VNU Journal of Science: Earth and Environmental Sciences, Vol. 41, No. 2S (2025) 283-290

VNU Journal of Science: Earth and Environmental Sciences

Journal homepage: https://js.vnu.edu.vn/EES

Original Article

Assess Water Usage Behavior and Calculate Personal Water Footprint of Lang Son Province Residents

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Received 08th August 2025
Revised 15th September 2025; Accepted 30th September 2025

Abstract: This study aims to assess water usage behavior and calculate the personal water footprint (WF) of residents in Lang Son province. A self-administered survey of water users was conducted for citizens in four wards from February to March 2025. The research develops a questionnaire to calculate personal WFs for Lang Son province using a cross-sectional approach. The results show that the average WF was 6030.41 liters per capita per day (LPCD), of which the direct WF was 464.32 LPCD and the virtual WF was 5566.10 LPCD. The daily water usage behavior of the residents is less than optimal. The study also indicates a significant average difference in WFs among different age groups and living areas. Based on these findings, the research provides recommendations and solutions to raise community awareness about the importance of water conservation, encourage a shift toward sustainable water usage behaviors, and propose effective water resource management policies.

Keywords: water footprint, personal water footprint, water usage behavior.

1. Introduction

Water is an invaluable resource and is often regarded as inexhaustible, forming the foundation of all life on Earth. Its role extends beyond sustaining life, it is an essential driver of most economic activities and transportation to livestock, water is present and makes an indispensable contribution. 71% of Earth is covered by oceans which contain 97.5% of the total water. Land contains 2.5% of the total water. A major part (1.9% of the total) of water occurs as ice caps and glaciers. The remaining (0.6% of the total) support total life. It is called fresh water (Water with salt content less than 0.5%). More than 90% of this fresh water is found underground as ground water. The remaining 10% fresh water occurs as surface

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https://doi.org/10.25073/2588-1094/vnuees.5415

water (rivers, dams, lakes, ponds) soil water and water vapour present in the atmosphere [1]. The increasing population in the world also pressures natural resources by increasing demand for energy and water. Projections indicate that the number of individuals with inadequate water access could reach approximately 4 billion by 2030 [2].

Population growth at national and global scales intensifies demand for freshwater resources. Moreover, the population of Vietnam reached more than 100 million people in 2024 [3]. Population increase may create environmental issues such as diminishing freshwater supplies. Domestic water use share is around 11% in the world [4] and domestic water use share in Vietnam is 9% [5]. Actions should be taken to decrease domestic water use which in return help to save water that is already diminishing. Vietnam has the high levels of water security threaten for several reason such as: water pollution, population growth, the depletion of water resources, the rising temperatures due to climate change and the lack of awareness of consumption in people's everyday life have become critical issues both in the present and for the future. Therefore, it is crucial to reduce water consumption across different sectors including domestic consumptions to mitigate these problems.

The water footprint (WF), introduced by Arjen Hoekstra, is a comprehensive indicator of freshwater use, capturing both direct and indirect consumption throughout the lifecycle of goods and services [6]. It consists of three components: Blue WF (water that has been sourced from surface or groundwater resources and is either evaporated, incorporated into a product or taken from one body of water and returned to another, or returned at a different time). Irrigated agriculture, industry and domestic water use can each have a blue WF. Green WF (water from precipitation that is stored in the root zone of the soil and evaporated, transpired, or incorporated by plants). It is particularly relevant for agricultural, horticultural and forestry products.). Grey WF (the amount of fresh water required to assimilate pollutants to meet specific water quality standards). The grey WF considers point-source pollution discharged to a freshwater resource directly through a pipe or indirectly through runoff or leaching from the soil, impervious surfaces, or other diffuse sources. The WF looks at both direct and indirect water use of a process, product, company, or sector and includes water consumption and pollution throughout the full production cycle from the supply chain to the end-user.

The WF can be calculated in terms of water used in the production process of a product, shipment, and supply chain of the product as a volume of water. WF has been used as an indicator of freshwater use of "processes, products, consumers, a group of consumers, a business, a business sector, and humanity" as a whole [6]. To sum up, WF is the volume of water used directly or indirectly. The direct WF is the volume of water used in the form of taking showers, drinking, washing dishes, doing laundry, and washing cars. However, indirect WF is the volume of water used in the production, and supply chain of the product. Moreover, virtual water is water consumed by the production phase of everyday materials depending on where they are produced and used, and the production method. Since there is a limited supply of freshwater, water is also treated economically as virtual water trade.

