hand, must not be a health hazard. To put it another way, water should be of such high quality that it offers no substantial health risks to those who drink it. In terms of appearance, taste, and odor, it should be acceptable to users. Contaminant levels should not exceed the region's or country's widely accepted water quality standards where it is consumed (UN-Water, 2013).

3- **Water affordability:** Affordability of water is another important aspect of water security. Affordability and availability of water for fundamental requirements such as sanitation and hygiene are essential, as well as the protection of people's health and well-being requirements. In this case, regulations must establish standards for water pricing. To put it another way, water and sanitation services should not be provided for free, and tariffs are required to ensure service sustainability. The most important criterion for meeting human rights standards is that tariffs and connection costs are designed in such a way that they are affordable to everyone including those living in extreme poverty (Grey et al., 2007).

2.10 Israeli Occupation control of water resources

Water has been identified as an emerging cause of conflict between Israel and the Palestinian people. The Palestinian people in the OPT are experiencing a severe water crisis, not only due to the area's aridity, but also due to the political circumstances created by Israel's control over Palestinian water resources (Amnesty international, 2017).

Since Israel's occupation of the Palestinian Territory in 1948, Israel has imposed restrictions on Palestinian water use and exploited Palestinian water resources. Israel now uses more than 80% of Palestinian water from the West Bank's Aquifer Systems, accounting for 25% of Israel's water demands. On the other side, the Palestinian people in the OPT are denied the right to use their own water resources from the Jordan River System, which they previously used in part until 1967 (Qawasmeh et al., 2021).

The quantity of water provided to the Palestinians under the Oslo Interim Agreement is insufficient to support the population's basic requirements. Additionally, it does not take population increase or economic development into consideration (Qawasmeh et al., 2021).

. A series of Military Orders quickly put all water resources in the occupied Palestine under Israeli control (Ibrahim, 2017) :

- Military Order No. 92 is referred to as "The Order Concerning Water Provisions Powers." It took effect on August 22, 1967. This directive vests complete responsibility for any water-related matters in the West Bank in whomever the military commander of Israel's troops appoints as the Officer in Charge. All legislation relating to water in the West Bank, including laws, regulations, orders, decrees, proclamations, and directives, may be declared null and void and substituted by new ones (Ibrahim, 2017).

- Military Order No. 158 is known as "The Order Amending the Control of Water Law," and it stipulates that Water Establishments must get a permission and are subject to the Officer in Charge's direct authority. This legislation went into place on November 19, 1967 (Ibrahim, 2017).
- Military order 291 is titled "The Order Concerning the Settlement of Titles and the Regulation of Water." On January 1, 1969, it came into force. This ruling nullifies any agreements relating to land and water made before 1967 (Ibrahim, 2017).

Finally, Palestinian institutions' ability to manage water resources and maintain infrastructure must be increased in order to ensure long-term sustainable management of water resources (Amnesty international, 2017).

Chapter Three: Description of the Study Area

The purpose of this chapter is to describe the study area in terms of its location and physical characteristics, weather and rainfall, environmental conditions, and economic activity. The study area included Hebron and Bethlehem cities; these two cities were chosen for study because they are significant cities in Palestine and need an evaluation of their water security, particularly in light of the Israeli occupation and population expansion.

3.1 Hebron City

3.1.1 Location and physical characteristics

A major Palestinian city, Hebron occupies 42 square kilometers in the southern West Bank's Hebron Governorate. On the east, Bani Na'im is bordered by Hebron, while the north is bordered by Halhoul, the west by Taffuh, and the south by Yatta (See Figure 3.1) (ARIJ, 2010a).
It is estimated that Hebron's population in mid-2021 was 221,000 people, according to statistics provided by the Palestinian Central Bureau of Statistics (PCBS) (PCBS, 2021a).

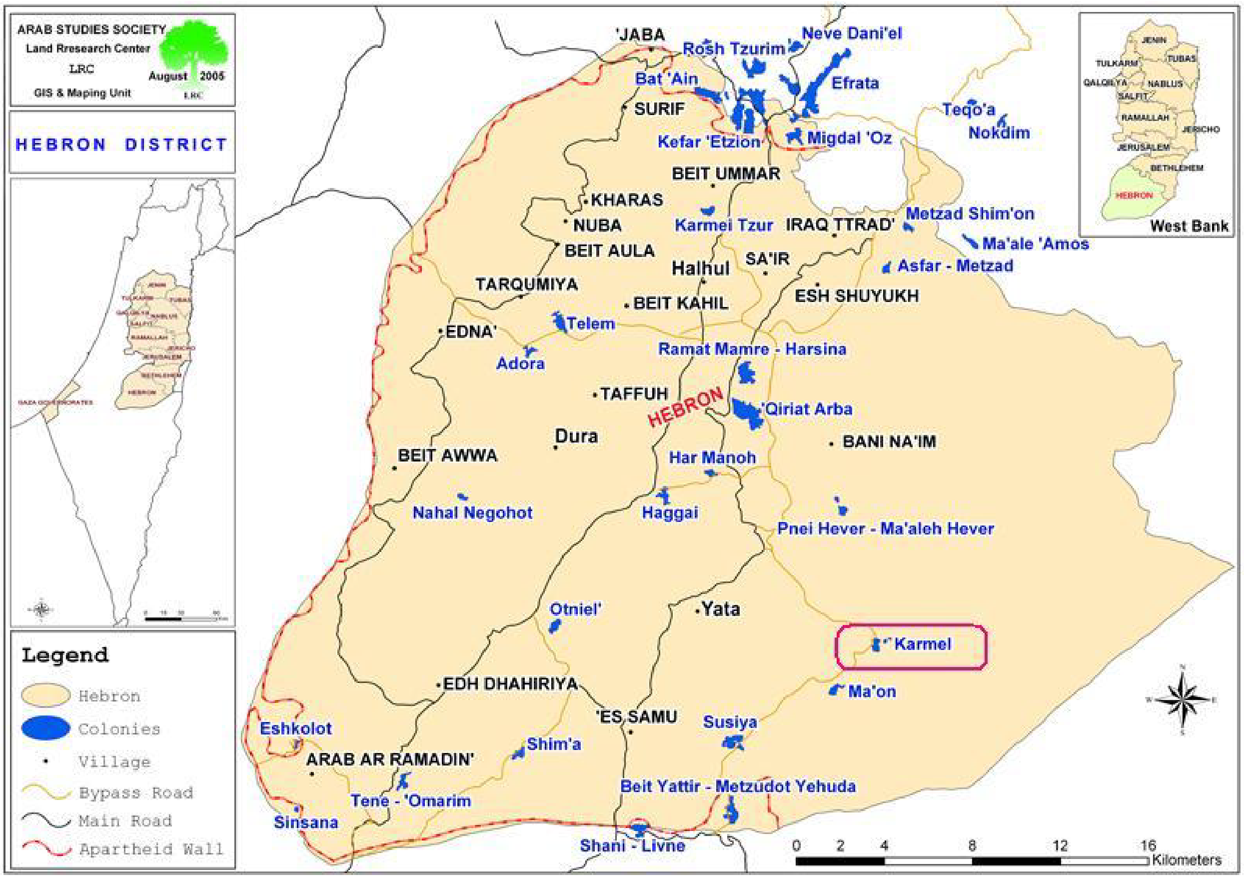

Figure 3.1 Hebron and its surroundings (PCBS, 2016).

3.1.2 Weather and Rainfall

Long, hot, dry, and clear summers are common in Hebron, generally clear winters are in the city. Every year, temperatures are normally between 3 °C and 29 °C , with temperatures seldom dropping below 0 °C or going over 32 °C (Weather Spark, 2021a).

Daily maximum temperatures reach 25.5 °C or higher for 4.4 months. There are 3.1 months of mild weather during which the daily maximum temperature is less than 14 °C on average. The cool season runs from December to March (Weather Spark, 2021a).

From October to April, the rainy season lasts 5.2 months, with a 31-day rainfall of at least 13 mm on average (Weather Spark, 2021a). The 31 days leading up to January with the most rain fall quantity, with an average total accumulation of 38 millimeters. From April to October, the year is devoid of rain for 6.7 months. July is the month with the least rain (Weather Spark, 2021a).

3.1.3 Natural Resources and Infrastructure

- Telecommunications and electricity services:

Hebron has been on the electricity grid since 1960. More than 99% of residences in the city have access to electricity via the city's network. The Israeli National Electrical Company provides power to Hebron's municipal government (ARIJ, 2010a).

A telecommunications network is also available in Hebron. The vast majority of families have access to a phone line (ARIJ, 2010a).

- Transportation Services:

Hebron's public transportation system is mostly composed of 148 bus routes and 944 taxicabs, all of which are operated by a single dispatch bureau. Military checkpoints west of the city, flying checks elsewhere, and metal gates in the segregation wall make transportation difficult. It is estimated that Hebron's road network is 206 km long. Of that, 112 km are paved and in good shape, while 85 km are surfaced but in poor condition, and 9 km have no pavement (ARIJ, 2010a).

- Water Resources:

The Palestinian Water Authority (PWA) provides water to Hebron via a water network that was established in 1936 and serves 80 percent of the city's housing units (ARIJ, 2010a). According to the PWA, the average daily consumption is 87.3 liters, but this varies by community, with 110 liters per person consumed in Hebron in 2009 (ARIJ, 2010a).

Based on how much water each person uses each day, the amount of waste that is produced each day is about 2500 cubic meters, or 910,000 cubic meters per year (ARIJ, 2010a). Palestinians in the city of Hebron get water from the Mekorot water company, which is owned by the Israeli government, even though most of the water comes from West Bank aquifers and is sold back to Palestinians (Abu Dayyeh, 2005).

- Sanitation:

Most of the homes in Hebron use the sewage system to get rid of waste, according to the results of a survey conducted by PCBS in 2007 and data from the Palestinian Water Authority. Only 30 percent use cesspits. Based on how much water each person is expected to use each day, the amount of wastewater generated each day in 2007 is expected to be about 2,500 cubic meters (ARIJ, 2010a).

3.1.4 Environmental Conditions

There are numerous issues confronting the Hebron area, particularly in terms of the environment, such as the water crisis, which is disrupted for lengthy periods due to Israeli control of water resources, as well as civilian conduct, such as illegal connections and theft in general (ARIJ, 2010a). Due to a lack of sewage networks, cesspits were built up, which might pollute groundwater and cause epidemics and diseases (ARIJ, 2010a). Environmental issues include waste management, where there is no place for waste disposal, because the appropriate waste areas are located in Area "C," Israel, and we also need external funding to implement these projects (ARIJ, 2010a). A reduction in the landfills is a health hazard, as is the absence of a system for separating the different types of hazardous waste (ARIJ, 2010a).

3.1.5 Economic Activities

The city of Hebron is largely depend on the trade sector, which employs 50% of the population, services sector fills 10%, government with 5%, manufacturing sector takes 15% and agriculture employs 15% of Hebron's population, while the remained 5% of population works in Israeli market (ARIJ, 2010a).

