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1. Evaluation of Water Productivity

A master plan under Thailand's National Strategy, 19th issue: Water management (2018 - 2037), established goal No. 2 as enhancing the productivity of an entire water system to promote water-use efficiency and generate value added for water consumption, water productivity will increase by 3-fold its original average (2018) in 2018-2022 and by 10-fold its original average (2018) in the late 20-year plan (2033 - 2037), delivering on the 20-year national water resource management master plan (2018 - 2037). Water productivity (WP) is identified in an objective No. 3, "To increase the water productivity in the whole system by arranging water supply, using water economically, and creating value-added from water use on an international level for approaching future economic and social growth in the agricultural, industrial, service, and energy sector." According to the purpose above, water productivity related to the agricultural, industrial, service, and energy sectors is in line with the International Standard Industrial Classification of All Economic Activities: ISIC rev.4, in which the energy sector is classified as an integral part of the economic activities under industrial sector. The energy sector is combined with the industrial sector for water productivity assessment. This assessment of water productivity can compare different water use across sectors.

The analytical results of economic, social, and global changes affecting the country's water management based on the 20-year national water resource management master plan are estimated that agricultural production remains the pillar of the rural socio-economic sector and increases economic productivity. Therefore, the agricultural sector must increase production productivity by increasingly using technology and innovation, coupled with marketing management that the water management direction is to provide water supply and improve irrigation efficiency for increasing agricultural productivity, especially in the low-income area of North-east Thailand, using the irrigated areas to increase the productivity of high-value economic crops and restructure the use of water in the production aspect both agricultural and industrial sectors. The 20-year national water resource management master plan attaches great importance to the agricultural sector, showing the largest proportion of water use in the country, followed by the industrial sector, which often leads to conflicts with the agricultural sector in a dry season because of the shortage of water supply. In this study, there is supporting data to compare both provincial and river basin levels to consider the situation that occurred in the area and perceive the changes during the study period. In other words, if there is no change caused by the numerical outcome, it will refer to traditional management or operation patterns.

1.1 Project objectives

1) To collect and formulate guidelines for the analysis of water productivity by agricultural, industrial, and service sectors (including consumer water).

2) To evaluate the water productivity in the agricultural, industrial, and service sectors (including consumer water) at the national, provincial, and river basin levels.

3) To analyze the water productivity in the agricultural, industrial, and service sectors (including consumer water) at provincial and river basin levels, leading to the suggestions for water productivity.

Office of National Water Resources (ONWR) conducted a study of SDG indicator 6.4.1: water use efficiency, completed in July 2021, which overall is similar to water productivity assessment, but details and implementation were different. The relevant data was also used in this study. Thus, Kasetsart University summarizes the main principles and differences between water productivity and water efficiency before further study in detail as follows:

1) The water productivity principle is to find the proportion of the Gross Domestic Product: GDP (output) to the amount of water used in production (input) in the agricultural, industrial, and service sectors. Therefore, a comparison across different water-used sectors influences different outputs, so the economic values were compared to maintain the same base.
2) Water productivity is calculated from the proportion of economic output to the amount of water used in production (Water consumed was not water used) [1], which is different from the water use efficiency, calculated from the proportion of economic value-added per overall water use, extracted from the water source system excluding effective rainfall.
3) Water productivity was evaluated in all agricultural areas, including irrigated and rainfed areas, as well as effective rainfall. Water use efficiency solely evaluated manageable water; thus, it only included irrigated land, excluding effective rainfall.
4) The economic value uses to account for water productivity is derived from Gross Domestic Product (GDP), which is the market value of all final goods and services produced in a country in a given period, but the economic value of water use efficiency is the value added, calculated from the difference between the value of total output and intermediate consumption of goods and services.

[1] FAO 2019, Step by step monitoring methodology for indicator 6.4.1

5) Water productivity is only one indicator; its implementation must be considered coupled with other indicators and the context of comparison. In the economic structure of Thailand, the largest proportion of water used is in the agricultural sector to meet the majority needs of the population in the country. Consequently, productivity adjustments consist of two important parts: (1) increasing water productivity in each sector by using technology to collaboratively drive policy planning and (2) for the long term, changing the country's economic structure to increase water productivity.

The study period of water productivity is from 2015 to 2020 to illustrate the national level change in overall water productivity in agricultural, industrial, and service sectors, as well as crisis cases that occurred during the study period; moreover, it provides details on provincial and river basin levels. The agricultural water productivity assessment covered irrigated areas and rainfed areas. As a result, for the agricultural sector, there is a comparative study of water productivity between irrigated areas and rainfed areas. The industrial sector assesses water productivity inside and outside of the industrial estate, and the water productivity in the service sector evaluates by economic activities (to the extent that data on water consumption is available) to generate a practical guideline that is consistent with the real situation.

The latest World Bank data on March 19, 2021, updated data of the World Development Indicators. Water productivity is one of the indicators which can compare Thailand's water productivity indicators with significant countries at the ASEAN-, regional-, and global-level in 2017 (fixed price in 2010), as follows:

Country/Region/World	Water Productivity (USD/m^3)
Thai	7.41
Vietnam	2.14
Malaysia	54.43
Singapore	654.39
East Asia and Pacific (EAP)	17.95
World	20.61

Source: https://databank.worldbank.org/reports.aspx?source=2&series=ER.GDP.FWTL.M3.KD

When comparing the results of the previous year's water productivity study from different departments, as shown in **Table 1.1-1**, it is found that 4 variables affecting the different findings from this study are as follows:

1) Using the values of GDP at current prices vs. using Chain Volume Measures (CVM).
2) Calculating from all GDP values vs. calculating from only related values.
3) For the different details to estimate water volume, previous studies are estimated by the water volume of irrigated areas in the agricultural sector, excluding effective rainfall, while this study is calculated by water used in the agricultural area, including effective rainfall.
4) Previous studies employ the calculation values, but this study uses the actual water-used data as much as possible.

Table 1.1-1 Comparison of previous studies on water productivity results

Details	2015	2016	2017
GDP (at 2010 Prices, USD), WB	401,296	413,336	424,638
Freshwater Withdrawal (million m^3), FAO			57,306
WP (USD/m^3) at 2010 Prices, WB			**7.41**
GDP (Current prices, million m^3), The research offers ADB	416,576	440,408	
Water Used (million m^3), The research offers ADB	80,923	81,194	
WP (USD/m^3) Current prices, The research offers ADB	**5.19**	**5.43**	
GDP CVM (million m^3) (Exchange rate in 2012: 1 USD = 31.23 THB) Calculating from values related ONWR	304,652	316,068	329,725
Water Used (million m^3), ONWR	207,395	202,405	220,987
WP (USD/m^3), ONWR	1.61	1.66	1.55
GDP (at 2010 Prices, USD), WB	401,296	413,366	424,628
Water Used (million m^3), ONWR excluded the effective rainfall	63,371	49,629	47,434
WP (USD/m^3), ONWR	**6.33**	**8.33**	**8.95**

Source: Summarize previous studies by a consultant

When considering water productivity value in 2017, the World Bank's study is 7.41 USD/m^3. In this study, it is 1.55 USD/m^3, but when using GDP constant prices and deducting effective rainfall to estimate water consumption, it is found that this study has a water productivity value of 8.95 USD/m^3.

The study results demonstrate that water productivity has 2 significant variables: GDP and water use. Only reducing water use does not dramatically increase water productivity in Thailand's current economic structure; a significant part is an increase in GDP, which is involved in all sectors of the country. Water Productivity (WP) cannot be compared between locations with differing economic conditions due to various factors. As a result, it should compare to an area or a group of areas with similar economic conditions. If water productivity increases year by year, it demonstrates the cost-effectiveness and success of water used.

2. Economic study

2.1 Data types and sources

Data types and data sources used in the study of economic water productivity are as follows:

1) The Statistic of National Accounts, provided by the Division of National Accounts, the Office of the National Economic and Social Development Council.
   (1) At the national level: GDP (CVM) in 2015 – 2020
   At provincial and basin level: GPP (CVM) in 2015 – 2019
   (2) The statistic of national accounts: Production activities from 2015 to 2020 at Nominal GDP and Real GDP (CVM)

2) Agricultural Statistics of Thailand (2015 - 2020), provided by the Office of Agricultural Economics: The data used for the cultivation of 11 types of crops, namely rice, maize, vegetables, field crops, sugarcane, perennial plants, rubber tree, cassava, palm oil, pineapple, and fruit trees by provinces, are as follows:
   (1) Cultivated areas in irrigated and rainfed areas
   (2) Harvested areas in irrigated and rainfed areas
   (3) Yields from irrigated and rainfed areas
   (4) Prices of products from irrigated and rainfed areas

3) Fisheries Statistics of Thailand
   (1) Fisheries production in quantity and value of capture (marine and inland fisheries) and culture (coastal aquaculture and freshwater aquaculture)
   (2) Number of farms and area under freshwater aquaculture by province and type of culture (pond, paddy cum fish, ditch, and cage)

2.2 Procedures and methods to calculate GDP of main economic activities

A study of the economic water productivity has the methods and procedures as follows:

1) **Categorize GDP based on the National Classification for the Economic Activities: ISIC (Rev.4)[2]**

ISIC (Rev.4) is divided the structure of economic activities into sections, divisions, groups, and classes. The description and examples based on the classification ISIC (Rev.4) are summarized as follows:

Section	The largest production unit (20 sections), using capital letters code (A – T)
Division	Sub-section, using a 2-digit code (01)
Group	Sub-division, using a 3-digit code (011)
Class	Sub-group, using a 4-digit code (0111)

Table 2.2-1 Example of the economic structure ISIC (Rev.4): Agricultural sector

Structure	Economic Activity Description	Code
Section	Agriculture, Forestry, and Fishing	A
Division	Crop and animal production and hunting, including related service activities	01
Group	Cultivation of non-permanent crops	011
Class	Cultivation of cereals (except rice), legumes, and oilseeds	0111
Product	Growing of grain maize	01111

Source: The standard of national classification for the economic activities provided by the United Nations Statistics Division (UNSD)

Economic studies use GDP (CVM) data that classify the category of economic activities, as shown in **Table 2.2-1,** to re-categorize into large categories and sub-categories for calculating water productivity.

The classification of economic production by ISIC (Rev.4) category, namely the agricultural, industrial, and service sectors, are shown in **Table 2.2-2**.

GDP (CVM) in 2015 - 2020, classifying economic activities into section, amounts to 9,521,425, 9,848,501, 10,259,940, 10,689,790, 10,932,065, and 10,265,322 million THB, respectively, as shown in **Table 2.2-3**.

[2] ISIC (International Standard Industrial Classification) is the standard of economic activity classification provided by the United Nations Statistics Division (UNSD). The objective is to collect, gather, analyze, and present the data in accordance with the international standard for cross-country comparisons. Recently, version 4.0 has been implemented; grouping is based on productive process rather than product type.

Table 2.2-2 Classification of economic activities by ISIC (Rev.4)

Economic sectors	Economic activities ISIC (Rev.4) codes
Agricultural sector	A
Industrial sector	B, C, D, and E
Service sector	F – T

Source: International Standard Industrial Classification of All Economic Activities ISIC (Rev.4): Section A–T

Table 2.2-3 GDP (CVM) in 2015–2020: Classification of economic activities by ISIC (Rev.4) (Section)

Unit: Million THB

Section	2015r	2016r	2017r	2018r	2019p	2020p1
GDP	9,521,425	9,848,501	10,259,940	10,689,790	10,932,065	10,265,322
A: Agriculture, forestry, and fisheries	615,883	608,752	638,105	675,335	671,012	647,033
B: Mining and quarrying	244,577	246,600	231,895	225,101	228,957	213,251
C: Manufacturing	2,670,311	2,730,588	2,809,907	2,906,772	2,886,789	2,722,846
D: electricity, gas, steam, and air conditioning	277,959	286,157	291,274	297,761	311,490	285,277
E: Water supply, wastewater, and waste management and related activities	43,420	46,682	49,777	52,840	55,928	55,625
F: Construction	268,506	289,919	281,274	287,666	292,305	298,910
G: Wholesale and retail and repair of motor vehicles and motorcycles	1,340,744	1,423,314	1,514,519	1,611,393	1,683,690	1,621,565
H: Transportation and storage	607,674	639,929	691,369	719,247	740,888	585,587
I: Accommodation and food services	496,115	542,057	600,677	647,922	698,505	442,982
J: Information and communications	468,115	479,369	497,977	539,746	606,147	634,159
K: Financial and insurance activities	652,508	698,413	744,932	772,050	788,759	809,762
L: Real estate activities	344,220	368,470	393,071	414,464	430,061	435,876
M: Professional, scientific, and academic activities	199,458	194,997	207,217	212,965	216,658	205,699
N: Administrative activities and other support services	169,527	172,062	177,330	183,068	188,109	155,911
O: Public administration and national defense	507,469	509,644	513,565	521,430	528,591	537,326
P: Education	324,312	323,601	324,972	328,198	332,050	338,840
Q: Public health and social work	208,552	214,829	223,609	234,362	242,691	244,012
R: Arts, entertainment, and recreation	66,668	80,858	90,649	101,742	116,348	102,581
S: Other service activities	139,544	144,949	151,937	158,319	163,082	154,605
T: Household employment	17,581	17,564	17,071	16,634	16,535	16,833

Source: Division of National Accounts, the Office of the National Economic and Social Development Council

Note: 1. r (revised) behind year refers to the data that was retrospectively revised.
2. p (preliminary) behind year refers to annual values derived from preliminary data processing
3. GDP and production branch used GDP_CVM (Section)

According to the data above, GDP in the agricultural, industrial, and service sectors from 2015 to 2020 is indicated in **Table 2.2-4**.

Table 2.2-4 GDP by economic sectors in 2015-2020: Section

Unit: Million THB

GDP (CVM)	ISIC Rev.4	2015r	2016r	2017r	2018r	2019p	2020p1
All section	A - T	9,521,425	9,848,501	10,259,940	10,689,790	10,932,065	10,265,322
Agricultural sector	A	615,883	608,753	638,106	675,337	671,013	647,033
Industrial sector	B, C, D, and E	3,235,844	3,308,253	3,378,509	3,476,318	3,476,567	3,270,205
Service sector	F - T	5,754,370	6,032,560	6,348,319	6,644,577	6,902,961	6,452,836

Source: GDP (CVM) the Division of National Accounts, the Office of the National Economic and Social Development Council

Note: Categorize sections A–T by ISIC (Rev.4) (Section)

2) GDP: Group, class, and product

Calculations of GDP (CVM) in 2015-2020 are adopted to analyze national water productivity, with data sorted by the major economic sectors, namely the agriculture sector (A), the industrial sector (B-E), and the service sector (F-T), as shown in **Tables 2.2-5 – 2.2-7**.

Tables 2.2-5 GDP (CVM) in 2015-2020: Agricultural sector

Unit: Million THB

Product	2015r	2016r	2017r	2018r	2019p	2020p1
Agricultural sector (A)	503,816.15	499,075.93	524,035.89	553,425.49	548,808.08	529,671.02
1. Rice	91,220.17	86,931.14	93,289.44	97,765.89	92,781.77	89,466.10
2. Field crop	19,152.65	19,853.48	19,970.77	20,485.84	18,394.49	17,737.14
3. Sugarcane	26,116.88	21,420.04	24,143.07	32,348.63	27,163.29	26,192.58
4. Cassava	19,042.30	19,047.83	18,133.37	18,150.02	18,337.08	17,681.78
5. Vegetables	61,865.01	64,542.82	66,769.35	69,896.51	73,820.79	71,182.72
6. Perennial crop	8,997.94	8,535.44	10,194.80	11,095.76	12,057.74	11,626.84
7. Fruit trees	50,072.72	47,957.63	53,228.60	56,496.29	58,131.43	56,054.03
8. Rubber Tress	84,846.69	83,858.42	85,698.44	89,104.49	88,903.21	85,726.15
9. Palm Oil	17,511.76	16,510.65	20,545.34	22,260.72	23,992.02	23,13464
10. Cows and Buffaloes	24,333.81	23,464.52	24,426.45	24,724.73	24,963.97	24,071.86
11. Sheep and Goats	660.05	620.06	666.46	690.56	705.07	679.87
12. Pigs	21,541.59	26,511.01	25,267.95	25,076.94	24,231.98	23,366.02
13. Poultry	25,850.27	27,095.02	28,606.80	29,839.80	30,938.10	29,832.49
14. Forestry	8,097.53	8,737.35	8,057.10	8,232.50	7,958.98	7,674.56
15. Aquaculture	15,812.47	14,464.55	13,357.48	15,595.20	14,807.42	14,753.52
16. Others	28,694.33	29,525.98	31,680.47	31,661.60	31,620.73	30,490.73

Source: 1. Division of National Accounts, the Office of the National Economic and Social Development Council
2. Fisheries Statistics of Thailand 2018

Notes: 1. Classified plants in group, class, and product level
2. Agricultural GDP by types of plants, employing the sum-up method
3. Freshwater aquaculture is considered only pond culture and paddy cum fish culture, excluding ditch and cage cultures

Table 2.2-6 GDP (CVM) in 2015-2020: Industrial sector

Unit: Million THB

Product	2015r	2016r	2017r	2018r	2019p	2020p1
Industrial sector (B-E)	3,236,268	3,310,027	3,382,852	3,482,474	3,483,165	3,276,999
1. Mining and quarrying (B)	244,577	246,600	231,895	225,101	228,957	213,251
2. Manufacturing (C)	2,670,311	2,730,588	2,809,907	2,906,772	2,886,789	2,722,846
3. Electricity and gas (D)	277,959	286,157	291,274	297,761	311,490	285,277
4. Water supply and wastewater (E)	43,420	46,682	49,777	52,840	55,928	55,625

Source: Division of National Accounts, the Office of the National Economic and Social Development Council

Notes: 1. Classify economic activities in section level (B–E) by ISIC (Rev.4)

2. Industrial GDP, adopting the sum-up method

Tables 2.2-7 GDP (CVM) in 2015-2020: Service sector

Unit: Million THB

Product	2015r	2016r	2017r	2018r	2019p	2020p1
Service sector (F-T)	5,810,992	6,099,976	6,430,167	6,749,206	7,044,419	6,584,648
1. Construction	268,506	289,919	281,274	287,666	292,305	298,910
2. Household	157,125	162,513	169,008	174,953	179,617	171,438
3. Accommodation and food	496,115	542,057	600,677	647,922	698,505	442,982
4. Business	3,848,913	4,057,413	4,317,062	4,554,676	4,770,661	4,551,140
5. Public	507,469	509,644	513,565	521,430	528,591	537,326
6. Education	324,312	323,601	324,972	328,198	332,050	338,840
7. Hospital	208,552	214,829	223,609	234,362	242,691	244,012

Source: Division of National Accounts, the Office of the National Economic and Social Development Council

Notes: 1. Classify economic activities in section level (F–T) by ISIC (Rev.4)

2. Service GDP, adopting the sum-up method

For the analysis of Gross Provincial Product Chain Volume Measures: GPP (CVM) or Gross River Basin Product in 2015-2020, GPP (CVM) of Thailand's 77 provinces adopts a sum-up method to analyze which differs from GDP (CVM).