During the survey in the research area, a notable fact is that people in Lang Son province still lack basic understanding of the concept of WF. This leads to their lack of awareness of how their daily water use behaviors are causing waste. The study will help calculate the personal WF of Lang Son province residents, assessing the current state of water use in the locality, from the amount of water consumed directly daily for living to the amount of "virtual" water in daily water use behaviors. At the same time, the study also assesses how factors such as gender, age group and living area affect WF. Finally, the above results will be a solid basis for proposing solutions for effective water management and use.

2. Method

This cross-sectional study was conducted in Lang Son province with the aim of determining water usage behavior and calculating the personal WF of local residents. The research utilized a questionnaire-based survey tool, which was specifically adapted and evaluated for validity and reliability to ensure accurate data collection. The questionnaire used in this study was adapted from WF calculator [7] and consisted of 35 questions related to three categories: direct indoor water use in households, direct outdoor water use outside households, and indirect water use. After translation, localization, and expert methods, a questionnaire including 39 questions contains a variety of socioeconomic characteristics such as age, gender, accommodation, number of households. Indoor water use behaviors such as average shower time, average faucet running time for both kitchen and bathroom, number of average flushing, dishwashing methods, laundry methods, availability of a greywater system, and availability of low-flow faucets in their living environments are enquired. Besides, for outdoor water use behaviors such as availability and size of lawn or garden at their living environments, availability of plants that require less or no water, availability of rain barrel and swimming pool, duration of keeping the pool covered, frequency of vehicle washing and vehicle washing methods are also enquired. Lastly, virtual water use behaviors such as kilometers traveled per week, source of electricity, frequency of shopping, paper recycling habits, plastic recycling habits, bottle and can recycling habits, donation preferences, dietary preferences, frequency of meat consumption. The questionnaire was developed to collect data. The calculation method for all components of WF using the data collected in this study is supplemented in the spreadsheet file.

2.1. The Reliability of the Questionnaire Tool

To assess the reliability of the questionnaire tool, this research used the content validity ratio (CVR) and the content validity index (CVI) [8]. An expert panel was established to assess the reliability of the questionnaire tool. These experts were selected based on their knowledge and experience on the field of WF and environmental research. A 3-point Likert scale is used with i) Essential; ii) Useful but not essential; and iii) Not necessary. The experts were asked to respond and were allowed to write comments [9].

While CVR is used to assess the reliability of each question in the survey form, CVI is used to assess the validity of the entire survey form. This approach ensures a comprehensive assessment of the content validity of the survey form. The CVR and CVI are calculated using the following formula:

Content Validity Ratio (CVR)

$$CVR = [ne-(N/2)] /(N/2) \quad (1)$$

Content Validity Index (CVI)

$$CVI = [ne/N] \quad (2)$$

Where ne is the number of panel members considered necessary, N is the total number of panel members.

In this study, with the panel of 15 experts including scientists from the universities who are experienced and knowledgeable in the field of water resources, and local people and managers who have in-depth knowledge of their own water usage habits, their participation helps the assessment form capture the water consumption characteristics of local people. The minimum acceptable value for CVR was set at 0.49. The CVI values ranging from 0.7 to 0.9 are acceptable to excellent. However, if the CVI is less than 0.7, it indicates that the questionnaire may have problems and should not be used.

2.2. Questionnaire Method

A questionnaire survey was administered to individuals in Lang Son province. The sampling method was random. For survey areas with large populations (more than 10,000 people) [10], the number of survey samples is applied according to equation (3):

$$N = \frac{Z^2 * q * p}{e^2} = \frac{(1.96)^2 * 0.5 * 0.5}{(0.05)^2} = 384 \quad (3)$$

Where:

N: Sample size;

Z: Distribution value corresponding to the selected confidence;

q: Estimated percentage of the population;

p = 1- q;

e: Allowable error.