Hebron has a diverse economy, including antiques, textiles, and stone factories, as well as various workshops (woodworks, carpentry, and aluminum), butcher shops, bakeries, super markets, clothing shops, and various retail commercial stores such as car parts, and flowers, as well as various services stores (ARIJ, 2010a). The economy has suffered as a result of Israel's occupation (ARIJ, 2010a). As a result, there are unemployed people in Hebron who have been forced to seek work in the services sector (ARIJ, 2010a). Unemployment in Hebron affects workers in the tourism sector, retail sector and industry workers (ARIJ, 2010a).

3.2 Bethlehem City

3.2.1 Location and Physical Characteristics

Located in the northwestern portion of the governorate of Bethlehem, Bethlehem is one of Palestine's most prominent cities. Beside Bethlehem on the east, the city of Jerusalem on the north, the towns of Beit Jala on the west, and the villages of Hindaza and Artas on the south, lays Beit Sahour, (see Figure 3.2) (ARIJ, 2010b).

Bethlehem had a total population of 30.880 people in mid-2021, according to the Palestinian Central Bureau of Statistics (PCBS, 2021b).

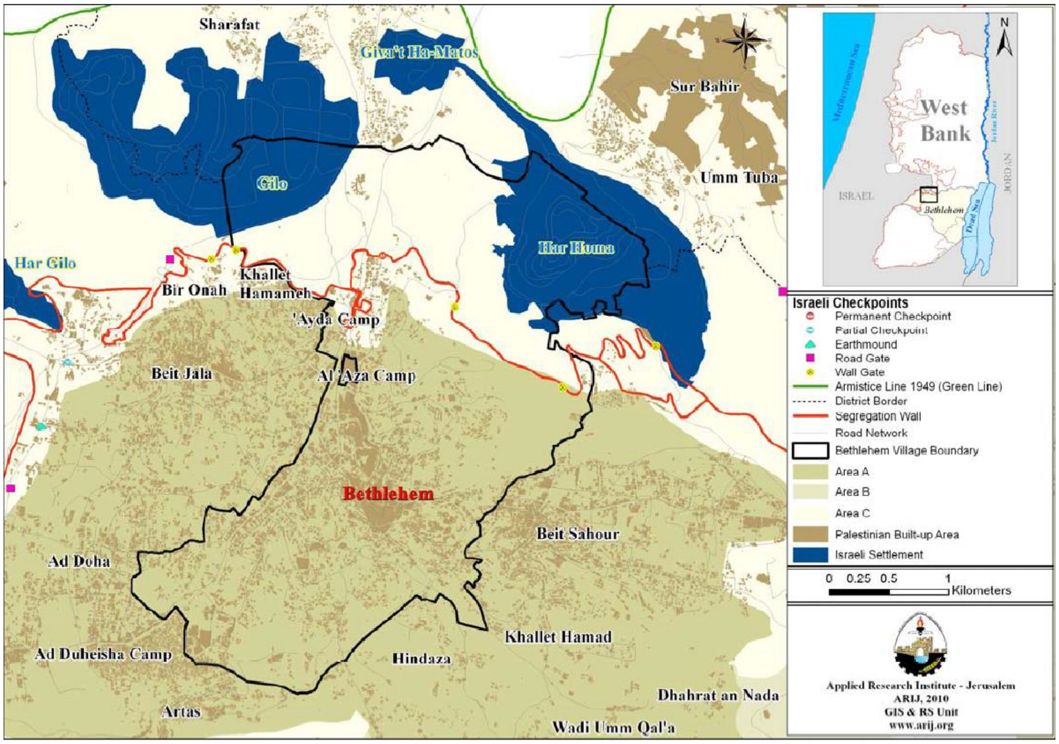

Figure 3.2 Bethlehem and its surroundings (ARIJ GIS, 2009).

3.2.2 Weather and Rainfall

Summers in Bethlehem are long, hot, and dry, with bright skies, but winters are chilly and mainly cloudy. Over the course of the year, the temperature normally fluctuates from 5 °C to 30 °C , with temperatures seldom dipping below 1 °C or going over 33 °C (Weather Spark, 2021b).

Summer lasts 4.5 months, with an average daily maximum temperature of more than 26 °C (Weather Spark, 2021b). Cool season lasts 3.1 months, with daily maximum temperatures averaging less than 15°C over this time period (Weather Spark, 2021b).

The rainy season lasts 5.3 months, with a sliding 31-day rainfall of at least 13 millimeters on average over that time. The 31 days preceding. 6.6 months of the year, from April to October, are always absent of precipitation (Weather spark, 2021b).

3.2.3 Natural Resources and Infrastructure

- Telecommunications and electricity services:

Since 1961, the Jerusalem Electricity Company has been distributing electricity to Bethlehem via the public distribution network. Nearly all of the city's housing units are linked to the electrical grid, with just 0.1 percent depending on private generators and 1.1 percent having no access to power (ARIJ, 2010b). Bethlehem is also wired for telephone service, with around 80% of the city's dwellings having access to this technology (ARIJ, 2010b).

- Transportation Services:

The city of Bethlehem acts as a significant transit hub, linking cities, rural areas, and other Palestinian territories. Transportation in Bethlehem consists mostly of buses and cabs (ARIJ, 2010b). City officials say there are 55 kilometers of asphalt roads that are in good shape, and seven kilometers of poor roads that need to be repaired (ARIJ, 2010b).

- Water Resources:

PWA delivers water to Bethlehem through a 1960-established water network, with 98.5 percent of dwelling units linked, 0.2 percent dependent on rainfall, and 0.1 percent relying on other sources of water (ARIJ, 2010b). While the PWA estimates daily use as 85.6 liters, actual consumption varies by neighborhood, with Bethlehem residents in 2009 using 120 liters daily (ARIJ, 2010b). Estimates of 2009 wastewater generation based on daily per capita water use yielded a daily total of 1,273 cubic meters, or 465,000 cubic meters yearly (ARIJ, 2010b).
Drinking water is provided by the Israeli water corporation "Mekorot," which is then delivered by the West Bank Water Department (WBWD) (Salem, 2019).

- Sanitation:

The length of Bethlehem's sewage system is 55 kilometers (ARIJ, 2010b). Most Bethlehem housing units (92.7 percent) rely on the sewage network to dispose of waste water, while 6 percent rely on cesspits, and 0.2 percent do not have wastewater collection and disposal service, according to data provided by PWA and the results of the PCBS Community Survey conducted in 2007 (ARIJ, 2010b). In 2007, roughly 1,273 cubic meters of wastewater were generated per day based on the projected daily water use per individual (ARIJ, 2010b).

3.2.4 Environmental Conditions

Many issues confront the Bethlehem area, particularly in terms of the environment, such as the water crisis, which is disrupted for long periods due to Israeli control of water resources, as well as citizen behavior, such as illegal connections and theft in general. Due to a lack of sewage networks, cesspits were used, which could pollute groundwater and cause epidemics and diseases. Environmental issues include waste management, where there is no place for waste disposal because the appropriate waste areas are located in Area "C," Israel, and we also need external funding to implement these projects. A reduction of these landfills is a health hazard because it is one of the pollution sources for underground, as well as the absence of a system separation of the types of hazardous waste, which is a risk itself (ARIJ, 2010b).

3.2.5 Economic Activities

The city of Bethlehem's is primarily reliant on trade sector and services sector which account for 30% and 25% of the workforce respectively, government sector fills 23%, industry employs 18%, while agriculture sector takes only 1% from workforces, the remaining work forces are in Israeli market (ARIJ, 2010b).

Bethlehem's economy includes distinct workshops (blacksmith, carpentry, and aluminum), butchers, bakeries, food and apparel stores, (auto parts, carpets, and flowers), service and retail businesses, and grocery stores (ARIJ, 2010b).

Israel's occupation has had a negative impact on the economy. Unemployed individuals have been compelled to choose jobs in the service industry as a consequence. Nearly two-thirds of Bethlehem's workforce is out of work, impacting employees in the tourism , trade and industry sectors following industries (ARIJ, 2010b)

Chapter Four: Methodology

To meet the study's primary goal, an integrated technique was adopted. This chapter reviewed the key steps and examined several definitions, allowing for the clarification and description of all components of the study; which are water security variables, indicators, dimensions and water security index.

4.1 Explanation of the Strategy for Dimensions, Indicators and Variables

A thorough review of the literature at the local, regional, and global levels was the first step in completing this study. This study examined water security in different aspects as the first step for improving water security and adapting to the problems facing water in Hebron and Bethlehem cities in Palestine..

Four major elements will present the framework, to assess the water security in the cities of Hebron and Bethlehem which are Water security index (WSI), dimensions, indicators, and variables

- **Water Security Index (WSI):** It is the result of the framework, which is scaled from one as the worst conditions to five which indicates that the water security is at the best conditions as Table 4.1 shows. Water security index is calculated by finding weighted average for each dimension.

Table 4.1 Interpretation of WSI scores (Babel et al., 2020).

WSI Score	Level ofWater Security	Interpretation
<1.5	Unacceptable	The city is incapable to fulfil the basic water needs of its residents.
1.5-2.5	Poor	Almost all dimensions show serious concern. Lack of proper management of water resources
2.5-3.5	Satisfactory	A reasonable level of water security where some dimensions require improvement
3.5-4.5	Good	The city performs considerably well in most aspects of water security
>4.5	Excellent	An exemplary city with an ideal level of water security with respect to every dimension

- **Dimensions:** The research studied five dimensions of water security; which are water supply, sanitation, water economy, ecosystem and environmental water security as well as vulnerable populations. These dimensions were adopted with reference to international researches in order to reach an effective assessment of water security in the cities of Hebron and Bethlehem. every dimension is given a specific weight according to its importance, so that we can measure the water security index. Figure 4.1 shows the five dimensions in the research.

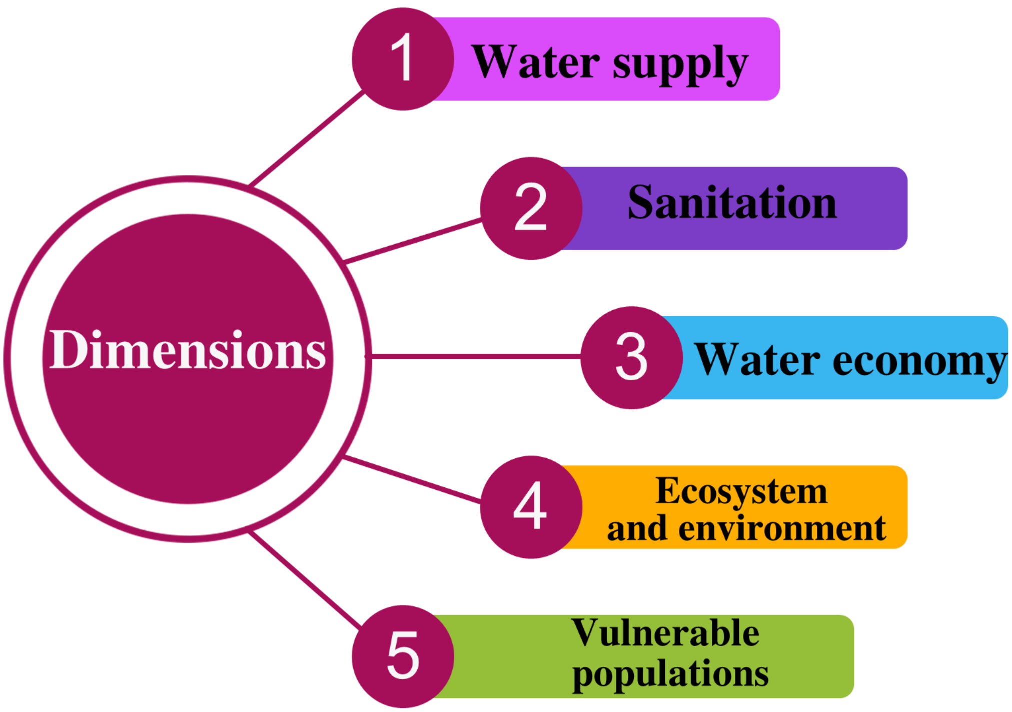

Figure 4.1 Water security dimensions

- **Indicators:** Several indicators of water security have been studied and weighted to describe dimensions that I linked, with reference to international researches and from official sources and institutions; In order to know the situation of the dimensions of water security in Hebron and Bethlehem.
- **Variables:** Different variables were associated with the indicators, based on their availability from official sources and institutions; in order to ascertain the state of each indicator. However, some variables must be calculated using data collected from official sources.