The scope of this study will analyze water productivity in irrigated areas and rainfed areas for the agricultural sector and water productivity in industrial estates and outside industrial estates for industrial sectors. When receiving GPP in each economic sector, it has to separate the data as follows:

- Calculate GPP in cultivation areas, separated into irrigated areas and rainfed areas in 3 steps.

  1) to find the cultivation areas of each crop in both irrigated areas and rainfed areas
  2) to find a total yield of each crop by yield (kg/1 rai) × area (rai) in both irrigated areas and rainfed areas
  3) to calculate the proportion of yields in both irrigated areas and rainfed areas to multiplicate with the product value of each crop.

  The descriptions of agricultural GPP by irrigated areas and rainfed areas are shown in **Table 2.2-8**.

  Note: GPP data by plant types excludes maize and pineapple culture, so they are combined with the category of field crops in this study. Nevertheless, the water used quantity can calculate. When it was used to assess water productivity, it must combine maize and pineapple as field crops.

- Calculating GPP in the industrial sector categorized by the registered horsepower of factories inside and outside industrial estates, which is the most plausible approach with currently available data. The hypothesis is set that the same type of factory utilizes the same horsepower for manufacturing. Therefore, the industry is divided into 9 categories: (1) wood products and furniture, (2) non-metal products, (3) paper industry, (4) chemical industry, (5) metal industry, (6) general industry, (7) parts and equipment manufacture, (8) textile and tannery, and (9) food and beverage industry. Power plants and water supply are separated, as shown in **Table 2.2-9**.

Table 2.2-8 Agricultural GPP by irrigated areas and rainfed areas

Unit: Million THB

Year	Agricultural sector			Rice		
	Total	Irrgiated area	Rainfed area	Total	Irrgiated area	Rainfed area
2015	387,941	96,980	290,961	90,474	47,206	43,267
2016	380,158	92,864	287,294	86,187	43,515	42,672
2017	406,047	106,164	299,884	92,709	50,948	41,761
2018	432,192	116,849	315,343	97,238	55,420	41,818
2019	427,572	112,004	315,567	92,189	52,802	39,387
Year	Field crops			Vegetables		
	Total	Irrgiated area	Rainfed area	Total	Irrgiated area	Rainfed area
2015	18,728	6,090	12,638	58,466	15,046	43,420
2016	19,407	6,784	12,623	60,984	15,900	45,084
2017	19,695	6,701	12,994	62,947	17,641	45,306
2018	20,023	6,575	13,448	66,871	20,215	46,655
2019	18,926	6,689	12,237	69,965	18,748	51,217
Year	Sugar cane			Fruits		
	Total	Irrgiated area	Rainfed area	Total	Irrgiated area	Rainfed area
2015	25,727	5,240	20,487	46,821	18,018	28,803
2016	21,059	3,880	17,179	44,380	16,941	27,439
2017	23,728	5,108	18,620	50,692	19,477	31,216
2018	31,812	7,318	24,494	51,250	19,823	31,427
2019	26,696	6,668	20,027	49,873	18,173	31,701
Year	Perennial crops			Rubber trees		
	Total	Irrgiated area	Rainfed area	Total	Irrgiated area	Rainfed area
2015	15,680	2,924	12,756	95,724	1,624	94,100
2016	17,592	2,963	14,629	95,233	1,816	93,418
2017	19,685	3,195	16,490	98,307	2,038	96,269
2018	23,565	4,213	19,353	101,548	2,096	99,451
2019	27,165	5,260	21,905	100,975	2,400	98,575
Year	Cassava			Oil Palms		
	Total	Irrgiated area	Rainfed area	Total	Irrgiated area	Rainfed area
2015	19,078	279	18,799	17,244	554	16,690
2016	19,120	389	18,731	16,195	676	15,519
2017	18,213	128	18,085	20,072	929	19,143
2018	18,225	114	18,111	21,661	1,075	20,586
2019	18,418	132	18,285	23,366	1,132	22,234

Source: To classify GPP CVM by the Office of the National Economic and Social Development Council and find the proportion of cultivated areas per rai and proportion of yield per rai

Table 2.2-9 Industrial GPP by inside and outside industrial estates

Unit: Million THB

Year	Industry sector		Power Plants	Waterworks	Total
	Inside industrial estates	Outside industrial estates			
2015	382,383	2,532,506	277,959	43,420	3,236,268
2016	390,556	2,586,633	286,157	46,682	3,310,027
2017	399,032	2,642,770	291,274	49,777	3,382,852
2018	410,848	2,721,026	297,761	52,840	3,482,474
2019	408,732	2,707,014	311,490	55,928	3,483,165

Source: To classify GPP CVM by the Office of the National Economic and Social Development Council and find the registered horsepower proportion of economic activity

3. Water consumption by main economic sectors

Water consumption assessment by economic sectors consists of agricultural, industrial, and service sectors. Kasetsart University conducts the study based on gathered information and categorizes economic activities according to the International Standard Industrial Classification of All Economic Activities (ISIC rev.4) to define the water use in economic activities adopted to determine water productivity. It consists of the main categories A – T as follows:

- ISIC A: Agriculture, forestry, and fisheries represent water used in the agricultural sector. Calculating the volume of water used excludes forestry, marine fishery, and freshwater fishery.

- ISIC B, C, D, and E: Mining and quarrying (B), manufacturing (C), electricity, gas, steam, and air conditioning supply (D), water supply; sewerage, waste management and remediation activities (E) represent water used in the industrial sector.

- ISIC F – T: Construction (F), wholesale and retail trade; repair of motor vehicles and motorcycles (G), transportation and storage (H), accommodation and food service activities (I), information and communication (J), financial and insurance activities (K), real estate activities (L), professional, scientific and technical activities (M), administrative and support service activities (N), public administration and defense; compulsory social security (O), education (P), Human health and social work activities (Q), arts, entertainment and recreation (R), other service activities (S), activities of households as employers; undifferentiated goods- and services-producing activities of households for own use (T) represent water used in the service sector.

From the review of the assessment of water use by economic sectors, consisting of the agricultural sector, the industrial sector, and the service sector, the previous studies are the overall study; it is not classified by main category (Section) according to ISIC. The agricultural water productivity assessment is calculated using irrigated and rainfed areas as a divider and GDP as a dividend, with no GDP extracted for individual irrigated and rainfed areas and no GDP deducted from forestry, freshwater fishery, and marine fishery. It still used the overall agricultural GDP value. In this study, water used volume is split into irrigated areas and rainfed areas, and agricultural GDP values are separately demonstrated in irrigation, rainfed agriculture, livestock, and freshwater aquaculture. Agricultural activities that require a small amount of freshwater or cultivated in natural water cycles, such as forestry, marine fishery, and natural freshwater fishery, are not calculated. As a result, the water productivity collected from the aforementioned categories in the agricultural sector can be used for further planning.

Previously, water consumption in the industrial sector is primarily analyzed by industrial type, which is the divider of industrial GDP (B, C, D, and E). ISIC E: water supply; sewerage, waste management and remediation activities are not calculated separately; however, in this study, it is calculated separately from water loss in the system to compare water productivity trends. Furthermore, water used is divided into industrial estates zone and outside the industrial estate zone.

Previous studies in the service sector assess the volume of water supply consumption, dividing the total service sector GDP (F–T), but water productivity by main categories (Section) is not measured. In this study, an assessment in the service sector is conducted by main categories (Section) with the existing available data to find water productivity value for defining policies.

3.1 Agricultural sector

3.1.1 Division of cultivated areas in irrigated and rainfed areas

In this study, for agricultural areas, there is water used assessment for crops such as rice (in-season rice and off-season rice), maize, sugarcane, cassava, pineapple, rubber, palm oil, field crops (soybean, mung bean, peanut, sorghum, etc.), fruit trees (longan, rambutan, durian, lychee, mangosteen, longkong, orange, banana, lemon, etc.), vegetables (garlic, shallots, onions, potatoes, vegetables, etc.), and perennial trees (coffee, tea, coconut, cocoa, etc.) by existing available data. When assessing water use by province, each crop is different according to the cultivated area, so cultivated area data is very important to approach a realistic assessment of water use.

The information on the cultivation area is provided by 4 departments as follows:

1) Office of Agricultural Economics (OAE) collects the data of each type of crop cultivation area and harvested area in agricultural areas in every province.

2) Office of the Cane and Sugar Board (OCSB) gathers the data on sugarcane farming areas in Thailand and controls the pricing of sugarcane and sugar each year.

3) Royal Irrigation Department (RID) provides cultivated and harvested areas in medium and large irrigation projects to separate cultivation area data between irrigated and rainfed agriculture.

4) Department of Agricultural Extension (DAE) provides information on agricultural cultivation areas for each crop, which has more details than the OAE data, collecting only the cultivated areas of main crops. Thus, the combined area by cultivated area data is very important to approach a realistic assessment of water use data is less than the annual cultivated area. As a result, the DAE data must be used.

Cultivation data acquired from the departments listed above is at the project/provincial level. Classification of irrigated and rainfed areas uses Geographic Information System (GIS) as a tool to divide the Land Development Department's latest landuse map, which overlaps the irrigated areas. The Land Development Department's landuse map by province is not the same year for the whole country but is the close year that will be used as the based area data for calculating the area of cultivation in irrigated and rainfed agriculture. Furthermore, the landuse map is used to examine the types of crops cultivated in the electric water pump project, small irrigation project, and water resources development projects of the Department of Water Resources (DWR) with a water delivery system because almost all of the information available is project location information, but only a small portion of the cultivation information is available. This differs from large/medium-sized irrigation projects that collect cultivation data on a regular schedule.

Consequently, the annual irrigated area consists of cultivated area data of large and medium-sized irrigation projects, collecting the actual cultivation data by RID. The area of the electric water pump project and small irrigation projects (including DWR projects) use the project area because the actual cultivated area is not collected.

Cultivated areas in irrigated and rainfed areas are shown in **Table 3.1.1-1** and **Table 3.1.1-2**. Short-lived crops are divided into the rainy season and dry season crops. Long-lived crops are cultivated throughout the year. According to data from 2015 to 2020, rice farming has the highest proportion of cultivated areas, with approximately 69.7 million rai/year that the cultivated area each year based on water volume, followed by 23.8 million rai/year of rubber trees, which has decreased by approximately 1 million rai in 2020 compared to previous years (2015). Sugarcane has the third highest average cultivated area of 10.6 million rai. Cassava ranks fourth in terms of average cultivated area, with 9.1 million rai. Fruit trees have a cultivated area of 6.2 million rai on average, ranking fifth, with a tendency to expand approximately 1.1 million rai cultivation area from 2015. In 2020, 5.2 million rai of palm oil, ranked No. 6, is likely to increase by 2 million rai from 2015. Maize has an average cultivated area of 4.1 million rai, ranking seventh; in 2017, the area of cultivation expanded by 1.6 million rai from 2016. Rank 8th perennial trees are fairly constant, with an average area of 3.8 million rai; Rank 9th vegetables, with an average area of 2.7 million rai, are likely to fall by approximately 1.3 million rai in 2020, compared to statistics in 2015. Field crops ranked 10th have an average cultivated area of 2.1 million rai, and pineapple has the smallest area of 0.5 million rai.

Table 3.1.1-1 Thailand cultivated area and short-lived crop cultivated area

Year	Total agricultural area (rai)			Irrigated area (rai)		Rainfed area (rai)	
	Total	Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season
2015	193,396,313	121,207,668	72,188,645	27,432,137	12,841,122	93,775,532	59,347,522
2016	188,883,214	121,027,717	67,855,497	27,077,050	10,676,477	93,950,667	57,179,020
2017	198,420,094	123,689,073	74,731,020	28,369,256	15,509,794	95,319,817	59,221,226
2018	201,600,963	125,022,725	76,578,238	29,108,518	17,469,296	95,914,207	59,108,942
2019	203,473,733	127,238,540	76,235,193	30,030,663	17,251,553	97,207,877	58,983,640
2020	197,855,373	125,703,062	72,152,311	30,800,274	13,530,374	94,902,788	58,621,937
Rice (rai)							
2015	67,379,403	58,268,938	9,110,465	20,553,780	5,968,828	37,715,158	3,141,637
2016	64,905,069	59,137,677	5,767,393	20,432,074	4,106,492	38,705,603	1,660,901
2017	70,791,962	59,428,909	11,363,053	21,056,862	8,491,993	38,372,047	2,871,059
2018	73,033,585	60,058,076	12,975,509	21,381,196	10,093,839	38,676,880	2,881,671
2019	72,947,931	61,041,042	11,906,889	21,811,605	9,338,604	39,229,437	2,568,285
2020	69,218,076	61,388,727	7,829,350	22,433,860	5,356,116	38,954,866	2,473,233
Maize (rai)							
2015	3,085,577	1,553,829	1,531,748	251,349	270,373	1,302,480	1,261,375
2016	2,702,645	1,308,550	1,394,095	215,728	298,909	1,092,822	1,095,186
2017	4,278,806	2,996,331	1,282,474	597,759	224,198	2,398,572	1,058,276
2018	4,741,521	3,271,251	1,470,270	673,284	287,325	2,597,968	1,182,945
2019	5,819,267	4,115,817	1,703,450	824,670	345,616	3,291,146	1,357,834
2020	4,216,672	2,327,258	1,889,414	493,684	351,905	1,833,574	1,537,509
Vegetables (rai)							
2015	3,410,993	1,521,339	1,889,654	420,103	275,531	1,101,236	1,614,123
2016	3,430,234	1,623,563	1,806,670	424,381	220,167	1,199,182	1,586,503
2017	2,774,416	1,072,915	1,701,501	357,478	240,438	715,438	1,461,062
2018	2,284,569	930,921	1,353,648	321,453	217,609	609,468	1,136,039
2019	2,349,360	877,452	1,471,907	316,806	246,961	560,646	1,224,946
2020	2,084,944	805,747	1,279,196	317,731	255,770	488,016	1,023,426
Field crops (rai)							
2015	2,527,374	1,367,079	1,160,295	300,006	419,491	1,067,073	740,803
2016	2,004,910	1,037,748	967,162	248,636	294,679	789,112	672,483
2017	1,957,848	882,387	1,075,461	209,543	405,550	672,844	669,911
2018	1,936,781	960,223	976,558	224,101	362,039	736,122	614,518
2019	1,801,128	926,206	874,923	218,546	461,335	707,660	413,588
2020	2,164,737	1,095,858	1,068,879	308,907	320,492	786,951	748,387

Source: OAE, OCSE, RID, DAE

Table 3.1.1-2 Cultivated area of long-lived crops

Year	Sugar cane (rai)			Fruit trees (rai)		
	Total area	Irrigated area	Rainfed area	Total area	Irrigated area	Rainfed area
2015	10,310,018	1,688,822	8,621,196	5,928,337	2,426,118	3,502,219
2016	9,969,016	1,549,136	8,419,880	5,943,552	2,371,023	3,572,528
2017	11,281,484	1,964,840	9,316,645	6,000,035	2,391,740	3,608,295
2018	12,065,791	2,301,185	9,764,606	5,988,301	2,394,882	3,593,419
2019	10,774,256	2,312,847	8,461,409	6,320,998	2,545,589	3,775,409
2020	9,430,708	2,458,477	6,972,231	7,040,998	2,707,143	4,333,855
	Perennail trees (rai)			Rubber trees (rai)		
2015	3,847,921	975,405	2,872,516	24,195,385	451,748	23,743,637
2016	3,846,075	873,578	2,972,497	24,172,018	502,976	23,669,043
2017	3,944,492	913,740	3,030,752	24,159,284	553,097	23,606,187
2018	3,842,995	915,589	2,927,406	23,614,048	557,039	23,057,010
2019	3,721,449	921,707	2,799,743	23,662,851	643,079	23,019,772
2020	3,815,712	982,292	2,833,419	23,212,285	644,844	22,567,441
	Cassava (rai)			Pineapple (rai)		
2015	9,315,012	138,807	9,176,205	455,371	25,969	429,402
2016	8,918,392	200,338	8,718,054	503,968	33,318	470,650
2017	8,624,284	65,159	8,559,125	565,687	23,406	542,281
2018	8,823,412	56,666	8,766,746	575,580	32,349	543,231
2019	9,439,009	70,307	9,368,702	491,117	53,898	437,219
2020	9,653,017	83,756	9,569,261	433,716	50,504	383,212
	Palm oil (rai)					
2015	4,444,439	200,030	4,244,409			
2016	4,567,158	225,863	4,341,295			
2017	4,733,264	235,632	4,497,632			
2018	4,892,126	250,774	4,641,352			
2019	5,868,343	311,609	5,556,734			
2020	6,499,037	319,075	6,179,962			

Source: OAE, OCSE, RID, DAE

3.1.2 Water used in the agricultural sector

The agricultural industry consumes the largest amount of water. Cultivation in irrigated and rainfed areas, livestock, and freshwater aquaculture are the main activities that necessitate water usage. Furthermore, economic activities in the agricultural sector that utilize water include fishery and forestry. Although freshwater fishery in natural water sources requires water use, natural freshwater circulates in the system. As a result, it is not considered in the calculation. Water usage of the marine fishery is not assessed because it is saltwater. Forestry water use is not assessed because it is part of the natural water cycle. As a result, agricultural water use includes irrigated and rainfed cultivation, livestock, and freshwater aquaculture.