To ensure the representativeness and objectivity of the survey results, the survey sample randomly selected from households living and working in Lang Son province. Individuals of all ages were selected, and each respondent was required to complete all the question. At a 95% confidence interval, at least 384 valid sample had to be completed to achieve statistical significance according to (3). A total of 390 questionnaires were collected, of which 384 were valid. The contents addressed food, clothing, shelter, transport, and direct and indirect water uses. Personal interviews were held from 12 February to 31 March 2025. Since the most important statistics are validity and accuracy, only carefully completed questionnaires could be used to generate the final statistical results. After the questionnaires had been collected, a second review was performed to ensure the reliability of the results. Questionnaires were judged to be invalid if they were returned with an excessive number of missing answers, without the respondent's background information. Incomplete questionnaires were discarded to ensure reliability.

2.3. Mean Difference Test

In this study, one-way ANOVA test on SPSS 20 software is used to analyze the average difference of individuals' daily WF by gender, age group and area of residence in Lang Son province.

2.4. Water Footprint (WF) Calculation

The total amount of water used in daily life and the amount of virtual water used are the individual's daily WF [11]. Data from individuals' WF survey.

$$WF = DWF + IWF \quad (4)$$

In which:

WF (lpcd): Total amount of water used

DWF (lpcd): Direct water used

IWF (lpcd): Virtual water

Direct water use: mainly based on answers from interviewees on the amount of water used directly for various purposes such as washing clothes, bathing, flushing toilets, washing cars, and caring for ornamental plants.

Virtual water use (indirect): derived from information on an individual's diet and the amount of virtual food and water used for other consumption.

$DWF = DWF_{in} + DWF_{out}$

DWF_{in}: Direct water used indoors.

DWF_{out}: Direct water used outdoors.

For direct water use, common activities such as washing dishes and laundry will be divided equally among all family members.

3. Result

3.1. Area of Residence, Gender, Household Size and Age Distribution

Table 1 details the distribution of study participants by location, which provides insight into the geographic diversity of the participants. The purpose of table 1 is to highlight the geographical distribution of study participants.

Table 1. Percentage distribution of participants in the study by area of residence

Area of residence	Percentage (%)
Luong Van Tri Ward	30.73
Dong Kinh Ward	40.10
Tam Thanh Ward	19.79
Ky Lua Ward	9,38

Table 2. Percentage distribution of the number of individuals residing in each household

Family size	Respondent	Percentage (%)
1-3 persons	66	17.19
4-6 persons	298	77.60
7-9 persons	20	5.21
Total	384	100

Table 2 shows the distribution of household size in the study area. Households with 4-6 members account for the highest proportion at

77.60%. Small households (1-3 members) and over 6 members account for 17.79% and 5.21% respectively.

The study results also show a small difference in both gender and age. Specifically, the gender distribution shows that women accounted for 59.5 % of the sample compared to 41.1 % of the male sample, indicating a moderate female majority. However, the most obvious feature was the age distribution: the 41-66 age group accounted for the largest segment at 44.53%, followed by the 18-40 age group at 37.24%. The youngest age group, 15-17 years old, accounted for the smallest proportion of the sample, accounting for only 18.23%, indicating that the study findings were mainly drawn from middle-aged and successful adults.

3.2. CVR and CVI

The CVR and CVI indices calculated for the survey tool have the following values:

For the CVR index in the survey, only the question about the amount of money spent on buying pet food only reached 0.33 and did not reach the minimum threshold to retain the question. Most experts agreed that pets in Lang Son province mainly eat leftovers after each meal and people are not willing to spend money to buy ready-made food for dogs and cats. The remaining questions all reached values from 0.87 to 1.0. This shows that experts have a high consensus for the remaining questions of the survey. The overall CVI index reached a value of 0.92, reflecting the consensus of experts on the necessity of the survey. The above results show that the questionnaire is a valid and reliable tool for estimating personal WF, ensuring that the objectives of the study are effectively met through accurate and appropriate data collection. The results of the validity and reliability analysis of the questionnaire demonstrated its effectiveness in measuring the WF.

3.3. One-way ANOVA test

Table 3 shows the results of one-way variance test of WF by gender, age group and area of residence.

Table 3. Mean difference test for water footprint.