In the framework, there was a water security index that covered many different aspects of water security as well as the indicators and variable factors that affect water security. One or more indicators were used to denote the dimensions. Indicators shall be explicit, quantitative, and feasible evaluation criteria that are both relevant and time-bound. As a consequence, each indicator was assessed using certain variables that were given a standard values to get the WSI result. The capacity to remain generic was the most significant aspect of this framework until site-specific features were captured. The same indicators were applied to both cities. One of the framework's guiding ideas was that every relevant variable may be used to measure an indicator. For picking a variable, we took into account the availability of data, simple calculations may be necessary to compute variables. See Table 4.2

To find the water security index, each parameter in the range of 1–5 is first modified using variables by reference values as shown in Table 4.3. The reference values can aid in the classification of variable quantities into separate categories, which can subsequently be awarded scores ranging from 1 to 5 which give the score of indicators that is weighted to result in dimensions which are also weighted to reach the final score of the water security index . Several discussions and interviews were held with key government agencies, such as Palestinian Water Authority (PWA), Hebron and Bethlehem municipalities, and non-governmental organizations such as Water Sector Regulatory Council (WSRC) in order to understand the "operational" background for water security. The water security framework was built using the information gathered during the interviews and discussions. The framework was tested as a case study in the municipalities of Hebron and Bethlehem to determine its efficacy and long-term viability, and it may be applicable to all other Palestinian cities because it is critical for everyone.

- The word "water supply" encompasses the quality, and availability of drinking water.
- . The sanitation component takes into account residents' access to and the status of the sewage network.
- Water productivity, revenue, and investment in the water sector are part of the water economy.
- Ecosystem and environmental water security is a term that refers to the water needs of the environment as well as the pollution status of natural water bodies.
- An individual's exposure and population's impact on water security are captured by vulnerable populations dimension.

4.1.1 Dimension 1: Water supply

Water supply dimension is made up of three indicators: Availability and natural context, water access, and water quality. The availability and natural context indicator is made up of variables like per capita water availability, imported water percentage, and the ratio of precipitation to evaporation as it has a direct effect on the quantity of the available water . In the same way, the second indicator; water access, is calculated by looking at how many people have access to piped water, how long the water is available each day, and how much water each person uses each day. Regarding the water quality indicator, it can be figured out from the percentage of samples of tap water that do not have any bacteria in them, according to WHO bacteria concentration should be between 0.02–0.5 mg/l (WHO, 2011).

When talking about the water availability and access indicators, Israel's role must be addressed, they put restrictions, which directly affect access to and availability of water. Israel owns water Company Mekorot and has systematically sunk wells and tapped springs in the occupied West Bank to supply their population, including those living in illegal settlements with water for domestic, agricultural and industrial purposes. Mekorot sells water to Palestine. As a result of continuous restrictions, Palestinian communities have no choice but to purchase water for Palestine (Amnesty International, 2009).

4.1.2 Dimension 2: Sanitation

Sewage and network access are two indicators used to look at sanitation as a whole. Only one thing is used to show the access indicator: how many homes in the city are connected to the drainage system (sewage coverage). Another way to look at the sewage indicator is to look at the sewage treatment factor (the ratio of treated wastewater to the total amount of wastewater generated in the city) and the amount of water used per person in the city.

4.1.3 Dimension 3: Water economy

In Hebron and Bethlehem, this dimension is employed to account for the productivity element of water security, as well as budget allocation for urban water supply and sanitation. It is represented by a single indicator, which indicates the water's economic worth. Non-revenue water (NRW) is a variable that is defined as produced or purchased water that is supplied but not paid for a variety of reasons, including technical losses from leakage, not billed water, illegal connections, poor water meter performance, and inaccurate reading and accounting of metered flows. The second variable is the price of water in dollars per cubic meter, with water fee collections (USD/m^3) as a third variable. As a result, by comparing these variables one to another and to the standards, we may scale the indicator.

4.1.4 Dimension 4: Ecosystem and environmental water security

This dimension is covered by three indicators, i.e., the state of water, watershed disturbance, and the water pollution indicator. The water indicator is evaluated by the natural water quality factor (the percent of microbiological tests of water within permissible limits). The second indicator, which is watershed disturbance which plays an important role in water quantity and quality, it is represented by one variable, which is livestock density. By knowing the livestock unit per km, the water pollution indicator is presented by four variables, which are salinity (the amount of salt dissolved in water in percentage or in parts per thousand (ppt) as the most common unit of measurement for salinity); fresh water has a salinity of less than 0.5 ppt.

Salinity levels in water bodies vary from 0.5 to 30 parts per million, depending on their length. Plants and animals are often sensitive to changes in salinity, and salinity levels influence local species composition. Droughts and storms can change salinity levels and signal events like increased urban runoff and sewer discharge. During these types of events, the condition of the water can change as the concentration of dissolved mineral salts rises (which tends to decrease general water quality) (Esteban et al., 1999).

The second pollution variable is Nitrate contamination. Nitrates can be found in water naturally, but high levels, which can be harmful to infants, are sometimes found. Nitrate levels in drinking water in Illinois have been set at 10 milligrams per liter (10 mg/l), which is a safe level for people to drink (Nitrogen). The nitrogen (N) standard of 10 mg/l is the same as the nitrate standard of 45 mg/l, so they are the same thing. Because there are so many possible sources of nitrates, it can be hard to find them. This includes runoff or seepage from fertilized agricultural land, waste water from cities and businesses, animal feedlots, septic tanks and private sewage disposal systems, urban drainage systems, dead plants, and other things that break down. Another factor that could affect nitrate concentrations is how the ground looks and where the groundwater flows. It is required by federal and state rules for public water systems to have nitrate tests done. However, high levels of nitrate can be found in private water wells. The WHO recommends that nitrate contamination be kept under permitted levels in 95% of samples collected over the course of a year (WHO, 2003).

Finally, total Coliforms contamination from source and network are the third and fourth variables of the pollution indicator. All warm-blooded animals and humans have coliform bacteria in their feces. Coliform bacteria rarely cause illness but their presence in water suggests the presence of pathogens (disease-causing organisms). The majority of infections found in water originate from human or animal waste. Testing water for pathogens is complicated, time consuming, and costly. Coliform testing is easy and cheap. The water systems examine the cause of pollution and restore clean drinking water if coliform bacteria are identified. Total Coliforms bacteria are abundant in the environment and are non-pathogenic. If total Coliforms bacteria are found in drinking water, the source is likely environmental, not fecal. However, diseases might infiltrate the system if contaminants are let in. The source of contamination must be identified and eliminated (Oram, 2007).

According to the World Health Organization, total Coliforms should not be found in any 100-mL sample. There can not be more than 5% of samples taken over a year if there are a lot of supplies and enough samples are looked at. We took two variables for total Coliforms (from source and from network), to know the source of contamination if there is any coliform found (WHO, 2011).

4.1.5 Dimension 5: Vulnerable populations

This dimension is represented by two indicators: the population indicator, which is applied to include the population density as well as growth rate variables for Hebron and Bethlehem cities, to link with water security in the cities. Overpopulation will put a strain on existing water resources, resulting in more pollution and conflict over limited water supplies. Water pollution will become more common as the region's and world's populations grow.

The second indicator is exposure, which is studied by the poverty rate variable to link with the water situation and other variables affecting water in the cities. Water scarcity causes water quality to deteriorate and pollution to occur, disproportionately affecting the poor. Many (possibly the majority) of the world's poorest people are forced to drink contaminated water. They suffer from a variety of skin conditions as well as other health problems. Having access to clean water, as well as proper sanitation and hygiene, can aid in poverty reduction, as access to clean water has the potential to save lives, boost economic growth, keep kids in school, and give women and girls more opportunities.Additionally, it is an excellent investment.

Ten indicators and their associated variables are used to represent these dimensions. Table 4.2 enlists dimensions, indicators, and the variables with sources of data, and how each variable is measured.

Table 4.2 Hebron and Bethlehem water security dimensions, indicators, and variables.

Dimension	Indicator	Variable	How to measure	Source
Water supply	Availability and natural context	Water availability	The amount of water available annually (m^3) per capita	PWA, WSSA
		Precipitation - Evaporation ratio	Ratio	PMD
		Imported water	Percentage of water imported from outside the city boundary for water supply	Hebron & Bethlehem municipalities
	Water access	Coverage	Percentage of city's population having access to piped water supply	Hebron & Bethlehem municipalities
		Supply duration	Hours in a day when water is available	JWU
		Water consumption	Liter per capita day (consumption)	PWA, WSSA
	Water quality	Residual chlorine	Percent samples with Residual Chlorine within the permissible limits	PWA, WSSA
		Safe water	Percent of samples of tap water free from bacterial contaminations	PWA, WSSA
Sanitation	Sewage	Sewage treatment factor	Wastewater treated/total wastewater generated in the city	PWA
	Access	Sewage coverage	Percentage of city's population having access to sewage system	Hebron & Bethlehem municipalities

Water Economy	Economic value of water	Non-revenue water (NRW)	Water lost/water produced (ratio)	PWA, WSSA
		Water price	USD/m3	Hebron municipality, WSSA
		Income	Collections of water fees "charges" (USD/m^3)	Hebron municipality, WSSA
Ecosystem and Environmental Water Security	Water state	Natural water quality factor	Percent of microbiological tests of water with permissible limits	PWA
	Watershed disturbance	Livestock density	Livestock unit per Square km	MoA
	Pollution	Salinity	Parts per thousand (ppt)	PWA
		Nitrate contamination	Percent of water samples free from Nitrate contamination to the tested of water samples	PWA
		Total Coliform (from source)	Percent of water samples (taken at the sources) free from total coliform to the tested of water samples (taken at the sources)	PWA
		Total Coliform (from network)	Percent of water samples (taken from network) free from total coliform to the tested of water samples (taken from Network)	PWA
Vulnerable Populations	Exposure	Population density	Persons per square meter	PCBS
		Growth rate	Percentage	PCBS
		Poverty rate	Percentage	Hebron & Bethlehem municipalities

Table 4.3 Benchmarking variables and their standards.