Water use in irrigated areas is generally estimated by deducting effective rainfall out of plant water requirements, water loss on infiltration, and water used in farm preparation (in the case of rice cultivation) and dividing by water use efficiency. For irrigated area, this study contrasts with the previous one in that effective rainfall is included in the assessment of water productivity. The assessment of water productivity is calculated by two main components: GDP or GPP as a dividend and water used volume as a divider. As a result, it is necessary to compare water productivity in irrigated and rainfed areas; if effective rainfall is not used to calculate in the rainfed farming area, the divider will be zero, which cannot be compared. Therefore, the water consumption value will be higher than the usual calculation because of combining with effective rainfall.

The irrigation efficiency employed in this study is a country-wide estimate. Because each project lacks sufficient information, the actual amount of allocated water is compared to the calculated volume. In 2015-2020, the average efficiency of irrigation projects during the rainy season was 32% and 98% during the dry season. Details are shown in **Table 3.1.2-1**. During the rainy season, the quantity of drainage for flood defenses is often considered, resulting in a substantially larger amount of water allocated than the water needs of plants, so the actual water consumption figure cannot be separated. Hence, 60% of irrigation efficiency in the rainy season is used to calculate water use. During the dry season, the actual amount of water is used. In-depth interviews are conducted in 4 Water Operation and Maintenance projects: Kiew Lom - Kiew Kor Mah Water Operation and Maintenance Project in Lampang Province, Nong Wai Water Operation and Maintenance Project in Khon Kaen Province, Prasae Water Operation and Maintenance Project in Rayong Province, and Phetchaburi Water Operation and Maintenance Project in Phetchaburi Province to confirm the figure acquired.

Water delivery authorities from all four projects agree on using such estimations during the period when there is insufficient data on the efficiency of irrigation projects.

When considering actual water use in irrigated and rainfed areas, there are significant differences in water use patterns depending on crop type and amount of rain. As a result, a field trip is planned to conduct in-depth interviews with stakeholders from various water use sectors to identify appropriate strategies to increase water productivity, as summarized in **Section 6**. The interview results, together with the theoretical water consumption calculation, can be used to summarize water use in irrigated and rainfed areas, as shown in **Table 3.1.2-2**.

Table 3.1.2-1 An efficiency comparison of actual delivered irrigated water and calculated irrigated water

Year	Region	Volume of actual water delivery (million m^3)		Volume of calculated water (million m^3)		Efficiency	
		Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season
2015	North	1,267	1,364	856	908	68%	67%
	Northeast	3,282	1,090	1,541	854	47%	78%
	Central	12,075	4,168	4,889	4,727	40%	113%
	East	1,080	935	351	921	33%	98%
	West	1,845	632	572	516	31%	82%
	South	1,309	360	181	579	14%	161%
Total 2015		20,858	8,548	8,389	8,505	40%	99%
2016	North	1,943	394	381	509	20%	129%
	Northeast	3,349	1,047	1,053	882	31%	84%
	Central	11,369	2,287	3,439	3,660	30%	160%
	East	1,203	916	206	778	17%	85%
	West	1,512	994	359	564	24%	57%
	South	1,401	0	84	484	6%	
Total 2016		20,776	5,638	5,523	6,876	27%	122%
2017	North	1,580	921	301	802	19%	87%
	Northeast	2,935	1,533	620	1,166	21%	76%
	Central	10,900	5,246	2,797	7,552	26%	144%
	East	1,320	804	237	838	18%	104%
	West	2,013	1,079	236	451	12%	42%
	South	1,541	832	106	243	7%	29%
Total 2017		20,290	10,416	4,298	11,052	21%	106%
2018	North	1,736	1,192	528	771	30%	65%
	Northeast	2,790	2,048	1,322	1,516	47%	74%
	Central	10,302	8,520	4,439	8,408	43%	99%
	East	1,195	507	261	686	22%	135%

Year	Region	Volume of actual water delivery (million m^3)		Volume of calculated water (million m^3)		Efficiency	
		Rainy season	Dry season	Rainy season	Dry season	Rainy season	Dry season
	West	2,152	2,160	430	790	20%	37%
	South	2,094	884	166	278	8%	32%
Total 2018		20,269	15,310	7,145	12,449	35%	81%
2019	North	1,984	1,090	944	1,133	48%	104%
	Northeast	2,749	1,263	1,905	1,135	69%	90%
	Central	11,648	9,486	5,996	9,439	51%	100%
	East	1,027	932	484	775	47%	83%
	West	1,620	1,517	615	1,056	38%	70%
	South	1,859	821	237	368	13%	45%
Total 2019		20,886	15,110	10,180	13,906	49%	92%
2020	North	1,694	654	473	636	28%	97%
	Northeast	3,590	1,128	678	1,109	19%	98%
	Central	11,994	2,743	3,653	5,797	30%	211%
	East	1,333	860	118	689	9%	80%
	West	1,757	1,602	248	1,026	14%	64%
	South	2,265	1,559	43	404	2%	26%
Total 2020		22,634	8,547	5,212	9,662	23%	113%
Average 6 years	North	1,701	936	580	793	34%	85%
	Northeast	3,116	1,352	1,186	1,110	38%	82%
	Central	11,382	5,408	4,202	6,597	37%	122%
	East	1,193	826	276	781	23%	95%
	West	1,816	1,331	410	734	23%	55%
	South	1,745	743	136	392	8%	53%
Total		20,592	10,595	6,791	10,408	**32%**	**98%**

Source: Water delivery data from Royal Irrigation Department, Rainy season - water allocation, Dry season - actual water volume, Water demand - assessment from cultivated areas

In addition, the calculation of the water used in freshwater aquaculture also combines effective rainfall falling in ponds. When occurring evaporation, it is recorded as consumed water. It is different from water use efficiency assessments (SDG indicator 6.4.1) that considers only water use drawn from natural surface water sources.

Table 3.1.2-3 provides a summary of agricultural water use. **Table 3.1.2-4** illustrates the water use of major crops in irrigated and rainfed areas. Water use for livestock is categorized following **Table 3.1.2-5**. Water use for livestock is increasing year by year, especially cow and buffalo cultures, taking the highest proportion of water use.

From the average water use data from 2015 to 2020, rice culture uses the largest water volume of 47.53%, followed by rubber 21.14%, fruit trees 7.59%, sugarcane 6.60%, palm oil

4.69%, cassava 4.43%, perennial trees 3.26%, freshwater aquaculture 2.00%, maize 1.04% vegetables 1.02%, and pineapple and livestock used same proportion of 0.18%, respectively, as shown in **Figure 3.1.2-1**.

Table 3.1.2-2 Water used by crops in irrigated and rainfed areas

	Crop type	Irrigated area		Rainfed area	
		Rainy season	Dry season	Rainy season	Dry season
1	Rice	Watering	Watering	Watering	Watering
2	Maize	Watering	Watering	No watering	No watering
3	Field crops	Watering	Watering	No watering	No watering
4	Vegetables	Watering	Watering	Watering	Watering
5	Sugar Cane	Watering	Watering	No watering	200 m^3/rai
6	Fruit trees	Watering	Watering	No watering	400 m^3/rai
7	Perennial crops	No watering	No watering	No watering	No watering
8	Cassava	No watering	No watering	No watering	No watering
9	Palm oils	No watering	No watering	No watering	No watering
10	Rubber trees	No watering	No watering	No watering	No watering
11	Pineapple	Watering	Watering	No watering	No watering

Note: The proportion of water used was assessed by theory, previous studies[3], and in-depth interviews.

Table 3.1.2-3 Volume of water used in the agricultural sector

Year	Water used in the agricultural sector (million m^3)						
	Rice	Corn	Vegetables	Field crops	Sugar cane	Fruits	Perennial crops
2015	97,482	1,412	2,580	2,775	11,848	14,031	6,384
2016	92,991	1,418	2,568	2,568	11,987	14,121	6,330
2017	97,056	2,512	2,152	3,754	15,806	15,170	7,179
2018	105,264	2,536	1,751	3,880	16,562	15,454	7,187
2019	107,398	2,767	1,825	3,936	12,451	14,658	6,067
2020	80,608	2,019	1,621	3,175	12,031	18,077	6,689
Year	Water used in the agricultural sector (million m^3)						
	Rubber	Cassava	Pineapple	Oil palms	Farm animals	Aquaculture	Total
2015	42,308	8,431	302	7,847	327	4,004	198,016
2016	41,428	8,857	358	7,746	339	3,870	192,803
2017	46,581	9,269	400	9,572	351	3,864	210,755
2018	44,858	9,576	473	9,696	381	3,941	218,551
2019	40,764	8,287	347	10,388	403	3,932	210,108
2020	42,421	9,746	323	12,099	422	4,830	191,719

Source: Assessed by consultant

[3] The study of agricultural water demand under the environmental changes for EEC development

Table 3.1.2-4 Water use for cultivation in irrigated and rainfed areas

Unit: Million m^3

Year	Rice			Maize			Vegetables		
	Total	Irrgiated area	Rainfed area	Total	Irrgiated area	Rainfed area	Total	Irrgiated area	Rainfed area
2015	97,482	40,604	56,878	1,412	507	905	2,580	588	1,992
2016	92,991	36,201	56,790	1,418	479	940	2,568	524	2,044
2017	97,056	41,084	55,972	2,512	681	1,831	2,152	510	1,642
2018	105,264	48,147	57,118	2,536	848	1,688	1,751	488	1,262
2019	107,398	48,753	58,645	2,767	1,070	1,697	1,825	497	1,328
2020	80,608	34,122	46,486	2,019	727	1,292	1,621	494	1,127
Year	Field crops			Sugar Cane			Fruit tree		
	Total	Irrgiated area	Rainfed area	Total	Irrgiated area	Rainfed area	Total	Irrgiated area	Rainfed area
2015	1,060	555	506	11,848	3,264	8,584	14,031	6,835	7,196
2016	792	360	431	11,987	2,937	9,050	14,121	6,654	7,467
2017	842	461	381	15,806	4,052	11,754	15,170	6,987	8,183
2018	871	467	404	16,562	4,951	11,611	15,454	7,185	8,269
2019	823	498	325	12,451	4,530	7,922	14,658	7,224	7,434
2020	833	438	395	12,031	4,824	7,207	18,077	8,380	9,696
Year	Perennial crops			Rubber trees			Cassava		
	Total	Irrgiated area	Rainfed area	Total	Irrgiated area	Rainfed area	Total	Irrgiated area	Rainfed area
2015	6,384	1,635	4,749	42,308	795	41,512	8,431	113	8,318
2016	6,330	1,454	4,875	41,428	894	40,533	8,857	210	8,647
2017	7,179	1,694	5,486	46,581	1,096	45,485	9,269	69	9,200
2018	7,187	1,721	5,467	44,858	1,105	43,754	9,576	64	9,512
2019	6,067	1,524	4,542	40,764	1,117	39,646	8,287	63	8,223
2020	6,689	1,708	4,981	42,421	1,189	41,232	9,746	78	9,668
Year	Pineapple			Oil Palms			Total cultivation		
	Total	Irrgiated area	Rainfed area	Total	Irrgiated area	Rainfed area	Total	Irrgiated area	Rainfed area
2015	302	30	272	7,847	346	7,501	193,686	55,272	138,414
2016	358	41	317	7,746	389	7,356	188,594	50,144	138,451
2017	400	27	373	9,572	475	9,097	206,540	57,136	149,404
2018	473	36	437	9,696	493	9,203	214,229	65,505	148,724
2019	347	66	281	10,388	544	9,843	205,773	65,885	139,888
2020	323	69	254	12,099	578	11,521	186,466	52,607	133,860

Source: Assessed by consultant

Table 3.1.2-5 Water use for livestock

Year	Water use (million m^3)				
	Livestock	Cattle and buffaloes	Swine/Pigs	Poultry	Sheep and goats
2015	327	170	72	82	3
2016	339	180	73	82	4
2017	351	190	74	83	4
2018	381	212	77	88	4
2019	403	227	82	89	5
2020	422	239	89	88	6

Source: Assessed by consultant

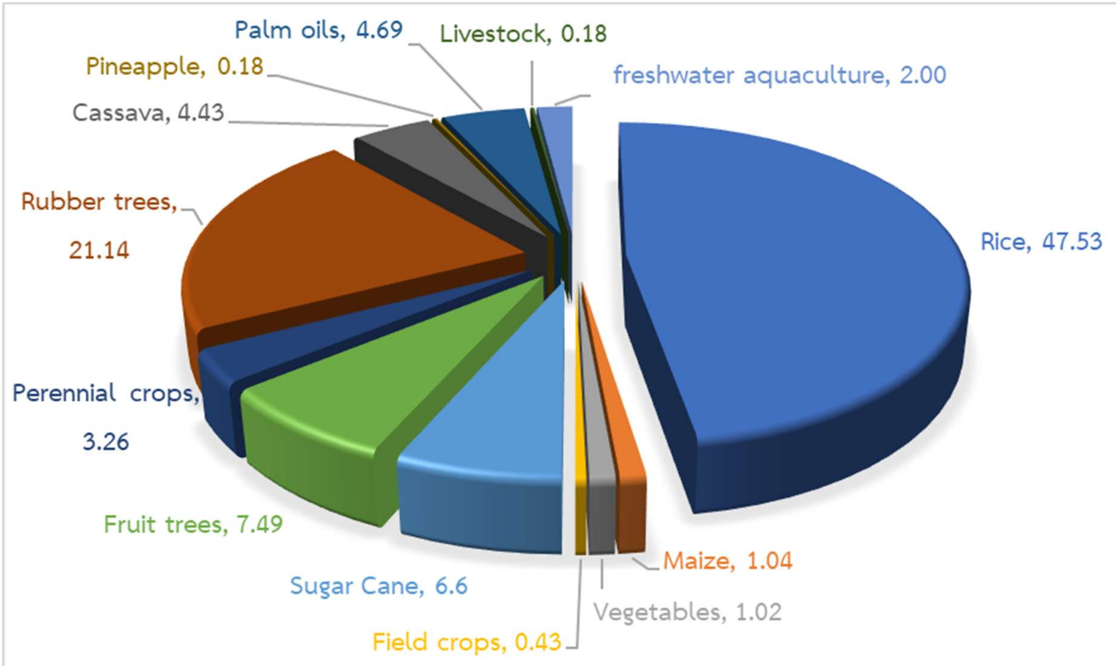


Figure 3.1.2-1 The proportion of average water use in 2015-2020.

When comparing the water use of rice farming in irrigated and rainfed areas, the water use proportion in irrigated areas is higher than in rainfed areas with the range of 65 - 74 and 35 – 42%, respectively, as shown in **Table 3.1.2-6** and **3.1.2-7**.

Table 3.1.2-6 Proportion of water used for rice farming in irrigated areas

Water used in irrigated area	2015	2016	2017	2018	2019	2020
Water use (million m^3)	55,272	50,144	57,136	65,505	65,885	52,607
water used for rice farming in irrigated areas (million m^3)	40,604	36,201	41,084	48,147	48,753	34,122
Proportion of water used for rice farming in irrigated areas (%)	73	72	72	74	74	65

Source: Assessed by consultant

Table 3.1.2-7 Proportion of water used for rice farming in rainfed areas

Water used in rainfed area	2015	2016	2017	2018	2019	2020
Water use (million m^3)	138,414	138,451	149,404	148,724	139,888	133,860
water used for rice farming in rainfed areas (million m^3)	56,878	56,790	55,972	57,118	58,645	46,486
Proportion of water used for rice farming in rainfed areas (%)	41	41	37	38	42	35

Source: Assessed by consultant

3.2 Industrial sector

Industrial water use assessments are separated into two categories: factories located inside the industrial estate zone and factories located outside of the industrial estate zone. The actual water use data collected by the Industrial Estate Authority of Thailand (IEAT) from 2017 to 2020 will be used in the industrial estate zone. Water use coefficient (m^3/day/horsepower) is used by factories located outside of industrial estates. According to the Department of Industrial Works' project to improve the industrial water database in 2019, 23 types of factories changed the water use coefficient based on the results of the ONWR project to study and evaluate indicators of water use efficiency and water scarcity.

Besides the water use coefficient, the water use assessment of power plants (Factory type 88 according to the Factory Act) employs the production capacity of each power plant type which water use volume is different. Hydroelectric power plants are not estimated because water is used to generate electricity and then released back into the stream (non-consumptive use). The wind power plant and the solar power plant do not use water.

The amount of water used in the industrial sector includes water used inside and outside of industrial estates, water used by power plants, and water lost in the water supply system. Currently, using of reuse and recycle water can minimize water use. If there is sufficient information, it is possible to increase water productivity in the industrial sector.

1) Volume of water used inside industrial estates

Industrial estates consist of 13 industrial estates operated by IEAT and 25 industrial estates jointly operated by IEAT. In 2020, there are 3 additional industrial estates jointly operated by IEAT, namely WHA Chonburi Industrial Estate 2, WHA Eastern Seaboard Industrial Estate 2, and Lakchai Muang Yang Industrial Estate, resulting in a total of 41 industrial estates. A summary of water use data of factories in industrial estates in 2017-2020 is shown in **Table 3.2-1**. The greatest amount of water used in industrial estates was 309.56 million m^3 in 2019, followed by 306.98 million m^3 in 2018, 294.35 million m^3 in 2020, and 290.53 million m^3. In 2020, the year of the COVID-19 epidemic, some industrial estates used relatively constant water; some increased or decreased overall water use compared to 2019; Northern Region Industrial Estate, Lamphun Province, Map Ta Phut Industrial Estate, Map Ta Phut Industrial Port, Amata City Chonburi Industrial Estate, Gateway City Industrial Estate, Bang Pa-In Industrial Estate, and Hi-Tech Kabin Industrial Estate had a dramatic decrease in water use, influenced by a decrease in production.