Testing factor	Levene test	ANOVA table results	Robust Tests table results
WF by gender	0.014	0.189	0.171
WF by age group	0.015	0.000	0.000
WF by area	0.001	0.000	0.000

The test results show that there was no mean difference in WF by gender because the average shower time for both men and women is 11 minutes. The virtual WF due to shopping habits of men is 1546.04 ldcp and women is 1709.01 lpcd while the average dietary WF of men is 4152.94 ldcp and women is 3784.42 ldcp, there is also no significant difference. There was a mean difference in WF by age group and area of residence. Dong Kinh and Ky Lua Wards are the central area, more economically developed, leading to higher consumption of goods, services, and comfortable lifestyle, has the highest IWF (Table 4). The difference is due to different age groups having different water usage and lifestyles which leads to differences in their individual WF. For example, the WF of shopping of the 15-17 year-old group is 1858.91 (lpcd) which is much larger than the 1411.25 L/day of the 41- 66 year-old group. This reflects the influence of modern consumer lifestyles, preference for new goods and services, or travel/mobility (gasoline) habits among young people, thereby increasing IWF.

3.4. Calculating Water Footprint of Residents

Figure 1 shows the personal WF results of Lang Son province residents calculated based on the results of 3 components including: Direct Water Use (DWF), Indirect Water Footprint (IWF) and Total Water Footprint (TWF) with the unit of lpcd (L/person/day).

The personal WF of Lang Son province residents is 6030.41 (lpcd). Of which the largest is virtual water use reaching 5566.10 (lpcd) using 92.3 % of the WF component. Direct water use only uses 7.7 % of the amount at only 464.31 (lpcd).

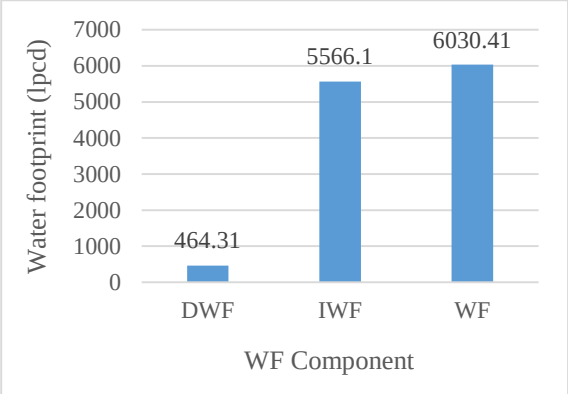

Figure 1. Distribution of water footprints components.

The average personal WF of Lang Son province residents is higher than the global average and consumption in Ho Chi Minh City (HCMC). At 6030.41 L/person/day (lpcd), Lang Son's WF far exceeds the world average of 3794 lpcd [12] and is also significantly higher than the 4498.63 lpcd recorded for Ho Chi Minh City residents [13]. This comparison highlights the urgent need to address the current wasteful water use of Lang Son province residents.

Table 4 shows that there is a significant WF difference between the regions in Lang Son province. Dong Kinh Ward get the highest daily WF (6390.78 lpcd) and the smallest daily WF is Luong Van Tri Ward (5818.82 lpcd).

Table 4. Per capital daily water footprint in each ward in Lang Son province

Location	N	Direct WF (lpcd)	Indirect WF (lpcd)	Daily WF (lpcd)
Luong Van Tri Ward	131	468.48	5350.35	5818.82
Dong Kinh Ward	59	514.22	5876.56	6390.78
Ky Lua Ward	99	489.40	5901.27	6390.67
Tam Thanh Ward	95	480.02	5388.75	5868.77

The average WFs of each activity are show in Table 5.

Table 5. WF results for individual water footprints of study areas in Lang Son province

Type	N	Mean (lpcd)	SD
Indoor direct use			
Shower	384	203.70	90.62
Bathtub	384	3.82	18.64
Bathroom sink	384	54.27	46.68
Toilets	384	62.53	33.13
Kitchen	384	58.76	79.53
Washing dishes	384	47.22	47.22
Cooler	384	1.60	2.43
Laundry	384	18.31	13.36
Greywater*	384	5.77	24.27
Outdoor direct use			
Garden watering	384	15.89	45.57
Xeriscaping*	384	0.09	0.12
Rain barrel*	384	0.49	1.24
Swimming pool	384	1.99	20.97
Vehicle washing	384	1.99	3.34
Virtual water use			
Gasoline	384	0.55	2.68
Electricity	384	1.24	0.00
Shopping	384	1642.07	917.00
Recycle paper*	384	0.98	1.56
Recycle plastic*	384	7.06	10.95
Recycle can and bottles*	384	1.51	2.29
Donating textile*	384	0.80	0.64
Diet	384	3931.61	842.83

(*) Represents saved water because of the activity.