			Scale					
Indicator	**Variable**	**Unit**	**1 (Min)**	**2**	**3**	**4**	**5 (Max)**	**Source**
Availability and natural context	Water availability	m^3/capita/year	<50	50-80	80-100	100-170	>170	Aboelnagaet al., 2019
	Imported water	Percent	>60	40-60	40-20	20-10	<10	Hartmann, 1993
	Rainfall-Evaporation ratio	ratio	0.1-0.3	0.3-0.4	0.4-0.6	0.6-0.8	0.8-1	Aboelnaga et al., 2019
Water Access	Coverage	Percent	>60	60–70	71–80	81–90	91–100	A.A.D, 2016
	Water consumption	L/Capita.day	<20	20–50	51–90	91–100	>100	(Howard et al., 2003) and (WHO, 2021)
	Supply duration	Hours	<8	8–16	17–20	21–23	24	Assefa et al., 2018
Water Quality	Residual chlorine	Percent	<60	60–70	71–80	81–90	91–100	WHO, 2021
	Safe water	Percent	<60	60–70	71–80	81–90	91–100	Howard et al., 2003
Access	Sewage coverage	Percent	<60	60–70	71–80	81–90	91–100	Assefa et al., 2019
Economic value of water	Non-revenue water (NRW)	Percent	>25	25–20	20–15	15–10	<10	Sharma, 2008
	Water Price	USD/m^3	>1	1	0.75	0.5	<0.4	Assefa et al., 2019
	Income (Collections)	USD/m^3	>0.6	0.6-0.8	0.8-1.0	1.0-1.5	1.5-2	WSRC, 2022
Water state	Natural water quality factor	percent	<60	61–70	71–80	81–90	90–100	Babel et al., 2017
	Sewage treatment factor	Ratio	<60	61–70	71–80	81–90	90–100	Assefa et al., 2019

Watershed disturbance	Livestock density	Unit/km^2	>2500	1999-2500	2000-1499	1500-1000	<1000	Gilbert et al., 2018
Pollution	Salinity	ppt	>3.5	2-3	1-2	0.5-1	<0.5	Esteban et al., 1999
	Nitrate contamination - free	Percent	<75				>95	WHO, 2003
	Total Coliform (from source)-free	Percent	<75				>95	Oram, 2007
	Total Coliform (from network)-free	Percent	<75				>95	Oram, 2007
Exposure	Population density	Persons per square meter	>3000	3000-2000	2000-1500	1500-1000	<1000	Litman, 2016
	Growth rate	Percentage	>10	10-7.5	7.5-5	5-3	3-2	Kitov, 2008
	Poverty rate	Percentage	>10	7.5-10	5-7.5	2.5-5	<2.5	The Word Bank,2020

4.2 Standardization of Dimensions and Indicators

A primary step for finding the water security index is standardization of dimensions and indicators, as the indicators and dimensions in a data set often have different importance according to the situation of the city. An interview was done with Eng Ahmed Atrash from the water sector regulatory council to give a standard weight for every dimension and its related indicator, see Figure 4.2. The standard weight for dimensions and indicators will be summarized in the next points (WSRC, 2022).

❖ **Water Supply (50%)**

Water availability, access, and quality are the main indicators in water supply dimension.

➢ Availability of water (50%)

Bethlehem and Hebron buy their water from Israel through the West Bank water department.

➢ Water access (25%)

Is there a network and is it accessible to all residents? The network is critical to the water service's security.

➢ Water Quality (25%)

Water quality must be monitored on a regular basis to ensure that it is not contaminated at the source or throughout the network.

❖ **Water Economy (25%)**

It is an indication of the financial sustainability of the service

➢ Economic value of water (100%)

It has three variables, with non-revenue water serving as the primary indicator of the service's efficiency, and it is separated into two primary values: Physical deterioration "Water is squandered and seldom utilized and commercial losses "Water is utilized but in an irregular manner due to the fact that it is not included in the billing system, such as theft and unauthorized connections, the second variable is water price, which indicates the tariff that must be imposed in order to pay the costs related with water supply, the third variable is collections (income), which indicates how much the utility collects from its consumers when the entire amount of issued bills is taken into account.

❖ **Vulnerable Populations (15%)**

Indication of the demand and the expected increase

- ➢ Exposure (100%)

It contains three variables; population density, growth rate, and poverty rate which will give us an overview of the demand of water, affordability and willingness to pay which may impact the tariff and the financial sustainability of the service.

- ❖ **Sanitation (5%)**

It is not intrinsically linked to water security, but it is related to the environment and public health, and it has the potential to enhance the amount of water available if properly treated and reused.

- ➢ Access to sewage network (70%)

To handle wastewater properly, we need an effective collecting system.

- ➢ Treatment of wastewater (30%)

Have positive environmental and economical impacts if done correctly but this impact may flip to negative if the treatment facilities were improperly managed / designed.

- ❖ **Environmental water security (5%)**

This was not regarded as a main concern to the area of study; Bethlehem and Hebron as they depend on external water resources

- ➢ Water Pollution (60%)

It is not of major concern in Bethlehem and Hebron, but it does play a significant role when the utility is in control of its own resources.

- ➢ Water state (30%)

It can be also linked to the water pollution indicator, as it is the percent of microbiological tests of water with permissible limits.

- ➢ Watershed disturbance (10%)

Livestock density describes this indicator, it is an environmental variable which plays an important role in water quantity and quality.

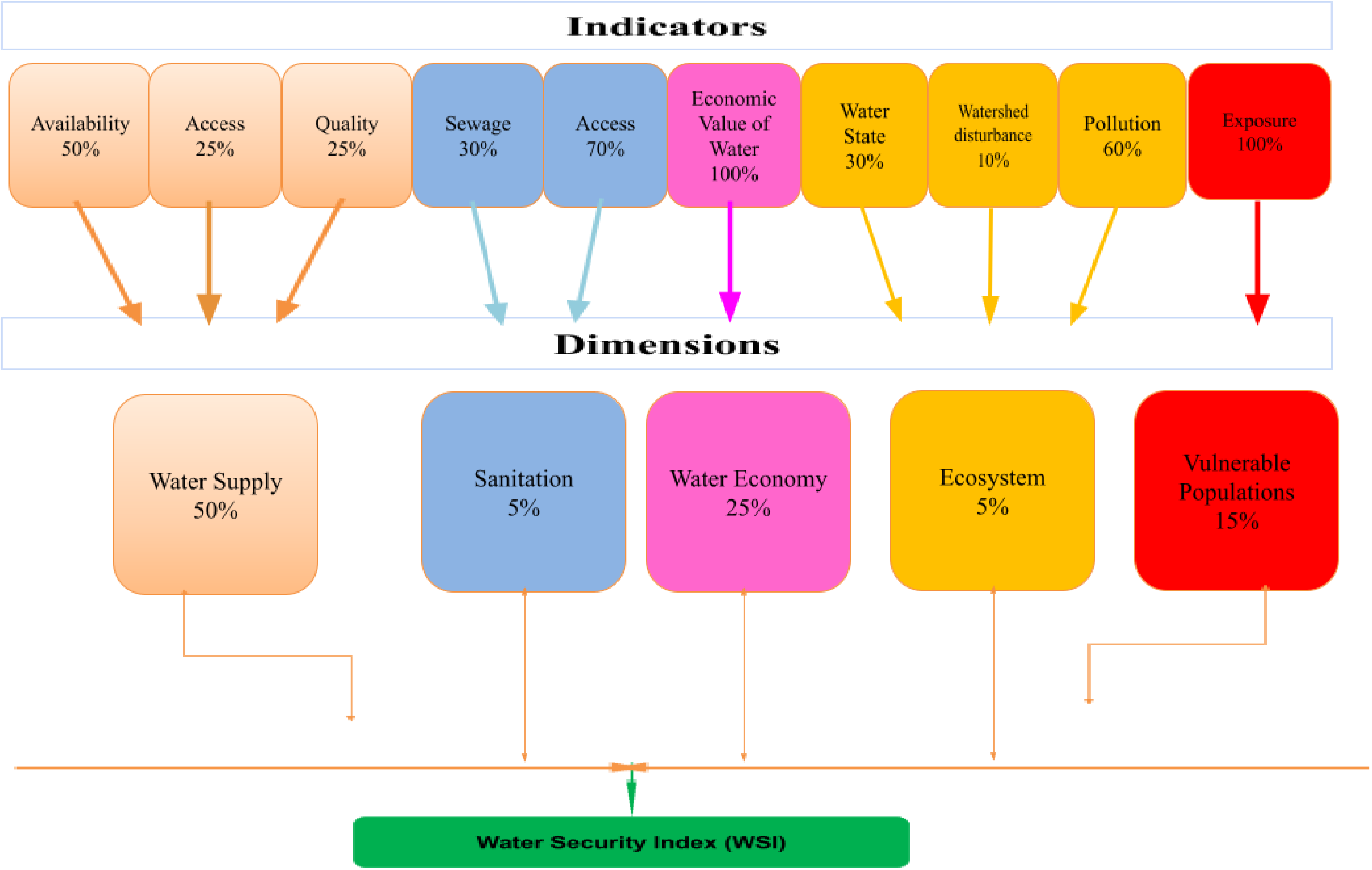

Figure 4.2 Flow chart of the procedure for obtaining the water security index and respective component weighting.

Chapter Five: Results and Discussion

In this chapter the results of the study are presented and discussed with reference to the aim of the study, which was to study and assess water security in the cities of Hebron and Bethlehem from Palestine by calculating the water security index , through a methodology based on dimensions and indicators.

5.1 Hebron and Bethlehem water security calculated variables

The variables associated with various indicators and dimensions were calculated as shown in Tables 5.1 and 5.2, taking variables that were not taken directly from the questionnaire for the years 2018-2020, such as the water availability variable and natural context indicator for water supply dimension. Water availability variable was calculated by dividing the amount of water produced annually in cubic meters by the city's population, which resulted in 37.48, 38.04, and 36.84 in Hebron for the years 2018, 2019, and 2020, respectively.

It was conducted to ascertain the number of persons in Hebron and Bethlehem who had access to sewage systems on sanitation dimension. For this, the number of people who had access to sewers was divided by the city's population, which was about 85% for the years 2018, 2019 and 2020 in Hebron. By taking the number of people who had access to the water pipe system and multiplying that number by the total number of people living in the city, the coverage variable was then found. The percent was 100% in Hebron, which is how many people had access to the water pipe system. Also, and for the first dimension; daily water consumption in liters per capita is the variable that was measured by dividing yearly water consumption by the total population in 365 days.

For pollution indicator, nitrate contamination, and total Coliforms are variables that took place. These variables were calculated as percent of water samples free from Nitrate contamination, free from total Coliforms from water source and free from total Coliforms from network and find the percent in comparison to the tested water samples, the score indicates that there is no pollution.