There is no data on water use in 2015 and 2016. Therefore, the water used for both years is relied on the volume of water use data from 2017, because the number of water used in industrial estates does not differ significantly each year, as proven by available data. This data includes the power plant's water use. When estimating the quantity of water used in industrial estates, the amount of water used by power plants must be deducted to combine with water use data from outside the industrial estate zone. Because the estimate of water use relies on the type of power plant and production capacity, when combined with industrial water use, the water productivity in industrial estates will be lower than outside of industrial estates.

When considering 3 provinces located in the Eastern Economic Corridor (EEC), namely Rayong, Chonburi, and Chachoengsao, it was found that the proportion of water use in industrial estates of all three provinces in 2017-2020 was approximately 77% of the water use in industrial estates across the country. Map Ta Phut Industrial Estate used the most water, accounting for 26% of water use in industrial estates across the country.

Table 3.2-1 Water used volume by industrial estates

No.	Name of industrial estate	Province	Water use volume (million m^3/year)			
			2017	2018	2019	2020
Operated by the Industrial Estate Authority of Thailand (IEAT)						
1	Northern Lamphun	Lamphun	6.34	6.25	6.25	4.86
2	Bangchan	Bangkok	1.78	1.75	1.78	1.78
3	Lat Krabang	Bangkok	9.49	10.22	10.10	9.14
4	Bang Poo	Samut Prakan	11.71	12.41	12.41	12.41
5	Samut Sakhon	Samut Sakhon	5.29	4.90	4.54	4.06
6	Southern Songkhla	Songkhla	0.63	0.62	0.62	0.52
7	Laem Chabang	Chonburi	9.13	9.13	9.13	9.13
8	Map Ta Phut	Rayong	76.65	80.45	82.22	71.66
9	Map Ta Phut Industrial Port	Rayong	8.05	8.47	8.93	6.72
10	Phichit	Phichit	0.08	0.07	0.11	0.30
11	Bangplee	Samut Prakan	2.23	2.26	2.48	2.33
12	Kaeng Khoi	Saraburi	0.36	0.46	0.47	0.50
13	Saharattana Nakhon	Ayutthaya	0.90	0.86	0.87	1.05
Jointly operated by IEAT						
14	Amata City Chonburi	Chonburi	17.43	17.52	18.04	16.83
15	Amata City Rayong	Rayong	14.96	16.07	16.88	16.01
16	Eastern Seaboard (Rayong)	Rayong	7.83	10.28	8.90	8.87
17	WHA Chonburi	Chonburi	1.33	1.46	1.49	1.56
18	WHA Chonburi 2	Chonburi				0.08

No.	Name of industrial estate	Province	Water use volume (million m³/year)			
			2017	2018	2019	2020
19	WHA Eastern Seaboard	Rayong	3.01	5.64	4.83	5.58
20	WHA Eastern Seaboard 2	Rayong				0.46
21	Pinthong	Chonburi	1.24	1.23	1.30	1.28
22	Pinthong (Laem Chabang)	Chonburi	0.99	0.99	1.05	1.02
23	Pinthong (Project 3)	Chonburi	0.44	0.45	0.44	0.47
24	Pinthong (Project 5)	Chonburi	0.00	0.01	0.01	0.01
25	Gateway City	Chachoengsao	3.53	3.59	3.49	2.99
26	Well Grow	Chachoengsao	8.09	8.40	8.40	8.40
27	Anya Thani	Bangkok	0.79	0.91	1.05	1.05
28	TFD	Chachoengsao	0.22	0.22	0.20	0.24
29	Bang Pa-In	Ayutthaya	8.15	8.85	9.43	8.76
30	Ban Wa	Ayutthaya	7.33	8.03	8.76	9.49
31	Nong Khae	Saraburi	4.38	4.42	4.96	5.44
32	Sinsakhon	Samut Sakhon	2.71	2.81	2.81	2.81
33	Ratchaburi	Ratchaburi	2.37	3.32	3.61	3.78
34	Hemaraj Eastern (Map Ta Phut)	Rayong	36.50	36.50	36.50	36.76
35	Asia	Rayong	14.60	14.60	14.60	14.60
36	RIL	Rayong	13.38	12.72	12.05	12.05
37	Padaeng	Rayong	7.51	8.89	8.89	9.21
38	Lakchai Muang Yang	Rayong				0.66
39	Asia (Suvarnabhumi)	Samut Prakan	0.23	0.91	0.28	0.31
40	Maharaj Nakorn	Samut Sakhon	0.75	0.55	0.45	0.52
41	Hi-Tech Kabin	Prachin Buri	0.11	0.78	1.23	0.66
Total			**290.53**	**306.98**	**309.56**	**294.35**

Source: Industrial Estate Authority of Thailand

Note: Include the water use for power plant inside industrial estates

2) Volume of water used outside industrial estates

The most completed industrial factory data by the Department of Industrial Works was the data in 2019, applying to all sizes of factories, both small and large. The estimation of water use outside the industrial estate zone in 2015-2018 was based on data from more than 400 large-sized factories under the Department of Industrial Works. Correction values of water use outside industrial estates were used from 2016 to 2020. In 2015, there was no data on water use in large-size factories, so data from 2016 was adopted because the number of factories was similar. The trend of water usage increased, as shown in **Table 3.2-2**.

Using the horsepower data of factories located outside the industrial estate to multiply with the water use coefficient (m³/day/hp) and adjusting the proportion of water usage each year based on large-size factory data, the estimation of water use volume outside the industrial estate area was as follows:

Year	2015	2016	2017	2018	2019	2020
Water used (million m^3)	2,575.80	2,575.80	2,925.43	3,889.52	3,513.88	3,462.91

Table 3.2-2 Water use in the large-sized factory by sources of water

Unit: Million m^3

Source of water	2016	2017	2018	2019	2020
Tap water	331.1	376.66	517.42	513.11	419.42
Groundwater	92.46	103.01	339.92	179.4	338.58
Surface water	814.11	824.68	961.92	936.21	866.35
Other sources	47.07	154.78	120.74	123.92	102.87
Total	**1,284.75**	**1,459.14**	**1,940.00**	**1,752.64**	**1,727.22**
Proportion	**0.73**	**0.83**	**1.11**	**1.00**	**0.99**

Source: Department of Industrial Works

3) Volume of water used by power plants (Factory type 88) (Veg)

According to ONWR's 2021 project to study and evaluate indicators of water use efficiency and water scarcity, water use per production capacity in each type of power plant was assessed using actual data from EGAT and a literature review of the power plant's water use data from the report of the environmental impact study. The assessment of water used volume per production capability was stated as follows:

Type	Total water use (m^3/ MW)
Natural gas and coal	7,400
Biomass	25,000
Biogas	9,300

Source: ONWR's 2021 project to study and evaluate indicators of water use efficiency and water scarcity

The information given above was used to calculate the water use by power plants across the country in 2019 based on the production capacity shown in **Table 3.2-3**. Water use by power plants in other years was calculated by annual production capacity data from the Ministry of Energy, available at: https://data.energy.go.th/factsheet/country/0/2020, which includes data from 2016 to 2020. In 2015, water use was estimated based on the rising trend of electricity use from 2016 to 2019. **Table 3.2-4** summarizes the annual water use by power plants.

Table 3.2-3 A summary of water use volume by power plants (Factory type 88)

	Energy source	Amount	Production capacity (MW)	Rate of water use (m^3/MW)	Total water use (million m^3/year)
EGAT	Diesel	4	30.40	7,400.00	0.22
	Thermal	3	3,687.00		45.96
	Combined cycle	11	8,262.00		85.55
Total		**18.00**	**11,979.40**		**131.73**
Private	Natural gas	76	6,895.00	7,400.00	51.02
	Natural gas, Coal, Fuel oil	1	45	7,400.00	0.33
	Natural gas/Diesel	12	10,089.00	7,400.00	74.66
	Natural gas/ Fuel oil	1	1,440.00	7,400.00	10.66
	Coal	6	377.5	7,400.00	2.79
	Bituminous coal	2	2,006.50	7,400.00	14.85
Total		**98**	**20,853.00**		**154.31**
Renewable energy	Biogas power plant	187	317.55	9,300.00	2.95
	Waste power plant	40	294.98	25,000.00	7.37
	Biomass power plant	218	1,690.84	25,000.00	42.27
Total		**445**	**2,303.36**		**52.6**
Grand Total		**561**	**35,135.76**		**338.64**

Source: ONWR's 2021 project to study and evaluate indicators of water use efficiency and water scarcity

Table 3.2-4 A summary of water use volume by power plants from 2015 to 2020

Unit: Million m^3

Year	2015	2016	2017	2018	2019	2020
Water volume	321.77	330.43	327.33	328.97	338.64	333.20

4) Water loss in the water supply system

ISIC E: water supply; sewerage, waste management and remediation activities were categorized in industrial water use. Almost all of the water produced from the water supply system was used in the service sector, so this section will be assessed water productivity in the service sector. In the process of the water supply system from the raw water source to the consumer, there is a part of the water loss in the system. Water loss was utilized to assess the water productivity of the water supply because it is under the responsibility of waterworks authorities. Water productivity in this section will decrease if water loss decreases. Water was not used for wastewater and waste management, so the amount of water was not used to calculate. The calculation of water loss in water supply production was based on actual water loss data in 2015-2020 from the Metropolitan Waterworks Authority in Nonthaburi, Bangkok, and Samut Prakan and water loss data from the Provincial Waterworks Authority, available at: https://www.pwa.co.th/province/report. For the remaining provinces, use the proportion of national actual water loss in 2015-2020 to find the water loss rate by provinces in the year 2015-2020. The result of calculating the water loss in the water supply system was based on the difference between the water production and water sales; then, it was combined with the industrial water consumption in items 1) to 3) above to be the total industrial water consumption. The amount of water loss in the annual water supply system was summarized as follows:

Year	2015	2016	2017	2018	2019	2020
Water used (million m^3)	1,588.66	1,683.51	1,889.26	2,028.49	2,209.15	2,396.98

Sections 1) - 4) above summarized the industrial water use from 2015 to 2020, as indicated in **Table 3.2-5**, separated according to ISIC rev.4. According to the findings, the greatest water use was found in 2018, and the least water use was in 2015. Water use increased by 1,775.39 million m^3 in 2018 compared to 2015, accounting for 38% growth over 4 years, which is in line with water used in industrial plants (B, C) in 2019-2020. During the COVID-19 pandemic in 2020, the total water use was less than the number in 2019 at 65.43 million m^3.

The amount of water loss in the water supply system was likely to increase every year, corresponding to the increasing water use for water for consumption. The highest water loss volume was in 2020, increasing by 808.32 million m^3 from 2015, accounting for 51%.

Water use of power plants was also likely to increase. Water use approached the highest record of 338.64 million m^3 in 2019, increasing 59.71 million m^3, accounting for 21% over 2015. The water use of power plants in 2020 was slightly lower than in 2019.

Table 3.2-5 A summary of water use in the industrial sector

Unit: Million m^3

	2015	2016	2017	2018	2019	2020
Water used inside industrial estates	246.74	245.57	261.39	262.67	248.21	246.74
Water used outside industrial estates	2,575.80	2,575.80	2,925.43	3,889.52	3,513.88	3,462.91
Total water uses in the industrial plant (B, C)	2,822.54	2,821.96	3,171.00	4,150.91	3,776.55	3,711.12
Water used by power plant (D)	330.43	321.77	327.33	328.97	338.64	333.2
Water loss in the water supply system (E)	1,588.66	1,683.51	1,889.26	2,028.49	2,209.15	2,396.98
Total water uses in the industrial sector (B, C, D, E)	**4,835.90**	**4,732.98**	**5,387.59**	**6,508.37**	**6,324.34**	**6,441.30**

Source: Assessed by consultant

3.3 Service sector

The calculation of water use in the service sector used the data from 2 main parts: actual water consumption based on storage and assessment of water use in service sector activities.

Data used to assess water use in the service sector includes

- Data on water use by sections (7 sections), provinces, and years (separating industrial water use from MWA and PWA information), as well as the number of water consumers provided by MWA, PWA, and DLA.
- Groundwater pumping volume by Private sector; data from the Department of Groundwater Resources (DGR)
- Water use assessment data of the village water supply from the project to study and evaluate indicators on water efficiency and water scarcity.

To be consistent with the major category (Section) of economic activities according to ISIC rev.4, water use was based on the water user code of MWA and PWA. Kasetsart University examined them with the document UN (2008) International Standard Industrial Classification of All Economic Activities (ISIC), Rev.4; both agencies' water consumption codes were grouped in the industrial and service sectors. Because it is part of the industrial water use, the quantity of industrial water use from PWA and PWA will not be assessed in water use.

To estimate the water based on the available data, water consumers in the service sector were re-categorized into economic activity groups, as shown in **Table 3.3-1**. Water productivity indicators were designed in line with the 20-year national water resource management master plan.

Table 3.3-1 Grouping types of users and economic activities (Sections) based on ISIC Rev.4

No.	User type	Economic activity (Section)
1	Accommodation	S, T
2	Business	G, H, J, K, L, M, N, R
3	Public/government organization	O
4	Hotel and restaurant	I
5	Hospital and social work	Q
6	Education	P
7	Industry	B, C, D, E
8	Construction and others	F

Furthermore, water use in the service sector was assessed using combined water use data both inside and outside the service area, derived from the rate of water use in villages by provinces (data from ONWR's 2021 Project to Study and Evaluate Indicators of Water Use Efficiency and Water Scarcity). Then, it was multiplied by the total population, including the latent population, as can be seen below:

Year	2015	2016	2017	2018	2019	2020
Water use (Million m^3)	4,645.80	4,766.17	4,843.74	4,880.40	5,135.68	5,199.17

In this study, water use value in the service sector was different from a project to study and evaluate indicators of water use efficiency and water scarcity because section F: Construction and others were grouped in the service sector. In the previous study, section F was in the industrial sector, according to SDG 6.4.1 Indicators by FAO.

The study's findings indicated that water use in the service sector was likely to rise year after year. Water use approached the largest volume during the research period of 2020, increasing from 2015 by 553.37 million m^3 or 12%. The biggest increase in 2019 was 255.28 million m^3, accounting for 5% over 2018, while the lowest increase in 2018 was 36.66 million m^3, representing a 1% increase over 2017.

Water use data by the service sector was analyzed by the economic activity category based on ISIC rev.4 as far as data could be extracted. Water use was summarized in **Table 3.3-2**.

Table 3.3-2 A summary of water used volume in the service sector in 2015 - 2020

	Volume of water used in the service sector (million m^3)					
	2015	2016	2017	2018	2019	2020
Construction and others (F)	132.14	131.53	130.96	127.79	132.79	128.31
Business (G, H, J, K, L, M, N, R)	1,007.65	1,011.56	1,009.40	1,005.45	1,048.69	1,006.17
Hotel and restaurant (I)	115.81	124.81	132.75	136.94	137.79	75.98
Public/government organization (O)	231.74	225.11	228.12	231.5	243.36	225.08
Education (P)	134.63	131.63	128.57	128.14	133.46	120.75
Hospital and social work (Q)	73.40	77.39	77.20	78.90	80.74	82.94
Accommodation (S, T)	2,950.44	3,064.15	3,136.74	3,171.68	3,358.85	3,559.93
Total water use in the service sector	**4,645.80**	**4,766.17**	**4,843.74**	**4,880.40**	**5,135.68**	**5,199.17**

Source: Assessed by consultant

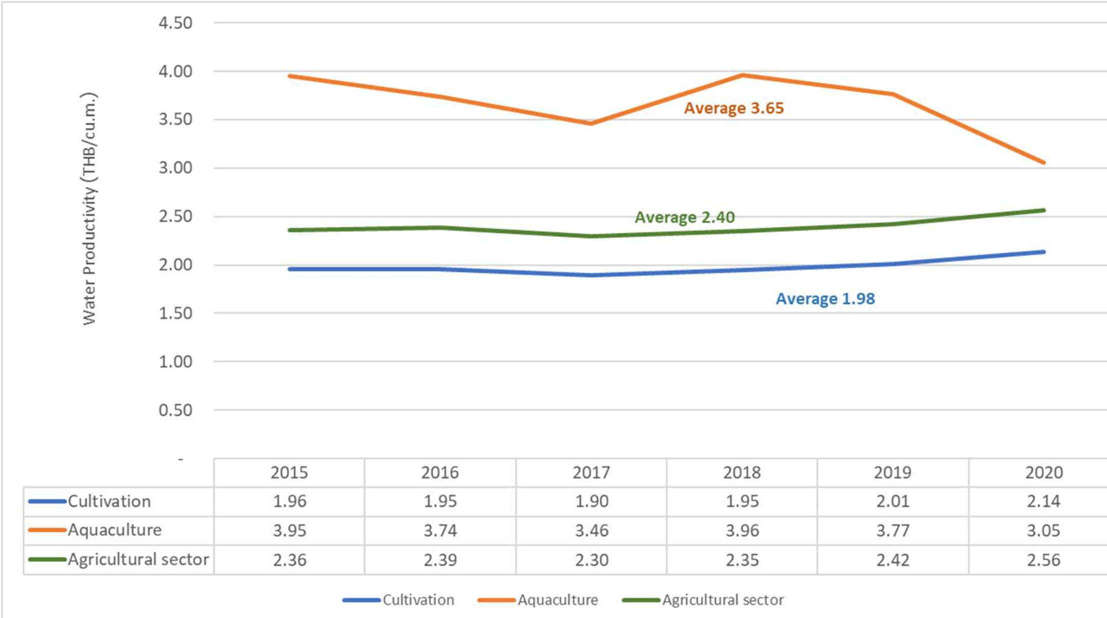
4. Water Productivity (WP)

According to the results of the economic value calculation in section 2 and the water consumption in section 3, it was adopted to assess water productivity at national, provincial, and basin levels as follows:

4.1 National water productivity

4.1.1 Agricultural sector

The overall agricultural water productivity in 2015 - 2020 averaged 2.40 THB/m^3, divided into the average water productivity of the cultivated area at 1.98 THB/m^3 in correspondence with the overall agricultural water productivity trend because the amount of water used in the cultivated area had the largest proportion, affecting overall water productivity of the agricultural sector. The average water productivity for freshwater aquaculture was 3.65 THB/m^3, with both rising and falling trends. In 2018, the highest water productivity was 3.96 THB/m^3, similarly to the value of 3.95 THB/m^3 in 2015. Livestock had average water productivity of 211.95 THB/m^3, continuing a downward trend. The highest livestock water productivity was 229.33 THB/m^3 in 2020, whereas the lowest water productivity was 184.50 THB/m^3. **Figure 4.1.1-1** demonstrated a comparison of water productivity in overall agriculture, cultivated areas, and freshwater aquaculture. Water productivity of livestock was shown in **Figure 4.1.1-2**.