3.5. Some Remarks About Water Usage Behavior and WF for Residents in Lang Son Province

Most of the survey respondents seem to not understand and underestimate the importance of water resources. The wasteful use of water will cause water shortages soon. Water is an essential source for everything that people consume and use every day such as food, clothing, and building houses. To reduce WF, some suggestions are given below.

- While conducting the survey, most of the respondents did not know the meaning of WF. It is necessary to strengthen the propaganda about the importance and meaning of personal WF and help people to be self-aware of its importance.

- On average, the survey respondents let the water run for 12.61 minutes at the sink and 12.45 minutes at the sink (including: washing food, cleaning, not including washing dishes). The water should be turned off when doing personal hygiene and the water should not be left running continuously when cleaning the kitchen. This will minimize water waste.

- Watering plants consume a lot of water. It is recommended to use less water than watering plants, up to 85% of survey participants use rain barrels. It is recommended that people use additional rain barrels to save water for irrigation.

- On average, only 14% of survey participants recycle and reuse all recyclable materials. People should form the habit of recycling and reusing to avoid waste and reduce waste.

- 34% of survey participants use water-saving devices and low-flow devices. It is recommended to increase the installation and use of these devices to save water.

- Only 8% of survey participants install grey water systems at home. It is recommended to install and use grey water systems to reduce water use.

- Personal WF due to eating habits of Lang Son province residents is 3931.61 (L/person/day). 42% of survey respondents have a habit of eating meat at every meal. Change your eating habits to less water-consuming options such as reducing meat consumption or increasing the portion of green vegetables in your meals to reduce WF.

- 66% of survey respondents only shop for basic, necessary items. This is a positive number, if possible, limit buying unnecessary products to reduce waste.

The highest WF proportion of residents of Lang Son province is due to their eating preferences. A total of 384 people responded to the survey of which 0 people are vegan, 6 people are vegetarian, 124 people eat meat once a day, 90 people eat meat twice a day, and 163 people eat meat every meal of the day.

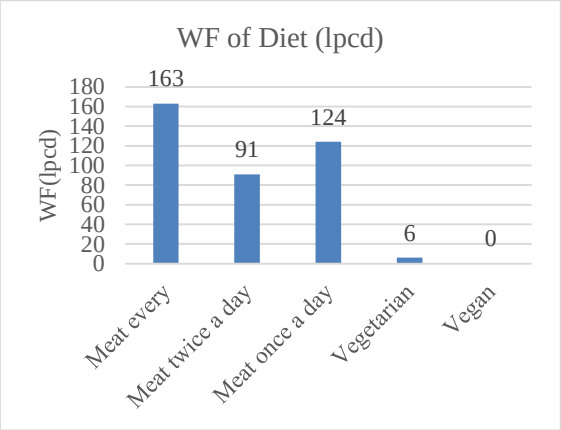

Figure 2. WF (lpcd) of diet preferences of Lang Son province.

4. Conclusion

Reseach has found that residents of Lang Son province have a personal WF of 6030.41 liters per capita per day (lpcd), which is substantially higher than the world average of 3794 lpcd. This high consumption is attributed to wasteful behaviors and lifestyle habits, including leaving water running for more than 10 minutes a day while showering, washing dishes, and using sinks. The habit of bathing and washing dishes multiple times daily also contributes to this direct water waste. In addition, the high-meat diet of the residents leads to an increased virtual WF, which is the water used to produce food. The study also found that there was an average difference between the WF of different residential areas. This level of consumption, combined with the pressures of climate change, water pollution and population growth, is placing significant strain on water resources. To address this, the study recommends a two-pronged approach: raising individual awareness to encourage daily habit adjustments like eating less meat, recycling, and using green energy, and implementing government-led green and smart solutions that prioritize public acceptance and cooperation.

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