Going to the vulnerable populations dimension; population density, growth rate, and poverty variables were studied. I obtained the result for population density by knowing the number of people per square meter. The growth rate is the percent of the population in two consecutive years. Finally, the income and livestock density variables were calculated as shown in Tables 5.1 and 5.2. Income is the ratio between collections of water fees "charges" - USD to the amount of water produced annually (m^3) and livestock density which is a variable to describe watershed disturbance, was calculated as livestock unit per square meter in Hebron and Bethlehem cities.

Table 5.1 Different variables calculation scores for Hebron city.

City	**Hebron**		
Year	**2018**	**2019**	**2020**
Population	204,662	210,081	215,571
The amount of water produced annually (m3)	7,671,294	7,992,443	7,942,588
Water availability (m3/capita/year)	**37.48**	**38.04**	**36.84**
City's population having access to sewage system	176,000	180,000	180,000
Sewage coverage (Percent)	**86%**	**86%**	**84%**
City's population having access to improved piped water supply	204,662	210,081	215,571
Coverage (Percent)	**100%**	**100%**	**100%**
Water consumption (m3)	5,071,233	6,082,497	5,083,791
Water consumption (liters per capita per day)	**68**	**79.3**	**64.6**
Number of water samples tested for Nitrate contamination	120	40	43
Number of water samples free from Nitrate contamination	120	40	43
Percent of samples free from Nitrate contamination	**100%**	**100%**	**100%**

<table>
<tr><td>Number of water samples (taken from source) tested for Total coliform</td><td>128</td><td>118</td><td>114</td></tr>
<tr><td>Number of water samples (taken from source) free from Total coliform</td><td>123</td><td>118</td><td>114</td></tr>
<tr><td>Percent of samples free from Total coliform</td><td>96.0%</td><td>100.0%</td><td>100.0%</td></tr>
<tr><td>Number of water samples (taken from network) tested for Total coliform</td><td>262</td><td>272</td><td>214</td></tr>
<tr><td>Number of water samples (taken from network) free from Total coliform</td><td>260</td><td>270</td><td>211</td></tr>
<tr><td>Percent of samples free from Total Coliform (Taken from network)</td><td>99.0%</td><td>99.0%</td><td>98.5%</td></tr>
<tr><td>Population density (persons per square kilometer)</td><td>4873</td><td>5002</td><td>5133</td></tr>
<tr><td>Growth rate (Percent)</td><td>4.50%</td><td>2.65%</td><td>2.61%</td></tr>
<tr><td>Collections of water fees "charges" - USD</td><td>4,468,725</td><td>4,734,835</td><td>4,205,204</td></tr>
<tr><td>The amount of water produced annually(m3)</td><td>7,671,294</td><td>7,992,443</td><td>7,942,588</td></tr>
<tr><td>Collections of water fees "charges" (USD/m^3)</td><td>0.58</td><td>0.59</td><td>0.53</td></tr>
<tr><td>Precipitation (mm/year)</td><td>616.7</td><td>394</td><td>757</td></tr>
<tr><td>Evaporation (mm/year)</td><td>1,936</td><td>1,791</td><td>2,008</td></tr>
<tr><td>Precipitation - Evaporation ratio</td><td>0.31</td><td>0.22</td><td>0.38</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td rowspan="2">Livestock density</td><td>Total Number</td><td>Area (km^2)</td><td>Livestock unit per km^2</td></tr>
<tr><td>146,220</td><td>42</td><td>3,480</td></tr>
</table>

Table 5.2 Different variables calculation scores for Bethlehem city.

City	Bethlehem		
Year	**2018**	**2019**	**2020**
Served population	116,157	114,280	111,365
The amount of water produced annually (m3)	5,446,023	5,904,403	5,806,111
Freshwater resource (m^3/capita/year)	**46.5**	**51.66**	**52.13**
City's population having access to sewage system	81,301	81,301	77,856
Sewerage coverage (Percent)	**70%**	**71%**	**70%**
City's population having access to improved piped water supply	116,157	114,280	111,365
Coverage (Percent)	**100%**	**100%**	**100%**
Water consumption (m^3)	3,359,443	3,478,447	4,335,585
Water consumption (liters per capita per day)	**79.23**	**83.4**	**106.7**
Number of water samples tested for Nitrate contamination	10	12	13
Number of water samples free from Nitrate contamination	10	12	13
Percent of samples free from Nitrate contamination	**100%**	**100%**	**100%**
Number of water samples (taken from source) tested for Total coliform	94	108	110
Number of water samples (taken from source) free from Total coliform	94	108	110
Percent of samples free from Total coliform	**100%**	**100%**	**100%**
Number of water samples (taken from network) tested for Total coliform	226	264	268

Number of water samples (taken from network) free from Total coliform	226	264	268
Percent of samples free from Total coliform (taken from network)	**100%**	**100%**	**100%**
Bethlehem city population	28,963	29,593	30,233
Population density (persons per square kilometer)	**1270**	**1298**	**1326**
Growth rate (Percent)	**0.30%**	**2.17%**	**2.16%**
Collections of water fees "charges" - USD	4,271,520	5,138,241	3,680,750
The amount of water produced annually(m^3)	5,446,023	5,904,403	5,806,111
Collections of water fees "charges" (USD/m^3)	**0.79**	**0.88**	**0.64**
Precipitation (mm/year)	517	493	811
Evaporation (mm/year)	2,001	1,842	2,257
Precipitation - Evaporation ratio	**0.26**	**0.27**	**0.36**
Livestock density	**Total Number**	**Area (km^2)**	**Livestock unit per km^2**
	34,319	22.8	1,500

5.2 Dimensions and Indicators Result

Indicator scores were measured by taking an average score for every variable, and then dimension scores were calculated by measuring a weighted average score for the indicators. We noticed that some water security variables earned a perfect score of 5, while others received a poor score. The next sections classify the scores for both cities along with their respective standard scores according to Table 4.3. Figures 5.1 and 5.3 summarize the results of the variables. Figures 5.2 and 5.4 depict the outcomes of the water security dimensions in Hebron and Bethlehem cities, with their significance.

5.2.1 Water Supply Dimension Score

According to the standards outlined in the methodology, the score for dimension one, water supply in Hebron was 2.58, with a score of 1 for availability and the natural context indicator, which is a poor score due to a lack of available water, a high percentage of imported water, and a low precipitation evaporation ratio. The second indicator, water access, got a score of 3.33 due to excellent water network coverage in the city and average water consumption for residents with low supply duration hours. The third indicator of the water supply dimension, water quality, received a full score because the quality of supplied water is good; this results in a 2.58 for the first dimension (See Table 5.3).

The score for dimension one for Bethlehem was 2.83 with a score of 1.3 for availability and natural context indicator, which is a poor score due to lack of available water, high percent of imported water, and low precipitation evaporation ratio. The second indicator, which is water access, got a score of 3.7 with excellent water network coverage in the city and average water consumption for inhabitants with low supply duration hours. The third indicator of the water supply dimension is water quality indicator, and it got a full score since the quality of supplied water is good; this led to a 2.83 score for the first dimension as shown in Table 5.4.

In comparison with the previous studies, water supply got a very high score in Shanghai city. The availability of water is about 140 liters per capita, which indicates that the availability indicator meets WHO standards and there is no imported water since they depend on rivers in the city and the accessibility and coverage is more than 95% (Zhu and Chang, 2020).

Table 5.3 Water Supply variables, indicators and dimension Scores for Hebron city.

Indicator (Weight)	Variable	Unit	2018	2019	2020	Variable average	Score	Indicator score	Dimension score
Availability and natural context (50%)	Water availability	m^3/capita/year	37.48	38.04	36.84	37.45	1	1.00	2.58
	Imported water	ratio	100%	100%	100%	100%	1		
	Precipitation - Evaporation ratio	Percent	0.31	0.22	0.38	0.30	1		
Water Access (25%)	Coverage	Percent	100%	100%	100%	100%	5	3.33	
	Water consumption	Liters per capita per day	68	79.3	64.6	70.63	3		
	Supply duration	Hours	12	12	24	16.00	2		
Water Quality (25%)	Residual chlorine	Percentage	94%	95%	95%	95%	5	5.00	
	Safe water	Percentage	99%	99%	98%	99%	5		

Table 5.4 Water Supply variables, indicators and dimension Scores for Bethlehem city.

Indicator (Weight)	Variable	Unit	2018	2019	2020	Variable average	Score	Indicator score	Dimension score
Availability and natural context (50%)	Water availability	m^3/capita/year	46.5	51.66	52.13	50.10	2	1.3	2.83
	Imported water	Ratio	100%	100%	100%	100%	1		
	Precipitation - Evaporation ratio	Percentage	0.26	0.27	0.36	0.30	1		
Water Access (25%)	Coverage	Percentage	100%	100%	100%	100%	5	3.7	
	Water consumption	Liters per capita per day	79.23	83.4	106.7	89.78	3		
	Supply duration	Hours	11	24	24	19.67	3		
Water Quality (25%)	Residual chlorine	Percentage	100%	100%	100%	100%	5	5.0	
	Safe water	Percentage	92%	100%	98%	97%	5		

5.2.2 Sanitation Dimension Score

Two indicators were used in the second dimension, sewage and access. In Hebron and as Table 5.5 shows, the sewage indicator received a one-point score due to the lack of water treatment in the city, while the access indicator received a four-point score due to excellent sewage coverage, by taking the weighted average for both indicators, the result is 3.1 score in the water security index.

Table 5.5 Sanitation variables, indicators and dimension Scores for Hebron city.

Indicator (Weight)	Variable	Unit	2018	2019	2020	Variable average	Score	Indicator score	Dimension score
Sewage (30%)	Sewage treatment factor	Percentage	0	0	0	0	1	1.00	3.1
Access (70%)	Sewage coverage	Percentage	86.00%	86.00%	83.50%	85.17%	4	4.00	

For Bethlehem, Table 5.6 mentions the score for the sanitation dimension; the sewage indicator has a one-point score because of the absence of treatment for water in the city, while the access indicator got a two point score with low sewage network coverage, so that by taking the weighted average for both indicators, the result for sanitation dimension in Bethlehem city is 1.7.

Table 5.6 Sanitation variables, indicators and dimension Scores for Bethlehem city.

Indicator (Weight)	Variable	Unit	2018	2019	2020	Variable average	Score	Indicator score	Dimension score
Sewage (30%)	Sewage treatment factor	Number	0	0	0	0	1	1.0	1.7
Access (70%)	Sewage coverage	Percentage	70.00%	71.00%	70.00%	70.33%	2	2.0	

In a study done for Asia-Pacific countries, the score for the sanitation dimension varies from one country to another. For example, sanitation access in Afghanistan is only 37% while in Armenia it is 90%, which gives a score of 1 from 5 in the national security index (Asian Water Development Outlook, 2013). In the same study, the wastewater treatment percentage in Georgia is only 74%, but in Australia it is 96%, with an index score of 3 and 5 respectively (Asian Water Development Outlook, 2013).

5.2.3 Water Economy Dimension Score

When it comes to the third dimension, water economy, the economic value of water is very low in Hebron because the percentage of non-revenue water is very high according to the methodology's standards, as well as the water price is very high and fee and charge collections are very low, especially when considering the high percentage of imported water as described in dimension one, giving it a score of 1. Table 5.7 illustrates the water economy dimension in Hebron which received a score of one.