	2015	2016	2017	2018	2019	2020
Cultivation	1.96	1.95	1.90	1.95	2.01	2.14
Aquaculture	3.95	3.74	3.46	3.96	3.77	3.05
Agricultural sector	2.36	2.39	2.30	2.35	2.42	2.56

Figure 4.1.1-1 Water productivity in overall agriculture, cultivation, and freshwater aquaculture

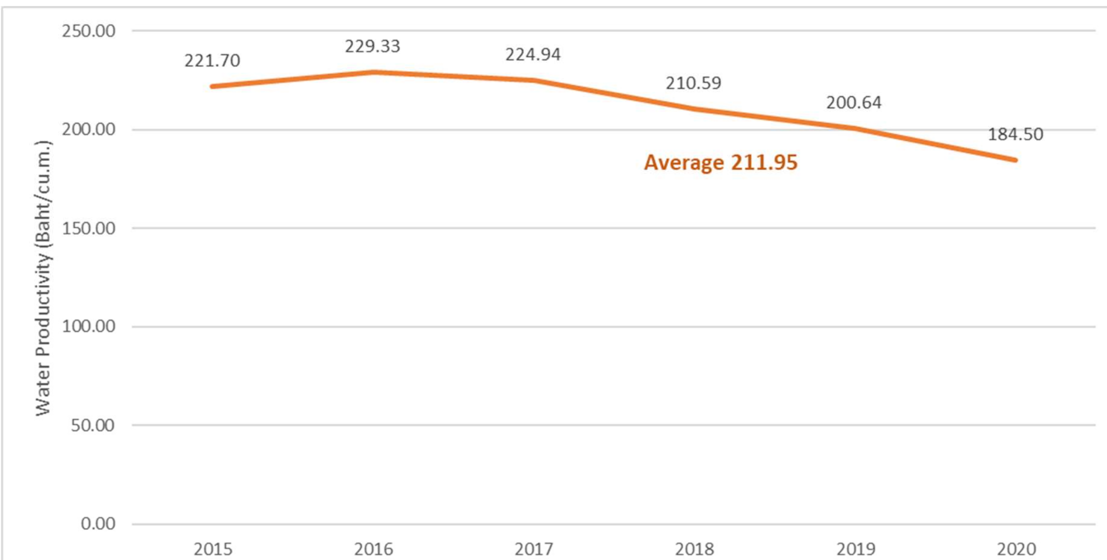
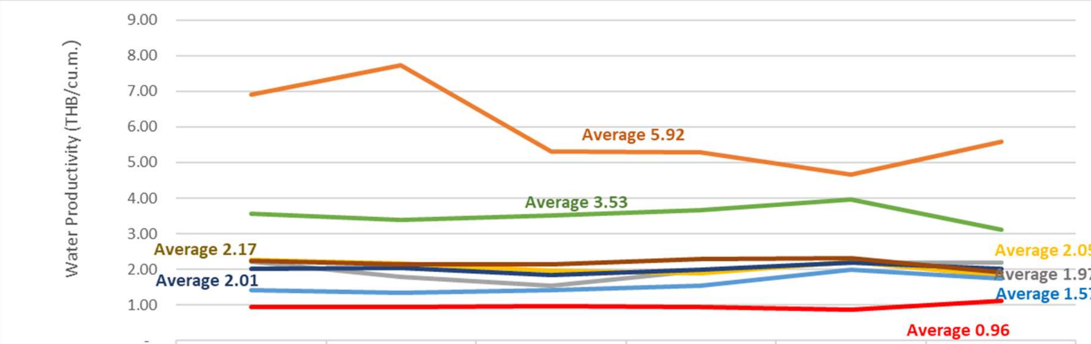


Figure 4.1.1-2 Livestock water productivity

Water productivity in cultivated areas is separated by main crops. The average water productivity for vegetables was 34.07 THB/m^3, with a rising trend. In 2015, water productivity was 23.98 THB/m^3, while water productivity was 43.91 THB/m^3 in 2020, accounting for an 83% increase. Followed by field crop, water productivity was on average 5.92 THB/m^3, which was likely to decrease during 2015-2019 and increase in 2020. Water productivity of fruit trees was 3.53 THB/m^3, increasing during 2015-2019 and decreasing in 2020. Palm oil, cassava, rubber tree, sugarcane, and the perennial tree had average water productivity of 2.17, 2.05, 2.01, 1.97, and 1.57 THB/m^3, respectively. Rice farming had the least water productivity at 0.96 THB/m^3 because it covered the highest water use proportion. Details are shown in **Figures 4.1.1-3** and **4.1.1-4**.



	2015	2016	2017	2018	2019	2020
Rice	0.94	0.93	0.96	0.93	0.86	1.11
Field crops	6.90	7.73	5.32	5.28	4.67	5.59
Sugar cane	2.20	1.79	1.53	1.95	2.18	2.18
Cassava	2.26	2.15	1.96	1.90	2.21	1.81
Perennial crops	1.41	1.35	1.42	1.54	1.99	1.74
Fruit trees	3.57	3.40	3.51	3.66	3.97	3.10
Rubber trees	2.01	2.02	1.84	1.99	2.18	2.02
Oil palms	2.23	2.13	2.15	2.30	2.31	1.91

Figure 4.1.1-3 Water productivity in the cultivated area by main crops

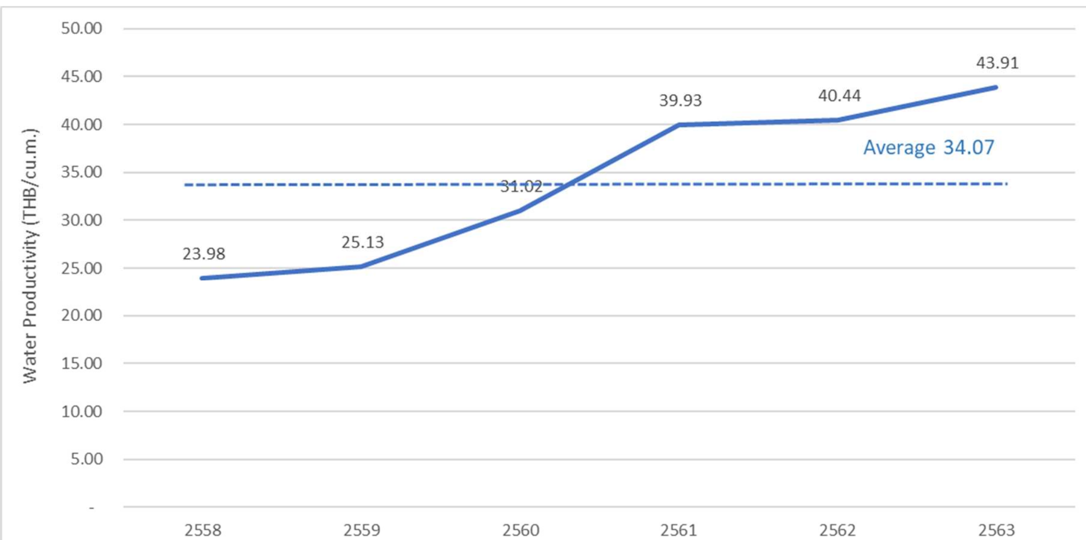
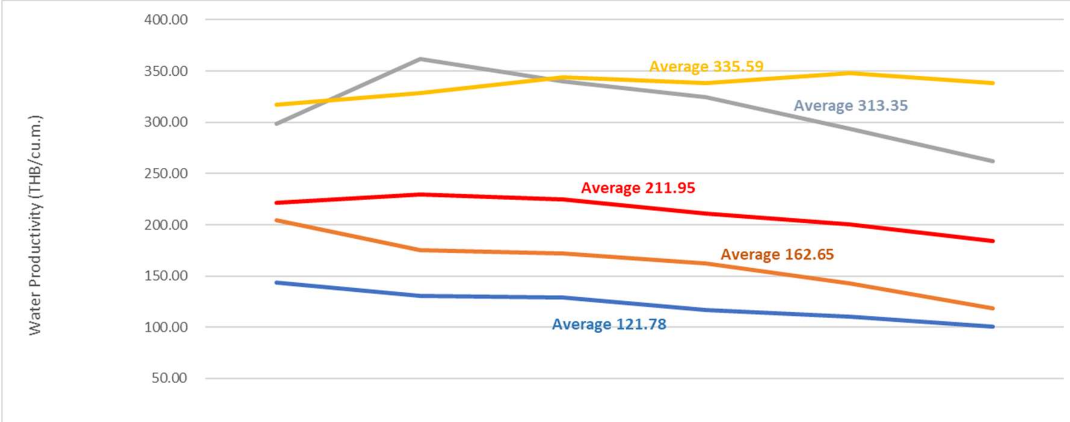


Figure 4.1.1-4 Cultivated water productivity by years

When considering livestock water productivity classified by animals, it was found that poultry had the highest water productivity averaging 335.59 THB/m^3; however, the value in each year was slightly different. Followed by pigs with average water productivity of 313.35 THB/m^3, it decreased by 12% from 2015 and was likely to continuously fall in 2020. Sheep and goats, with average water productivity of 162.65 THB/m^3, were in a falling trend, with the greatest decrease in 2020, falling by 42% from 2015. Cattle and buffaloes water productivity averaged 121.78 THB/m^3 and was in a downward trend in 2020, falling 30% from 2015. Details are shown in **Figure 4.1.1-5**.



	2015	2016	2017	2018	2019	2020
Cattle and buffaloes	143.56	130.71	128.88	116.79	110.10	100.61
Sheep and goats	204.67	174.88	172.37	162.60	142.67	118.70
Swine/Pigs	298.47	361.74	339.62	324.46	294.04	261.76
Poultry	316.81	328.70	343.55	338.16	348.30	338.05
Livestock	221.70	229.33	224.94	210.59	200.64	184.50

Figure 4.1.1-5 Livestock water productivity by animals

4.1.2 Industrial sector

Industrial water productivity in 2015 - 2020 was in a downward trend. Water productivity in 2015 and 2020 was 684 and 509 THB/m^3, respectively, indicating that it decreased by an average of 598 THB/m^3, accounting for 26%. The details of water productivity in the industrial sector are displayed in **Figure 4.1.2-1**.

For mining and manufacturing (Section B and C), the highest value averaged 903 THB/m^3, which was likely to decrease from 2015 to 2018 and increase during 2019 and 2020. Nevertheless, the overall WP was in a falling trend, compared to 2015, with an average value of 1,033 THB/m^3. It was reduced by 791 THB/m^3, accounting for 23%.

For electricity and gas consumption (Section D), it averaged 883 THB/m^3, with a rising trend during 2015 - 2019 and falling in 2020.

For water supply and wastewater management (Section E), the average value was 26 THB/m^3, which values were in the range of 28 - 23 THB/m^3. The least water productivity value was found in 2020.

	2015	2016	2017	2018	2019	2020
Mining + Manufacturing (B+C)	1,033	1,055	959	755	825	791
Electricity, Gas (D)	864	866	890	905	920	856
Water supply + Wastewater (E)	27	28	26	26	25	23
Industrial sector	684	684	628	535	551	509

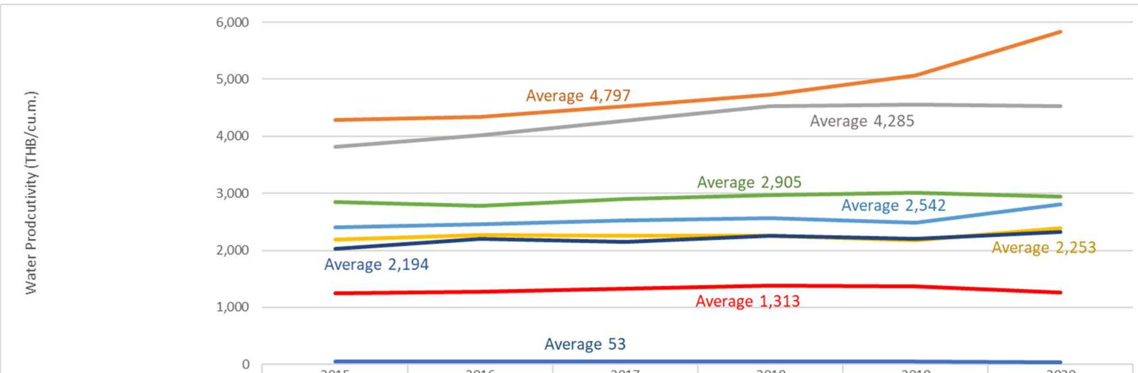
Figure 4.1.2-1 Water productivity by the industrial sector

4.1.3 Service sector

The average water productivity in the service sector from 2015 to 2020 was 1,313 THB/m^3. The classification of economic activities in detail is shown in **Figure 4.1.3-1**.

- Water productivity in hotels and restaurants (Section I) had the greatest value at 4,797 THB/m^3, with a rising trend. Water productivity approached the highest value in 2020, at 5,830 THB/m^3; though the COVID-19 pandemic occurred this year, it still had high water productivity. It was influenced by a 45 percent reduction in water use from 2019, while GDP also decreased but possessed a smaller proportion, decreasing by 37% from 2019.
- Water productivity in business (Section G, H, J, K, L, M, N, and R), averaging 4,285 THB/m^3, was likely to increase during 2015 - 2018 and stabilize during 2018 - 2020.
- Water productivity for hospitals and social work (Section Q) was relatively stable, averaging 2,905 THB/m^3.
- Educational water productivity (Section P), averaging 2,542 THB/m^3, was also relatively steady and likely to increase in 2020 due to the decrease in water use and increase in GDP.

- Government water productivity (Section O) had an average value of 2,253 THB/m^3 and was likely to increase slightly in 2020 due to the decrease in water use and increase in GDP.
- Construction water productivity (Section F) had an average value of 2,194 THB/m^3, which was similar to section O. It was likely to increase slightly in 2020 due to the decrease in water use and increase in GDP.
- Accommodation water productivity (Section S and T) had an average value of 53 THB/m^3, which was fairly constant but slightly decreased to approximately 48 THB/m^3 in 2020 due to increased water use, affected by WFH during the COVID-19 situation, and the decline in GDP.



	2015	2016	2017	2018	2019	2020
Accomodation (S,T)	53	53	54	55	53	48
Hotel and restaurant (I)	4,284	4,343	4,525	4,731	5,069	5,830
Business (G,H,J,K,L,M,N,R)	3,820	4,011	4,277	4,530	4,549	4,523
Public administration (O)	2,190	2,264	2,251	2,252	2,172	2,387
Education (P)	2,409	2,458	2,527	2,561	2,488	2,806
Public health and social work (Q)	2,841	2,776	2,897	2,970	3,006	2,942
Construction (F)	2,032	2,204	2,148	2,251	2,201	2,330
Service sector	1,251	1,280	1,328	1,383	1,372	1,266

Figure 4.1.3-1 Water productivity in the service sector

4.1.4 Overall water productivity

The average water productivity in Thailand from 2015 to 2020 was 48.12 THB/m^3, divided into 2.40 THB/m^3 of the agricultural sector, 598.45 THB/m^3. of the industrial sector, and 1,313.21 THB/m^3 of the service sector. Over 6 years, the overall water productivity was slightly changed; however, it increased minimally in 2020, approximately 50.91 THB/m^3. Details are shown in **Figure 4.1.4-1**. The largest factor that affected water productivity was agricultural water use at 95 %, followed by industrial and service sectors at 3 and 2%, respectively.

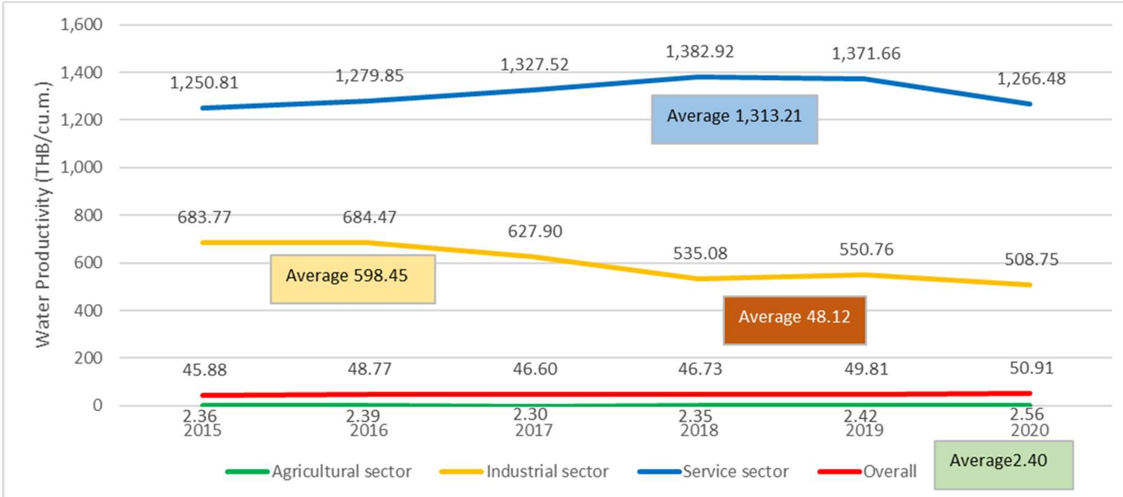


Figure 4.1.4-1 Overall and sector water productivity

When comparing the cost-effectiveness of economic activities, it was found that the service sector had the highest water productivity; this sector could generate the highest economic value from water use, especially in hotels and restaurants that had high GDP due to tourism. The long-term focus of all service sectors was human resources. For the industrial sector, the analysis results of water productivity were likely to decrease overall country. GDP during the study period was not much different while water use was on a rising trend. The agricultural sector had the lowest water productivity because its GDP was lower than the industrial and service sectors, whereas it used the largest amount of water. Furthermore, most yields in rainfed areas were vulnerable to rainfall, drought, flooding, and product price increases, as well as increased production factor prices and traditional cultivation in the original pattern.