Table 5.7 Water Economy variables, indicators and dimension Scores for Hebron city.

Indicator (Weight)	**Variable**	**Unit**	**2018**	**2019**	**2020**	**Variable average**	**Score**	**Indicator score**	**Dimension score**
Economic value of water (100%)	Non-revenue water (NRW)	Percentage	34%	24%	36%	31%	1	1.00	1.0
	Water Price	USD/m^3	1.66	1.45	1.66	1.59	1		
	Income (Collection)	USD/m^3	0.58	0.59	0.53	0.57	1		

Studying the third dimension in Bethlehem city, which is water economy, the economic value of water was very low also, since the percent of non-revenue water was very high, the water price was very high, and the collections of fees and charges were very low, especially by taking into consideration the high percentage of imported water as described in dimension one, so that the economic value of water has a score of 1.3. See Table 5.8.

Table 5.8 Water Economy variables, indicators and dimension Scores for Bethlehem.

Indicator (Weight)	**Variable**	**Unit**	**2018**	**2019**	**2020**	**Variable average**	**Score**	**Indicator score**	**Dimension score**
Economic value of water (100%)	Non-revenue water (NRW)	Percentage	38%	41%	25%	35%	1	1.3	1.3
	Water Price	USD/m^3	1.97	1.91	1.72	1.87	1		
	Income (Collection)	USD/m^3	0.79	0.88	0.64	0.77	2		

In research for Bangkok city which is "Measuring water security: A vital step for climate change adaptation". The economic value of water in Bangkok was 5 of water security index, in 2007, 2011, and 2015, which is a perfect result since the percentage of non-revenue water is very low and the water price to the consumers got a score of five (Babel et al., 2020).

5.2.4 Ecosystem and Environmental Water Security Dimension Score

In general, we can say that ecosystem and environmental water security achieved a very good score in Hebron as shown in Table 5.9. However, the problem is watershed disturbance, where livestock density is extremely high in comparison to the standards. Although the water is of good quality, we can state that there is no pollution in it, as well as salinity, nitrate contamination, and total Coliforms contamination. The dimension's score is 4.6.

Table 5.9 Ecosystem and environmental water security variables, indicators and dimension Scores for Hebron.

Indicator (Weight)	**Variable**	**Unit**	**2018**	**2019**	**2020**	**Variable average**	**Score**	**Indicator score**	**Dimension score**
Water state (30%)	Natural water quality factor	Percentage	90%	93%	86%	90%	5	5.00	

Watershed disturbance (10%)	Livestock density	Number	3,480			3,480	1	1.00	4.6
Pollution (60%)	Salinity	ppt	0	0	0	0	5	5.00	
	Nitrate contamination	Percentage	100.00%	100.00%	100.00%	100.00%	5		
	Total Coliform (from source)	Percentage	96.00%	100.00%	100.00%	98.67%	5		
	Total Coliform (from network)	Percentage	99.00%	99.00%	98.50%	98.83%	5		

In Bethlehem, the ecosystem and environmental water security dimensions are almost the same as in Hebron, with a very good score as shown in Table 5.10. The WSI score for the dimension is 4.2.

Table 5.10 Ecosystem and environmental water security variables, indicators and dimension Scores for Bethlehem.

Indicator (Weight)	Variable	Unit	2018	2019	2020	Variable average	Score	Indicator score	Dimension score
Water state (30%)	Natural water quality factor	Percentage	77%	75%	80%	77%	3	3.0	4.2
Watershed disturbance (10%)	Livestock density	Number	1,500			1,500	3	3.0	
Pollution (60%)	Salinity	ppt	0	0	0	0	5	5.0	
	Nitrate contamination	Percentage	100%	100%	100%	100%	5		

	Total Coliform (from source)	Percentage	100%	100%	100%	100%	5		
	Total Coliform (from network)	Percentage	100%	100%	100%	100%	5		

In a comparison with the result of this dimension for Pakistan's capital; the score for this dimension for Islamabad is 1.75, which indicates that the dimension shows serious concern with polluted ground and river water with an impermissible amount of heavy metals found in water and a poor water quality factor (Khan et al., 2020).

5.2.5 Vulnerable populations Dimension Score

The final dimension is vulnerable populations, which comprises two indicators: population and exposure. In Hebron; the population indicator has a score of 2.5 because the population density is extremely high in comparison to the range of standards, and the growth rate variable is excellent. With a score of 4, the poverty rate variable describes an exposure indicator; the poverty rate is extremely high, which has an impact on water security. The water security index for this dimension has a final score of 2.0. See Table 5.11.

Table 5.11 Vulnerable populations variables, indicators and dimension Scores for Hebron city.

Indicator (Weight)	Variable	Unit	2018	2019	2020	Variable average	Score	Indicator score	Dimension score
Exposure (100%)	Population density	Persons per square meter	4,873	5,002	5,133	5,003	1	2.00	2.00
	Growth rate	Percentage	4.50%	2.65%	2.61%	3.25%	4		
	Poverty rate	Percentage	20.30%	21.00%	19.30%	20.20%	1		

Table 5.12 shows the final score of the water security index for this dimension in Bethlehem. The exposure indicator has a score of 4.5 since the population density is in the best range compared to standards and the growth rate variable is very good with a score of 5. However, the poverty rate is very high, the final score of the dimension is 4.5.

Table 5.12 Vulnerable populations variables, indicators and dimension Scores for Bethlehem city.

Indicator (Weight)	**Variable**	**Unit**	**2018**	**2019**	**2020**	**Variable average**	**Score**	**Indicator score**	**Dimension score**
Exposure (100%)	Population density	Persons per square meter	1,270	1,298	1,326	1,298	4	4.5	4.50
	Growth rate	Percentage	0.30%	2.17%	2.16%	1.54%	5		
	Poverty rate	Percentage	9.40%	10.20%	10.40%	10.00%	1		

The Asian Water Development Bank did a vulnerability and hazard study for Asia-Pacific countries, by studying the exposure and population vulnerability of the countries by taking population density, growth rate, poverty rate, and land use variables. The results for the countries varied. For example, in Uzbekistan, the index of this dimension was 2. However, in Singapore it was 4 (Asian Water Development Outlook, 2013).

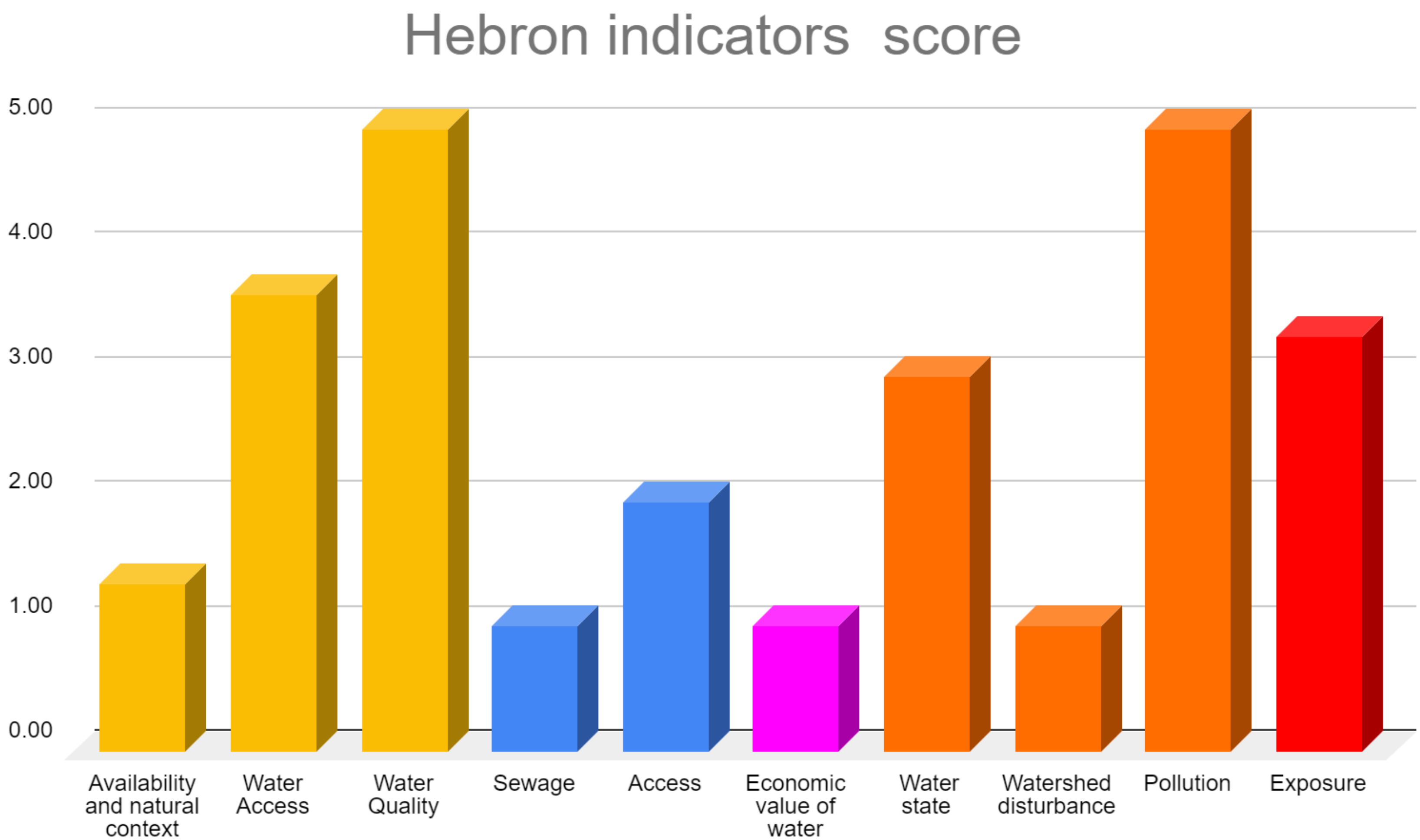

Figure 5.1 Hebron city indicators score.