GDP and water use were significant water productivity variables. Over the long term, GDP estimates were highly uncertain due to both domestic and exotic factors; consequently, considering feasibility was necessary[4]. If the relevant authorities perform based on the goal, the variable 'water use' is the better to approach prediction.

Analysis of GDP changes over the past period from 2010 – 2020 shows the uncertainty of the actual GDP value by using data from the National Income Report of Thailand 2020 (CVM), the latest officially announced. Also, in the previous year's report of the Office of the National Economic and Social Development Council, as shown in **Figure 4.1.4-2**, it was found that the

[4] Ton Yum Kung crisis in 1997 GDP fell by 7.6%; Hamburger crisis in 2009 GDP fell by 0.6%; COVID-19 crisis in 2020 GDP fell by 6.1%, Source: Matichon onlinr 19 April 2021 https://www.matichon.co.th/economy/news_2678319

GDP tends to increase continuously due to economic growth and decrease in 2020 due to the COVID-19 situation.

The proportion of GDP in the agricultural sector was between 8.12-11.59%. The overall GDP of the agricultural sector tends to decrease; however, the value increases yearly. While the important variable of the amount of water used in agriculture is the use of water in rice cultivation, especially in the irrigated area that can manage water use. If there is a lot of rice planting in any year, it will increase the amount of water used, resulting in a decrease in the water productivity in the agricultural sector. The proportion of non-agricultural GDP was between 88.41 - 91.87%, with an increasing proportion from 2015 onwards.

GDP changes increased most in 2010, 11.90% from 2009, due to the economic recovery after the hamburger crisis. It also increased in 2012, 9.29% from 2011, due to the recovery after the Great Flood. The most significant GDP drop was in 2020, falling 7.43% from 2019 due to the COVID-19 crisis. In 2011, despite the great floods, the GDP was still positive, with an increase of 4.61% from 2010.

Changes in GDP, both agricultural and non-agricultural sectors, have no apparent growth rate and have a sharp decline in 2020 due to the impact of COVID-19. Also, in 2022, challenges from the global economic slowdown, Russian-Ukrainian War, US and European inflation rising, and rising energy prices affect production and transportation costs. Although it was an opportunity for more exports, the cost burden also increased.

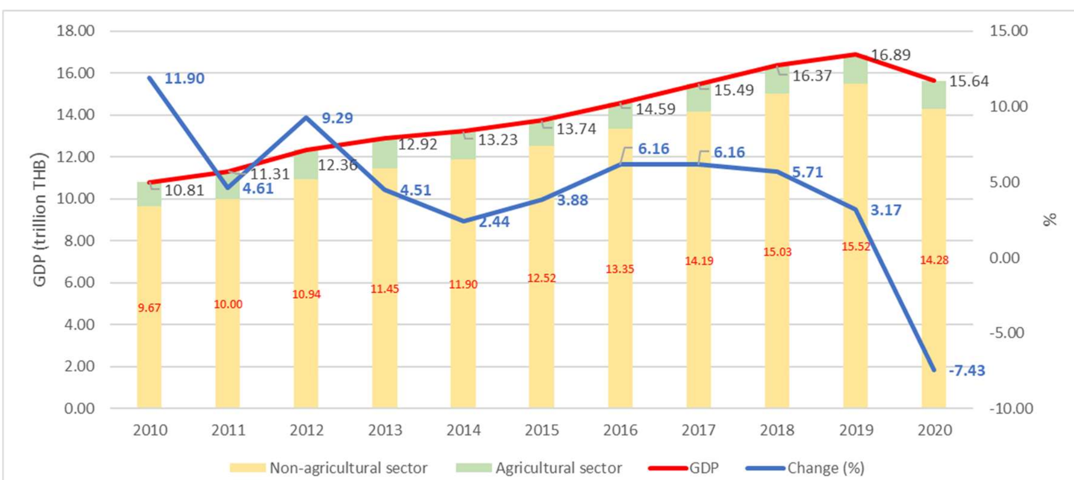


Figure 4.1.4-2 GDP (CVM) in 2015–2020

From the above information, the university compared the feasibility of guidelines involving two variables; details were shown in **Table 4.1.4-1**, consisting of

Condition 1 Normal

Condition 2 To reduce water use in the agricultural sector by 10%

Condition 3 To reduce water use in all sectors by 10%

Condition 4 To reduce water use in the agricultural sector by 10% and increase the GDP of the industrial and service sector by 10% (If over 5 years, GDP increases by 3% per year, it is possible.)

Condition 5 To reduce water use in the agricultural sector by 20%

Condition 6 To reduce water use in agriculture by 20% and increase GDP by 20% (if over 8 years, GDP increases by 3% per year, it is possible.)

Table 4.1.4-1 Water productivity by conditions.

Unit: THB/m^3.

Year	Condition 1	Condition 2	Condition 3	Condition 4	Condition 5	Condition 6
2015	45.88	50.72	50.97	55.26	56.70	68.04
2016	48.77	53.90	54.19	58.73	60.25	72.29
2017	46.60	51.51	51.77	56.13	57.58	69.10
2018	46.73	51.64	51.92	56.25	57.70	69.24
2019	49.81	55.03	55.35	59.94	61.47	73.76
2020	50.91	56.21	56.57	61.18	62.74	75.29
Total	**48.12**	**53.17**	**53.46**	**57.92**	**59.41**	**71.29**

Source: Assessed by consultant

According to **Table 4.1.4-1**, reducing water use had a minor influence on improving water productivity. GDP, based on the current economic structure, was the factor that obviously increased water productivity. As a result, water productivity should be assessed in areas of similar economic features or compared at the provincial or basin level.

4.2 Provincial water productivity

4.2.1 Agricultural sector

A comparison of water productivity in the irrigated and rainfed areas was conducted by using provincial-level data in 2015 - 2019 because GPP data must be extracted. During the study period, the data was available until 2019, so the water productivity was slightly different from the overview above, which used GDP to analyze the results. The results showed that water productivity in cultivated areas averaged 2.02 THB/ m^3 and was likely to increase. Water productivity in irrigated areas averaged 1.79 THB/ m^3, with a downward trend; the reason that its water productivity was lower than in rainfed areas, was a larger volume of water use per rai with similar yield prices. Water productivity in the rainfed agricultural area averaged 2.11 THB/ m^3, with a rising trend. Details are shown in **Figure 4.2.1-1**.

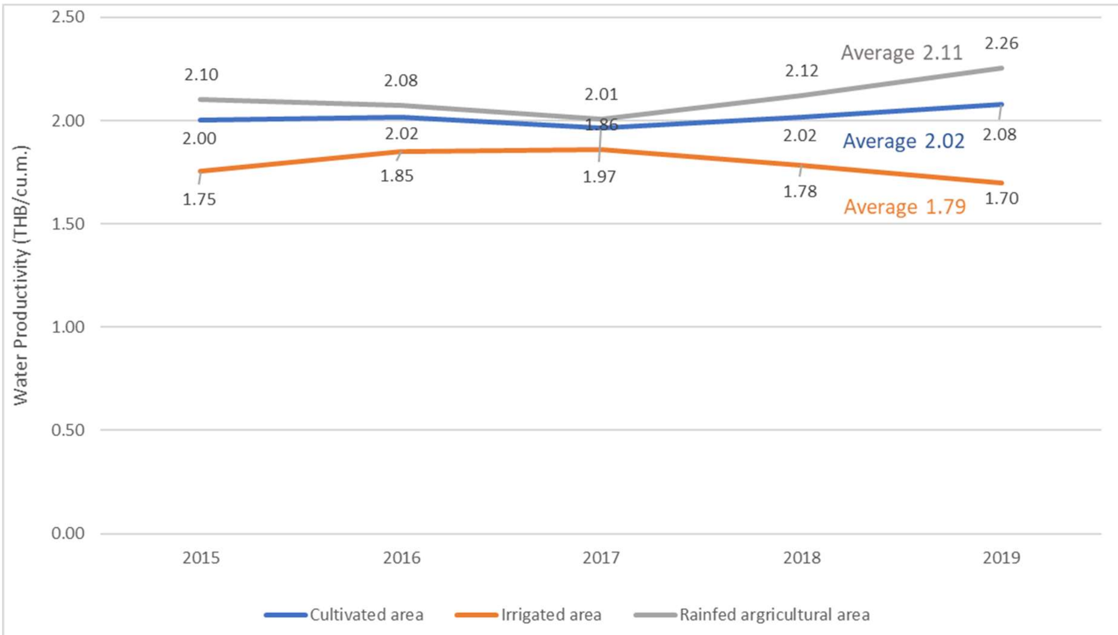


Figure 4.2.1-1 Comparison of water productivity in irrigated and rainfed areas

According to the findings, only focusing on statistics may lead to the inaccurate conclusion that increasing irrigated areas should be avoided. Indeed, cultivating in irrigated areas eliminates risks for farmers and increases their ability to earn profits from water use. In contrast to rainfed farmland, there is a risk of unpredictable rainfall and climate.

The top 10 highest agricultural water productivity provinces were Bueng Kan (8.33 THB/ m^3), Ratchaburi (6.87 THB/m^3), Chanthaburi (6.66 THB/m^3), Nakhon Pathom (6.18 THB/m^3), Saraburi (5.63 THB/m^3), Chonburi (5.36 THB/m^3), Tak (5.27 THB/m^3), Chiang Mai (5.06 THB/ m^3), Samut Sakhon (4.82 THB/m^3), and Nonthaburi (4.52 THB/m^3), as shown in **Figure 4.2.1-2**. Seven provinces had high water productivity in cultivated areas, namely Bueng Kan, Chanthaburi, Samut Sakhon, Nonthaburi, Tak, Chiang Mai, and Ratchaburi.

The top 10 lowest agricultural water productivity provinces were Maha Sarakham (1.68 THB/m^3), Nong Bua Lamphu (1.67 THB/m^3), Pattani (1.62 THB/m^3), Surin (1.58 THB/m^3), Ubon Ratchathani (1.54 THB/m^3), Sakon Nakhon (1.53 THB/m^3), Kalasin (1.51 THB/m^3), Amnat Charoen (1.38 THB/m^3), Yasothon (1.37 THB/m^3), and Roi Et (1.31 THB/m^3) as shown in **Figure**

4.2.1-3. Eight provinces had low water productivity in cultivated areas, namely Maha Sarakham, Surin, Ubon Ratchathani, Sakon Nakhon, Kalasin, Amnat Charoen, Yasothon, and Roi Et. Both high and low cultivated water productivity affected agricultural water productivity since it was the largest proportion of water use in the agricultural sector. Therefore, a significant method to increase water productivity in the agricultural sector is the cultivation of high economic value crops by using a marketing plan to reduce oversupply problems and create value-added to agricultural products instead of selling raw commodities.

A summary of the average agricultural water productivity by provinces (2015 – 2019) was shown in **Figure 4.2.1-4**.

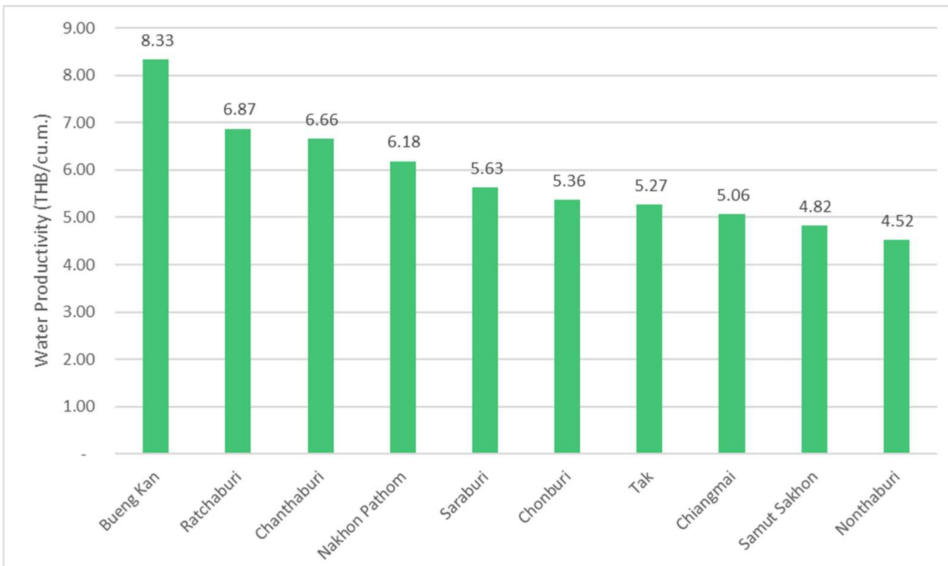


Figure 4.2.1-2 Top 10 highest agricultural water productivity provinces

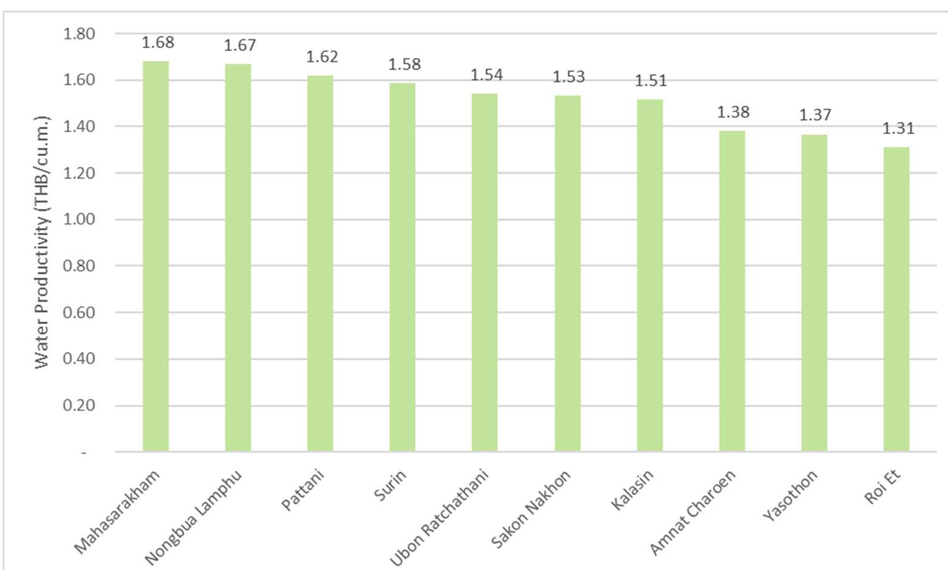


Figure 4.2.1-3 Top 10 lowest agricultural water productivity provinces

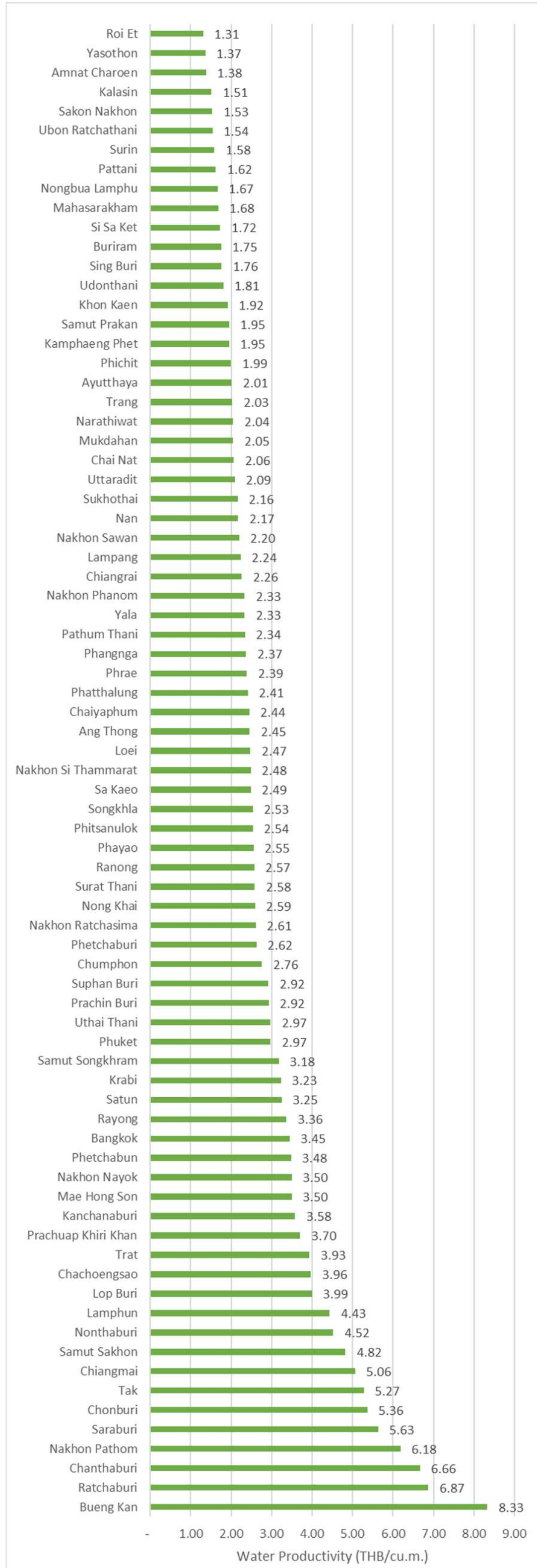
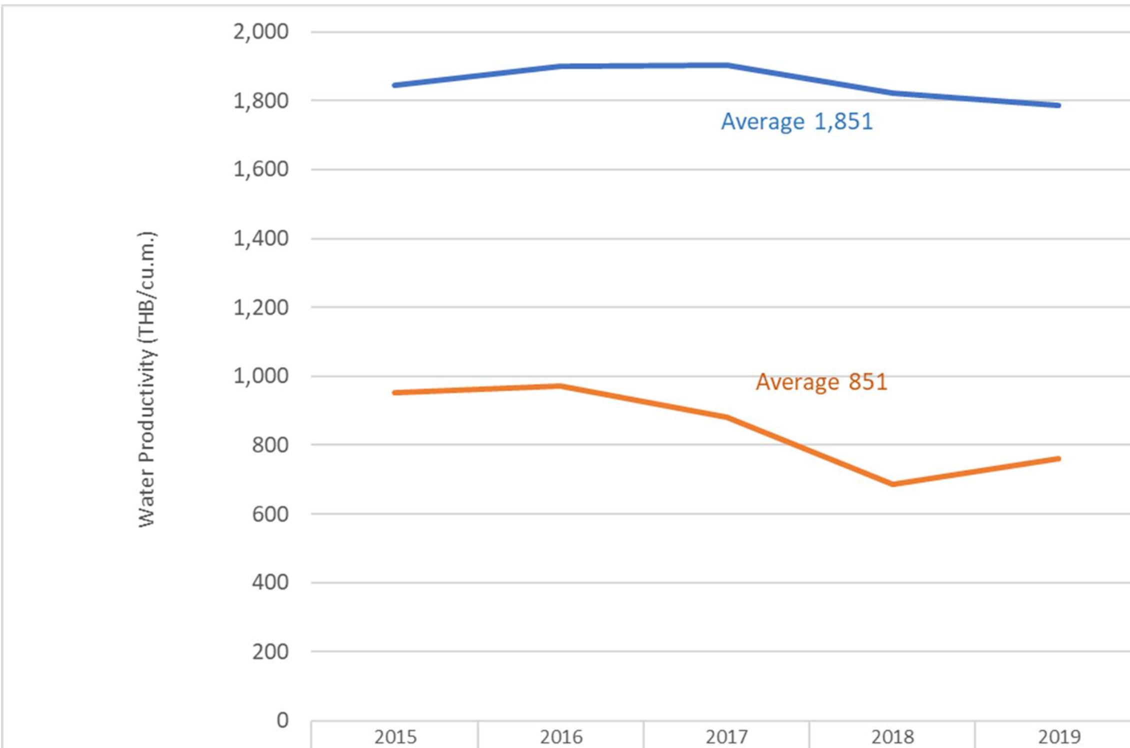


Figure 4.2.1-4 Summary of the average agricultural water productivity by provinces in 2015 - 2020

4.2.2 Industrial sector

Water productivity in industrial estates and outside industrial estates was assessed using provincial data on both GPP and water use of 13 provinces where industrial estates were located. The national water productivity was then assessed. Water productivity inside industrial estates averaged 1,851 THB/m^3 from 2015 to 2019, with a downward trend. Water productivity outside industrial estates averaged 851 THB/m^3, with a downtrend, as illustrated in **Figure 4.2.2-1**.



	2015	2016	2017	2018	2019
Inside industrial estates	1,845	1,900	1,904	1,821	1,786
Outside industrial estates	953	973	881	687	759

Figure 4.2.2-1 Water productivity inside and outside industrial estates

Overall national water productivity inside industrial estates was higher than outside industrial estates. When data at the provincial level were examined, it was shown that water productivity inside industrial estates was lower than outside industrial estates in several provinces and years. Although GPP was categorized into 9 types of industries based on a horsepower-license application, the main reasons were two: 1) GPP data was provincial-level data; when degraded at a sub-level, data discrepancy rose; 2) there was no data on water consumption, especially outside the industrial estate zones, which was calculated using the existing available information. Provinces that had water productivity inside industrial estates lower than outside industrial estates are Saraburi, Samut Sakhon, Prachinburi, and Rayong, as shown in **Table 4.2.2-1**.

Table 4.2.2-1 Annual water productivity separated inside and outside industrial estates

Province	2015		2016		2017		2018		2019	
	Inside industrial estate	Outside industrial estate	Inside industrial estate	Outside industrial estate	Inside industrial estate	Outside industrial estate	Inside industrial estate	Outside industrial estate	Inside industrial estate	Outside industrial estate
Lamphun	2,592	348	2,670	358	2,708	345	2,959	266	3,093	325
Phichit	4,837	390	4,989	367	5,654	321	5,720	251	1,572	275
Saraburi	411	805	486	830	522	725	528	570	423	599
Ayutthaya	4,238	1,498	3,936	1,463	3,841	1,256	3,487	931	2,973	982
Bangkok	6,590	1,605	7,245	1,609	6,811	1,362	6,520	1,063	6,682	1,171
Samut Prakan	2,463	682	2,258	656	2,243	549	2,320	464	2,275	485
Samut Sakhon	676	699	702	717	772	685	837	530	878	590
Chachoengsao	2,979	2,010	3,221	2,173	3,113	1,840	3,441	1,585	3,402	1,714
Prachin Buri	1,525	1,766	1,826	2,109	2,348	2,363	347	1,914	236	2,327
Chonburi	3,757	1,005	4,089	1,072	4,047	958	4,197	751	4,119	829
Rayong	1,010	1,375	1,042	1,406	1,094	1,274	983	927	972	1,009
Ratchaburi	2,150	510	1,496	493	1,830	453	1,322	311	1,092	339
Songkhla	1,658	898	1,632	887	1,409	724	1,429	533	1,388	570

Source: Assessed by consultant

According to the analytical data in the above table, the results of each province are very different and do not point in the same direction, even though the data was split based on industrial types and water consumption of industrial estates, which was the net volume of water, calculated from the amount of water recycled in the manufacturing process. Therefore, a comparison of water productivity inside industrial estates and outside industrial estates can be made at a national level. Although actual water use data was not accessible, average distribution statistics could be compared. The values obtained when the results were shown at the provincial level were different. As a result, in a future study, comparing water productivity should only be conducted at a national level until there will be water use close-to-reality data based on industrial types or actual water use data. When analyzing the top 10 highest industrial water productivity provinces, there were Prachinburi (1,933 THB/m^3), Chachoengsao (1,802 THB/m^3), Kamphaeng Phet (1,470 THB/m^3), Rayong (1,087 THB/m^3), Phra Nakhon Si Ayutthaya (1,066 THB/m^3), Chonburi (943 THB/m^3), Bueng Kan (874 THB/m^3), Lamphun (756 THB/m^3), Bangkok (689 THB/m^3), and Uthai Thani (620 THB/m^3), as shown in **Figure 4.2.2-2**. All 3 provinces located in the EEC project, namely Rayong, Chonburi, and Chachoengsao, were also ranked in the top 10, indicating that water use affected high water productivity. Most provinces that were ranked, had crowded factories, except Kamphaeng Phet, Bueng Kan, and Uthai Thani, which were mostly agricultural product processing industries. However, low water use was a factor that contributed to the high water productivity.

The top 10 lowest industrial water productivity provinces were Chiang Rai (136 THB/m^3), Phayao (121 THB/m^3), Phang-nga (121 THB/m^3), Amnat Charoen (120 THB/m^3), Mae Hong Son (110 THB/m^3), Phuket (91 THB/m^3), Nan (88 THB/m^3), Phatthalung (81 THB/m^3), Ranong (71 THB/m^3), and Narathiwat (67 THB/m^3), as shown in **Figure 4.2.2-3**. Most provinces in this group had few industrial factories.

A summary of the average industrial water use productivity by provinces (2015 – 2019) was shown in **Figure 4.2.2-4**.

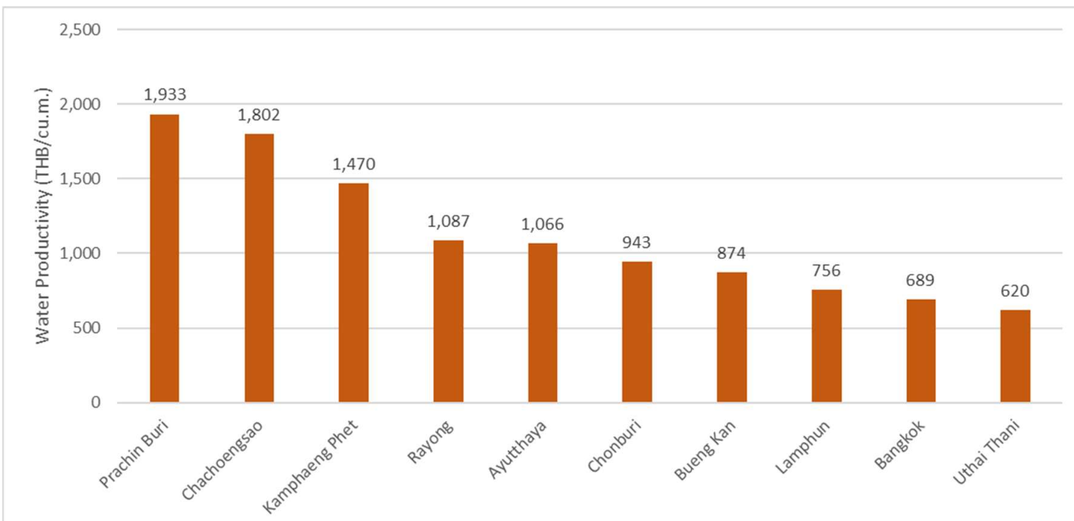


Figure 4.2.2-2 Top 10 highest water productivity provinces

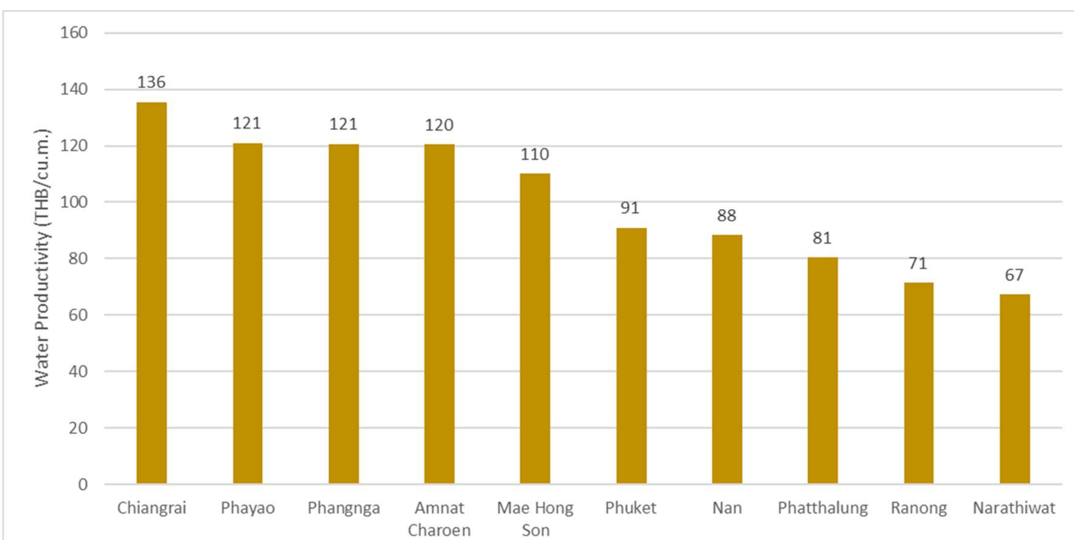


Figure 4.2.2-3 Top 10 lowest water productivity provinces

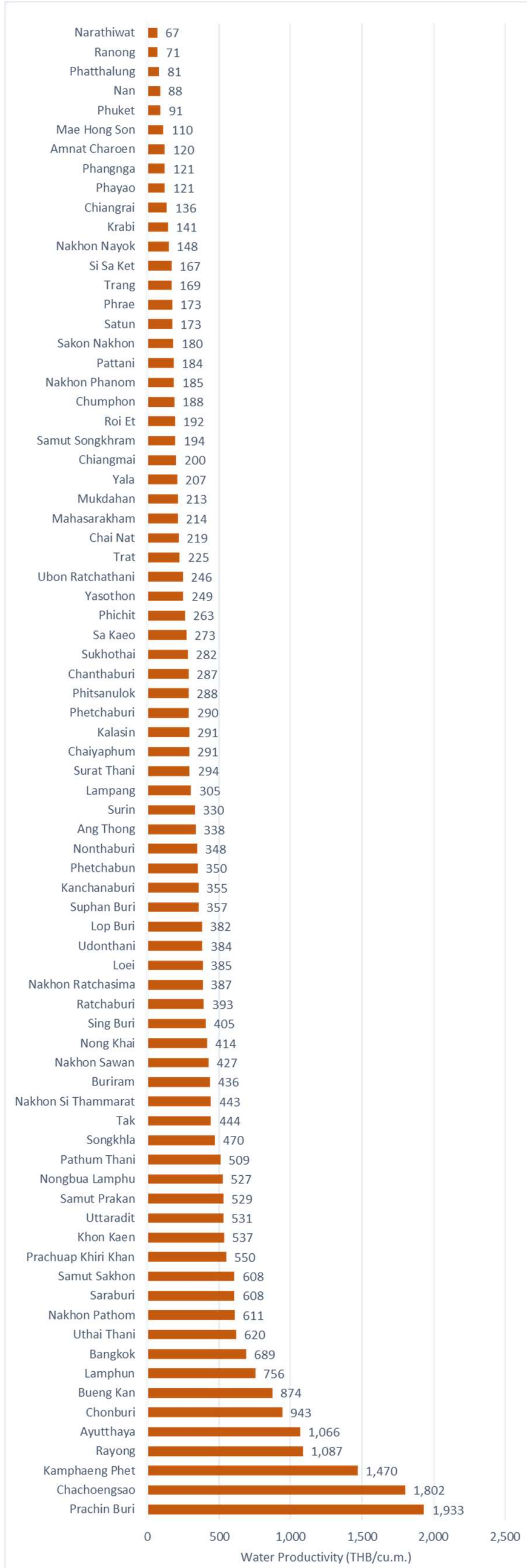


Figure 4.2.2-4 A summary of water productivity by provinces in 2015-2020

4.2.3 Service sector

To analyze the overall water productivity of the service sector by provinces in 2015-2019, the water productivity results according to the main economic sectors to be consistent with ISIC rev.4 can be described as follows:

The top 10 highest water productivity provinces in the service sector were Bangkok (3,597 THB/m^3), Phuket (2,355 THB/m^3), Phang-nga (2,269 THB/m^3), Samut Prakan (1,472 THB/m^3), Chonburi (1,264 THB/m^3), Nonthaburi (1,209 THB/m^3), Rayong (1,182 THB/m^3), Krabi (1,097 THB/m^3), Singburi (1,040 THB/m^3), and Surat Thani (1,030 THB/m^3), as shown in **Figure 4.2.3-1**. The six provinces mentioned above ranked in the top 10 highest GPP provinces were Rayong, Bangkok, Chonburi, Phuket, Samut Prakan, and Phang Nga. The most significant statistic of Sing Buri derived from education activities in the service sector, although the GPP was lower than in other provinces. However, the amount of water used in the education section was also low.

The top 10 lowest water productivity provinces in the service sector were Sisaket (477 THB/m^3), Sakon Nakhon (464 THB/m^3), Narathiwat (457 THB/m^3), Yasothon (456 THB/m^3), Buriram (442 THB/m^3), Chaiyaphum (432 THB/m^3), Maha Sarakham (411 THB/m^3), Trang (409 THB/m^3), Sa Kaeo (364 THB/m^3), and Mae Hong Son (355 THB/m^3), as shown in **Figure 4.2.3-2**. The five provinces mentioned above also ranked in the top 10 lowest GPP, namely Sakon Nakhon, Narathiwat, Yasothon, Chaiyaphum, and Mae Hong Son.

A summary of water productivity in the service sector by provinces in 20105-2020 was shown in **Figure 4.2.3-3**.