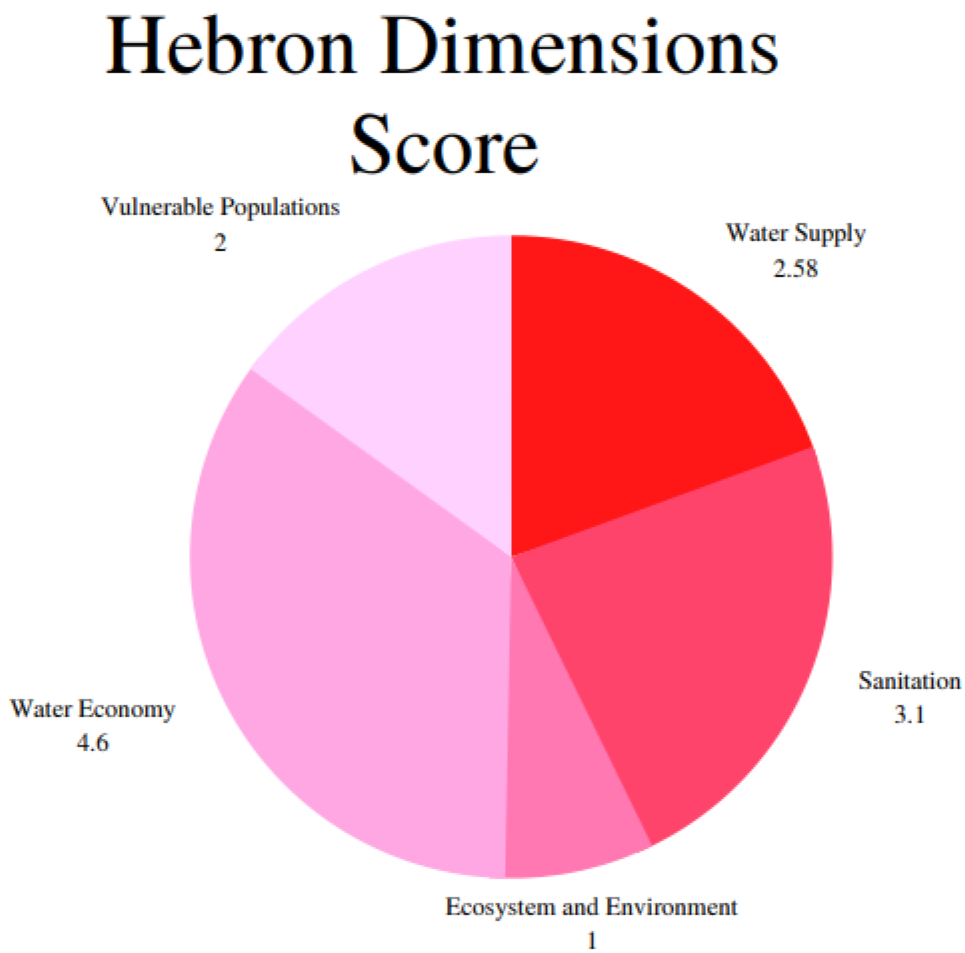

Figure 5.2 Hebron's dimensions score.

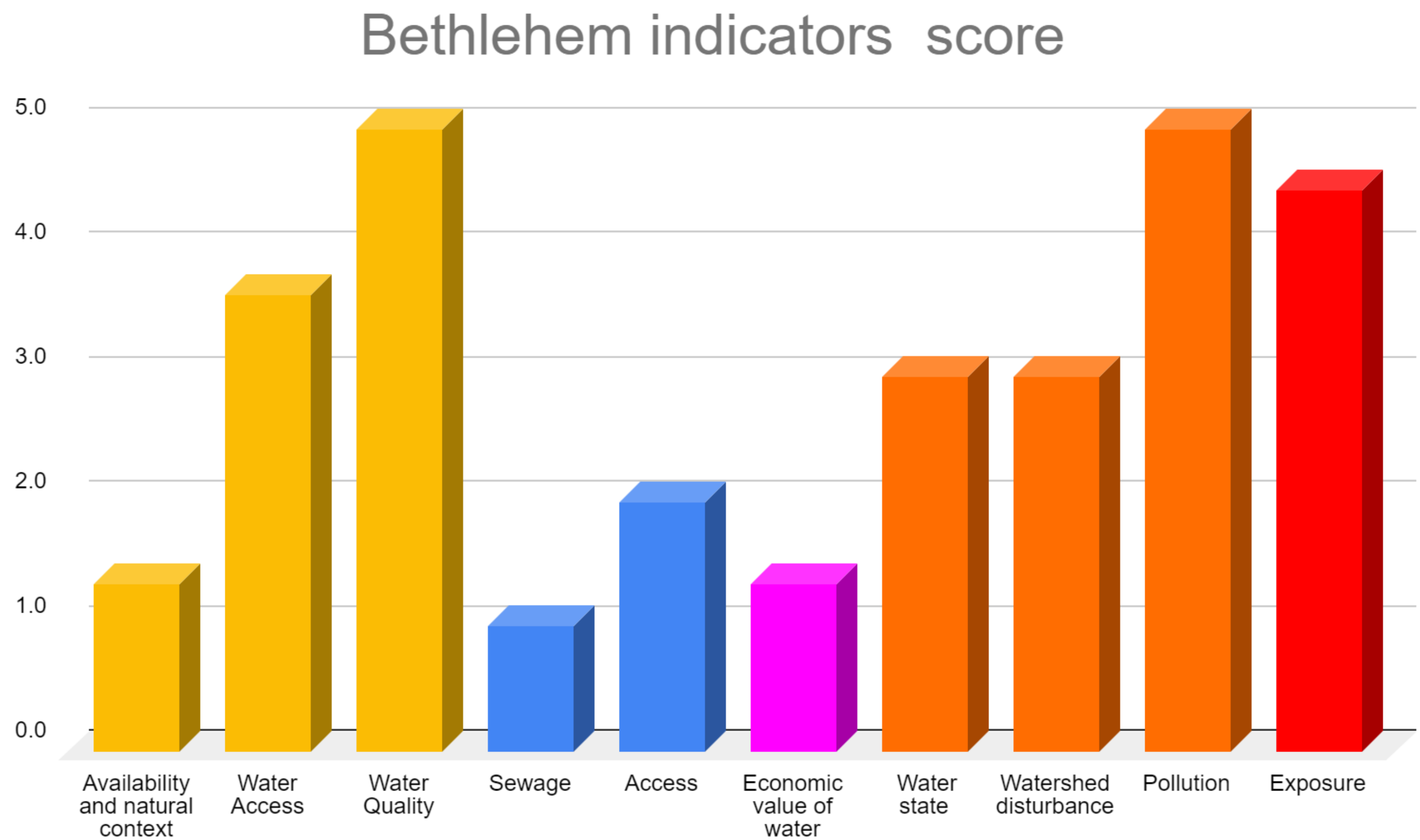

Figure 5.3 Bethlehem city indicators score.

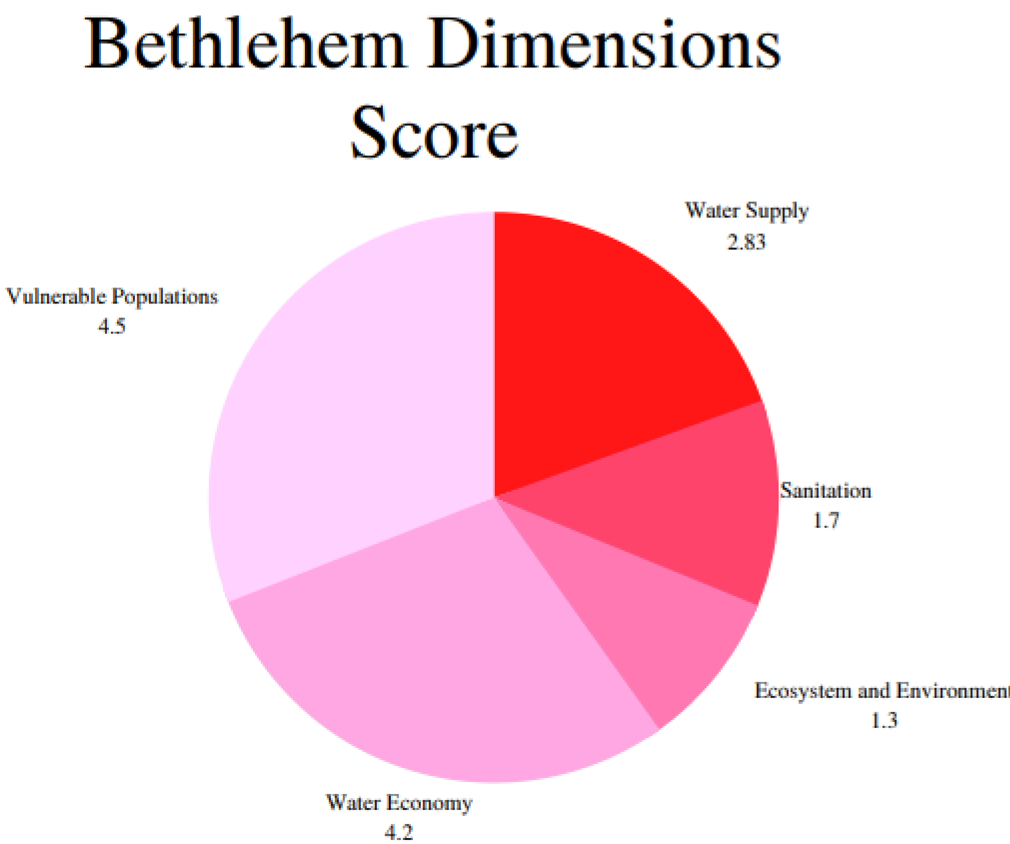

Figure 5.4. Bethlehem's dimensions score.

When comparing the findings for both cities (Hebron and Bethlehem), the dimensions were quite comparable for a variety of reasons. They are similar in terms of the status of the water and the technique used to get it, as well as their physical state.

Regarding water supply, the result in Hebron was 2.58, whereas it was very close in Bethlehem with a score of 2.83. Sanitation was much better in Hebron than in Bethlehem, owing to greater access to sanitation in Hebron, which resulted in a 3.1 and 1.7 score for sanitation dimensions in both cities, respectively. Going to the third dimension, water economy, the scores were quite low in both cities, with Hebron scoring a 1 and Bethlehem scoring a 1.3.

The most successful dimension was ecosystem and environmental water security; it received a score of 4.6 in Hebron and 4.2 in Bethlehem. The last dimension (vulnerable populations) differs between the two cities owing to the high population density in Hebron Bethlehem and the low population density in Bethlehem, resulting in a score of 2 in Hebron and 4.6 in Bethlehem, as Figure 5.5 shows.

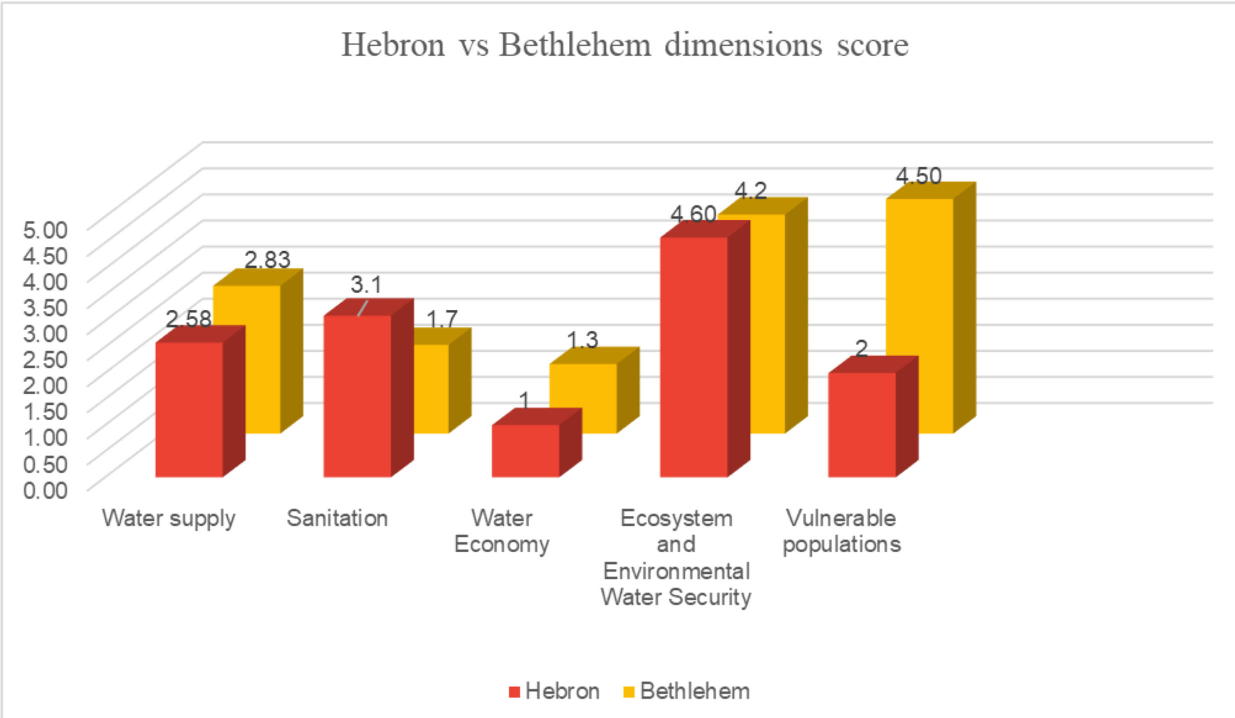

Figure 5.5 Hebron and Bethlehem dimensions score.

5.3 Water Security Index

Using the Water Security Index (WSI), you may learn about the water security paradigm in a certain location. So that we could acquire an overall picture of the water situation in both cities. One or more indicators were studied to indicate five distinct aspects of water security. Each indicator's value was calculated on a 1 to 5 scale based on a variety of variables. Table 5.13 shows the final water security index result for Hebron and Bethlehem cities are 2.5, indicating that the both cities' water situations are poor, with nearly every aspect being a major source of concern. And both cities' water resources are not properly managed.

Table 5.13 Water security index result for Hebron and Bethlehem cities.

Dimension (Weight)	Hebron Dimensions Score	Bethlehem Dimensions Score
Water supply (50%)	2.58	2.83
Sanitation (25%)	3.1	1.7
Water Economy (15%)	1	1.3
Ecosystem and (5%) Environmental Water Security	4.60	4.2
Vulnerable populations (5%)	2	4.50
Final WSI score	**2.5**	**2.5**

Chapter Six: Conclusions and Recommendations

The conclusions drawn from this study's results on the water security situation in Palestine's Hebron and Bethlehem cities, as well as the water security dimensions that need improvement, are discussed in this chapter. Recommendations will follow the conclusions, recommendations were given in consideration of the study's findings and objectives.

6.1 Conclusions

This study evaluated the current state of water security in Hebron and Bethlehem cities from a variety of perspectives, including water supply, sanitation, water economy, ecosystem and environmental water security, and vulnerable populations. We applied the water security assessment at a city scale methodology to find an index that reflects water security.

The findings were divided into indicator results, dimension results, and water security index result in order to evaluate and improve each indicator separately with the possibility of studying it and developing ways to solve the problems of the indicator separately, which would contribute to the development of weak dimensions. Standard weights were assigned to the dimensions and indicators in order to determine which one would have the most impact on the outcome.. The study concluded that Hebron and Bethlehem cities both scored 2.5 on the water security index. Referring to table 4.3, this score indicates that the cities have a poor water system with a lack of an adequate system and environment to promote water security; practically every dimension is a major source of concern. Most aspects of water security require prompt and vigorous intervention from authorities because the water resources are not under the control of either Hebron municipality, WSSA or even the Palestinian authority , they are under Israeli control and the quantities have been set and since the political situation is fragile it is very hard to increase the quantities received from Israeli . In terms of water supply and environmental water security, Hebron and Bethlehem score reasonably well, indicating that the majority of the population has access to adequate water services with excellent water quality, in spite of poor availability and a complete dependence on imported water from Mekorot which is the national water company of Israel. According to WSRC the water quality received from Mekorot is of good quality, but Also Bethlehem and Hebron are two of the few utilities with an active lab for testing water and they do frequently test the water from their network and with a clean resource and robust measures from the utility the Quality is assured (WSRC, 2021). Poor evaporation precipitation ratio and Israeli occupation are the main reasons why water availability is poor. Since Hebron has more livestock density they need more water and therefore it is poor in Hebron and good in Bethlehem. We can say that there is no pollution in the water, salinity, nitrate contamination, and total Coliforms got a score of 5.

Sewage network coverage varies for the two cities, since it covers about 85% in Hebron and only 70% in Bethlehem. The sanitation dimension needs an improvement, especially since there is an absence of treatment facilities in the cities. In addition, both cities have a high percentage of non-revenue water and low collection efficiency, with high water price, making poor financial sustainability of the service.

Another weak point that appears to be jeopardizing the city's water security is vulnerability to population due to the high poverty rate, which affects water conditions in the cities on different scales. The population indicator also affects water security, referring to table 5.11 and 5.12; population density measures well in Bethlehem and poor in Hebron. Hence, while the framework's dimensions and indicators are fixed, we can choose cities' own variables based on their context. As a result, it can be concluded that water security in Hebron and Bethlehem is likely to be affected by many factors such as non-revenue water and the lack of modern technologies, in addition to the Israeli occupation, in the largest way because there is no access groundwater (only two wells in Hebron, but they are closed) (WSRC, 2021).

Finally, it can be said that the dimensions are interrelated together, so improving an indicator in one dimension would improve indicators in other dimensions. Therefore, the water security will be better and Hebron and Bethlehem cities will progress and perform considerably well in most aspects of water security.

6.2 Recommendations

There are several recommendations that can be adopted in order to improve water security in the two study areas; these recommendations should be interconnected and comprehensive for all dimensions of water security, by providing observations or solutions for the different indicators in order to reach a better result for the water security index and thus a better water security in Hebron and Bethlehem cities. To achieve a better water situation in the cities of Hebron and Bethlehem, the following recommendations are derived:

- Enhancing water availability requires significant efforts in looking for new water resources such as artesian wells, ground water, etc, hence, reducing the dependency on the imported water.
- Governments and municipalities should prioritize infrastructure improvements and water pumping systems and networks to guarantee a better water coverage, increase supply duration .Thus,provide fair distribution of water for all communities in the area of service
- Define and allocate a budget to establish water treatment systems and provide support to these systems and monitor water treatment projects by a dedicated team from the Palestinian water authority; in conjunction with service providers engagement. Moreover a national strategy should be implemented and managed effectively to improve the sewage network system.
- It is recommended that proposed strategies be designed to determine the extent, category, and location of non-revenue water, and then devise prioritized plans that represent the most cost-effective way to achieve reductions. A variety of processes, such as dividing the water network into sections, rapid assessment and repair, monitoring network activities, taking control of the network pressure, and other measures, may be implemented. To combat illicit consumption.
- exploiting surface and groundwater, which would contribute to reducing water imports and the price of water to meet international standards.
- Raise social awareness of the importance of being the water bills systematically and rational water consumption should be encouraged. The government should address excessive water consumption.

- The exchange of know-how and resource strategies, as well as development assistance and private sector investment, will all provide opportunities to reduce poverty which will prevent conflicts over water resources in addition to guarantee a better water access for all community members.

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Appendices

Appendix 1 List of Institutions that have been contacted

Agricultural Development Association (PARC)

Bethlehem Municipality

Hebron Municipality

Ministry of Agriculture (MOA)

Palestinian Central Bureau of Statistics (PCBS)

Palestinian metrological department (PMD)

Palestinian Water Authority (PWA)

The Joint Water Committee (JWC)

Water Supply and Sewage Authority (WSSA)

West Bank Water Department (WBWD)

Appendix 2 Questionnaire

		Hebron			Bethlehem		
No	**Question**	**2018**	**2019**	**2020**	**2018**	**2019**	**2020**
1	The amount of water produced annually(m3)						
2	Percentage of water imported from outside the city boundary for water supply						
3	Mean temperature (celsius)						
4	Rainfall (mm/Year)						
5	Evaporation Quantity (mm)						
6	City's population having access to improved piped water supply						
7	Hours in a day when water is available						
8	Percent samples with Residual Chlorine within the permissible limits						
9	Percent of samples of tap water free from bacterial contaminations						
10	Total wastewater generated in the city (m3)						
11	Water consumption (m3)						
12	City's population having access to sewage system						
13	Percent of Water lost (leakage and theft etc.) (Non Revenue Water)						
14	The average price of of water (USD/m3)						
15	Collections of water fees						

	"charges" - USD						
17	Number of microbiological tests of water with permissible limits						
18	Number of microbiological tests of water carried out						
19	Total livestock (number of cows, sheep and sheep)						
20	Water salinity (ppt)						
21	Number of water samples tested for nitrate contamination						
22	Number of water samples free from nitrate contamination						
23	Number of water samples (taken from source) tested for total coliform						
24	Number of water samples (taken from source) free from total coliform						
25	Number of water samples (taken from network) tested for total coliform						
26	Number of water samples (taken from network) free from total coliform						
27	Poverty rate in the city (Percentage)						

Appendix 3 Table with All Data

	Hebron				Bethlehem			
Unit	**2018**	**2019**	**2020**	**Avg**	**2018**	**2019**	**2020**	**Avg**
m3/capita/year	37.48	38.04	36.84	37.45	46.5	51.66	52.13	50.10
Ratio	100%	100%	100%	100%	100%	100%	100%	100%
Percentage	0.31	0.22	0.38	0.30	0.26	0.27	0.36	0.30
Percentage	100%	100%	100%	100%	100%	100%	100%	100%
l/capita.day	68	79.3	64.6	70.63	79.23	83.4	106.7	89.78
Hours	12	12	24	16.00	11	24	24	19.67
Percentage	94%	95%	95%	95%	100%	100%	100%	100%
Percentage	99%	99%	98%	99%	92%	100%	98%	97%
Number	0	0	0	0	0	0	0	0
Percentage	86.00%	86.00%	83.50%	85.17%	70.00%	71.00%	70.00%	70.33%
Percentage	34%	24%	36%	31%	38%	41%	25%	35%
USD/m3	1.66	1.45	1.66	1.59	1.97	1.91	1.72	1.87
USD/m3	0.58	0.59	0.53	0.57	0.79	0.88	0.64	0.77
Number	90%	93%	86%	90%	77%	75%	80%	77%
Number	3,480			3,480	1,500			1,500
ppt	0	0	0	0	0	0	0	0
Percentage	100.00%	100.00%	100.00%	100.00%	100%	100%	100%	100%
Percentage	96.00%	100.00%	100.00%	98.67%	100%	100%	100%	100%
Percentage	99.00%	99.00%	98.50%	98.83%	100%	100%	100%	100%
Persons per square meter	4,873	5,002	5,133	5,003	1,270	1,298	1,326	1,298
Percentage	4.50%	2.65%	2.61%	3.25%	0.30%	2.17%	2.16%	1.54%
Percentage	20.30%	21.00%	19.30%	20.20%	9.40%	10.20%	10.40%	10.00%