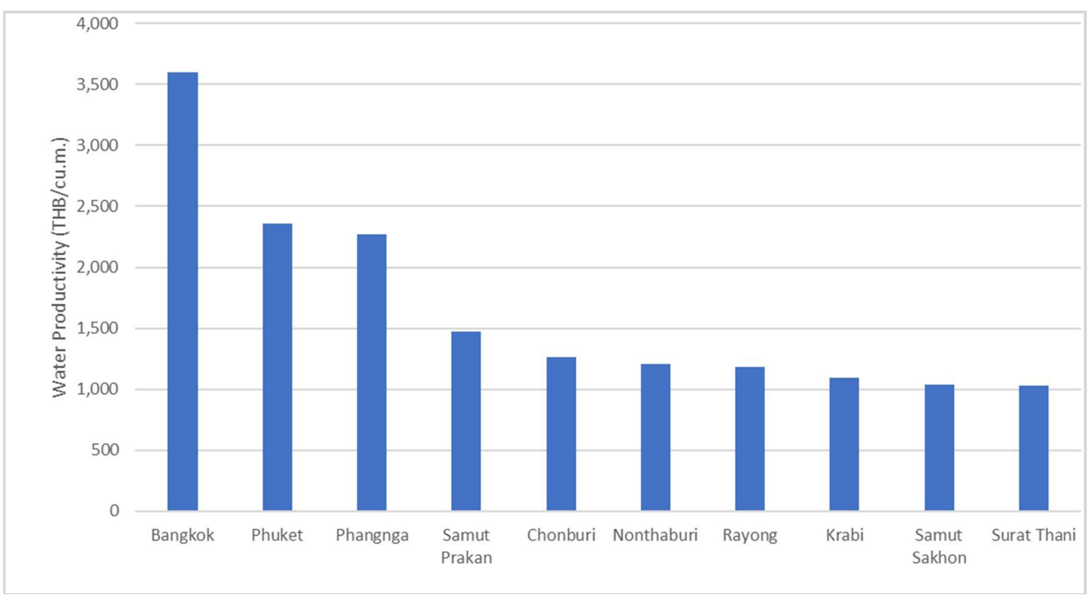


Figure 4.2.3-1 Top 10 highest water productivity provinces in the service sector

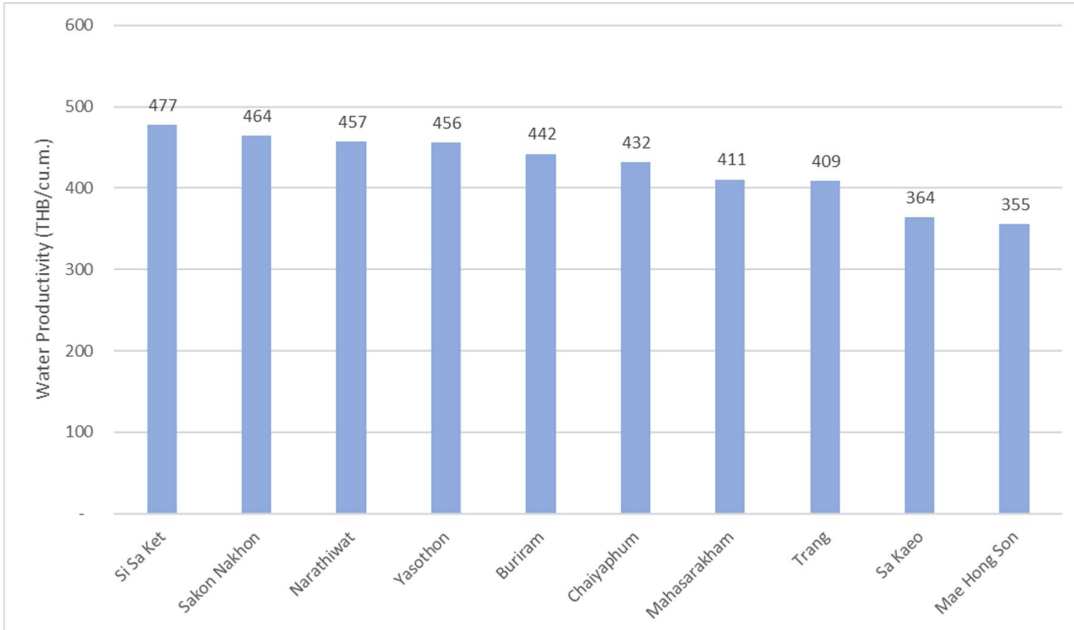


Figure 4.2.3-2 Top 10 lowest water productivity provinces in the service sector

4.2.4 Water productivity by provinces

The average water productivity by provinces was calculated based on the water productivity of the agricultural, industrial, and service sectors in 2015-2020.

The top 10 highest water productivity provinces were Bangkok (1,937 THB/m^3), Samut Prakan (578 THB/m^3), Phuket (479 THB/m^3), Nonthaburi (339 THB/m^3), Samut Sakhon (331 THB/m^3), Chonburi (271 THB/m^3), Rayong (193 THB/m^3), Pathum Thani (174 THB/m^3), Prachinburi (158 THB/m^3), and Saraburi (116 THB/m^3), as shown in **Figure 4.2.4-1**. Compared with the top 10 highest GPP provinces, it was found that 8 provinces were in line with the provinces mentioned above, namely Bangkok, Samut Prakan, Phuket, Samut Sakhon, Chonburi, Rayong, Prachinburi, and Saraburi.

The top 10 lowest water productivity provinces were Roi Et (8.53 THB/m^3), Narathiwat (8.43 THB/ THB/m^3), Phatthalung (8.30 THB/m^3), Surin (8.27 THB/m^3), Kalasin (7.97 THB/m^3), Sisaket (7.53 THB/m^3), Sakon Nakhon (7.09 THB/m^3), Phichit (7.05 THB/m^3), Yasothon (6.95 THB/m^3), and Amnat Charoen (5.90 THB/m^3), as shown in **Figure 4.2.4-2**. Compared with the top 10 lowest GPP provinces, it was found that only 2 provinces were in line with the provinces mentioned above, namely Sakon Nakhon and Amnat Charoen. In terms of economic activities, all 10 provinces were mainly driven by agriculture.

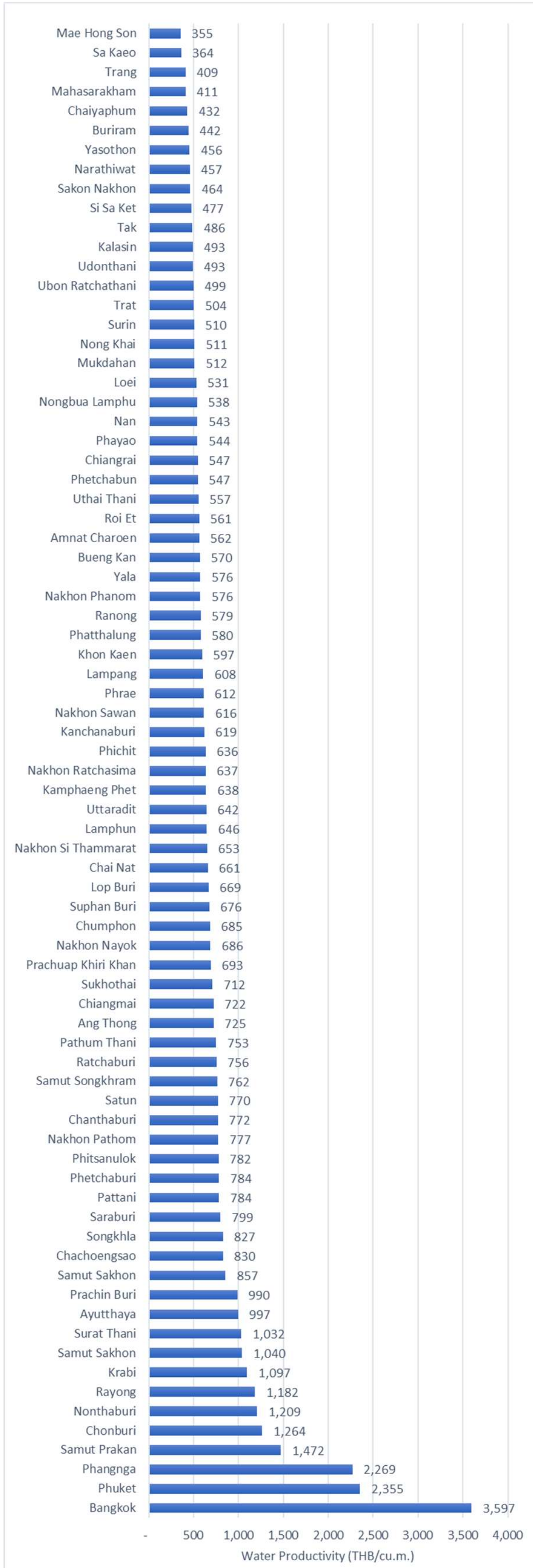


Figure 4.2.3-3 A summary of water productivity by provinces in 2015-2020

A summary of the average water productivity by provinces (2015-2019) was shown in **Figure 4.2.4-3**. The water productivity values indicated that the economic distribution was extremely different between Bangkok (1,936.60 THB/m^3) with the highest value and Amnat Charoen (5.90 THB/m^3) with the lowest value. The difference was 328-fold; with the same volume of 1 m^3, the economic value was significantly different. 64 provinces had water productivity of less than 100 THB/m^3, indicating the different distribution of the economy.

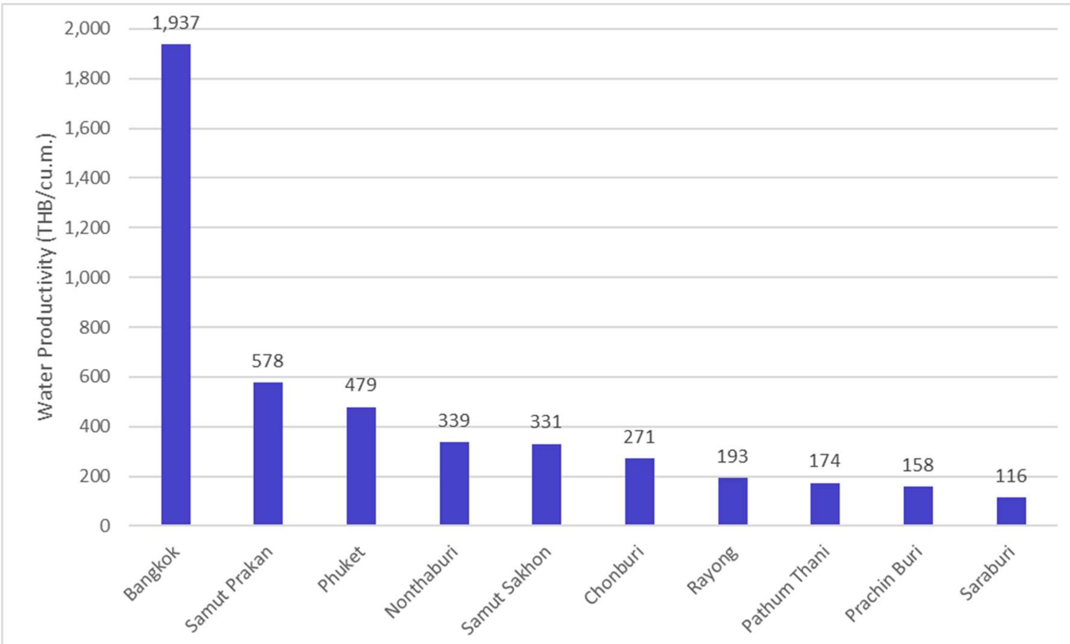


Figure 4.2.4-1 Top 10 lowest water productivity provinces

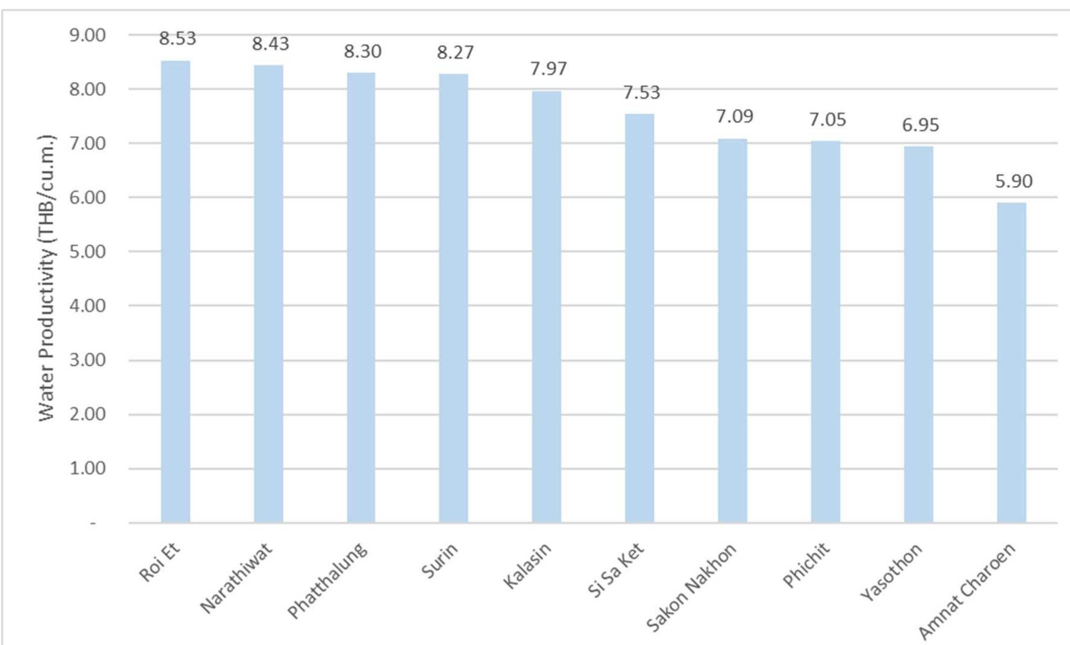


Figure 4.2.4-2 Top 10 lowest water productivity provinces.

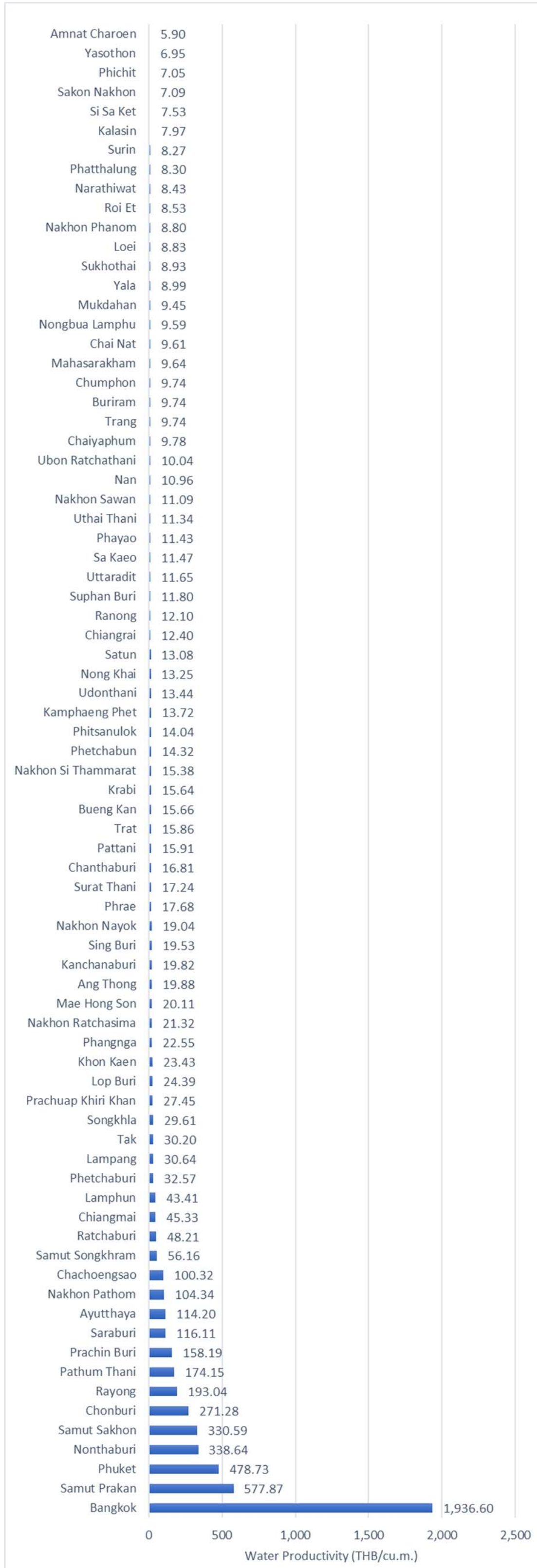


Figure 4.2.4-3 Water productivity by provinces in 2015 - 2020

4.3 River basin-level water productivity

The river basin-level water productivity assessment shows the economic impact of using water productivity from river basin management. Because each basin has different topography, hydrology, meteorology, and economic activities, so the future economic goals are represented by using water productivity as the basis for determining economic goals. Each manufacturing sector's economic activity can be summarized as follows:

4.3.1 Agricultural sector

The Salween Basin has the highest water productivity (5.88 THB/m^3), followed by the Mae Klong Basin (5.84 THB/m^3), the East-Coast Gulf Basin (5.58 THB/m^3), the Ping Basin (4.04 THB/m^3), the Pasak Basin (4.03 THB/m^3), and the Mun Basin (1.80 THB/m^3), which is close to the Chi Basin (1.82 THB/m^3) as shown in **Table 4.3.1-1**. The river basin with the highest agricultural water productivity is also the river basin with the highest plantation productivity. The Chi Basin and Mun Basin have different values by 3.3-fold from the Salween Basin, which has the highest value. Compared to the national average water productivity at 2.40 THB/m^3, there are 6 river basins that are lower than the average, including Wang Basin, Nan Basin, Lower Part of Peninsula-East Coast Basin, Yom Basin, Chi Basin, and Mun Basin. These river basin groups should be prioritized when targeting river basin groups to increase agricultural water productivity.

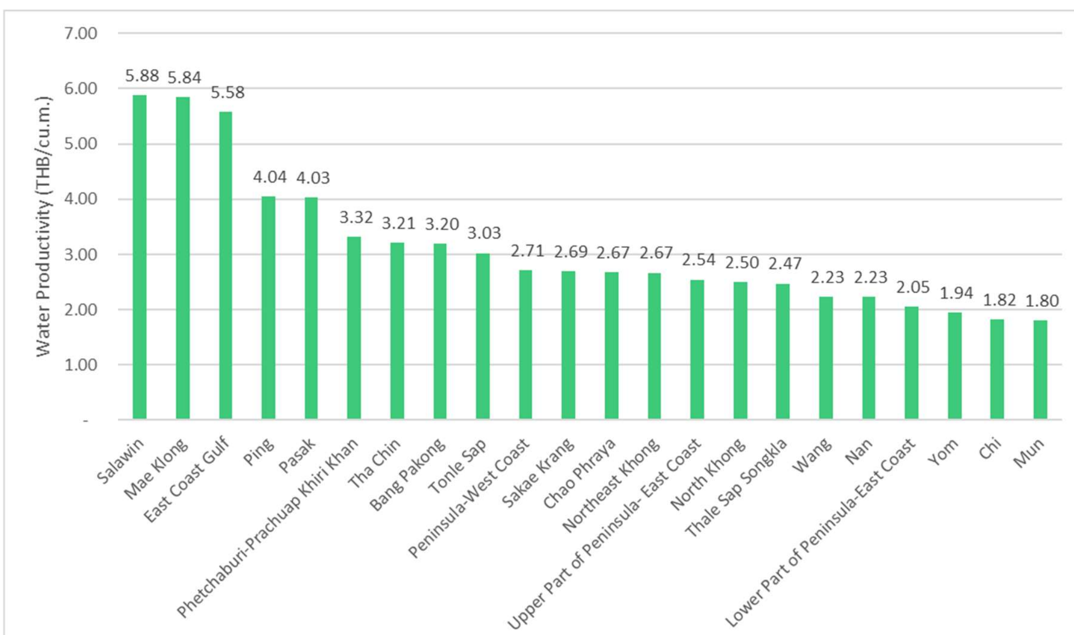


Figure 4.3.1-1 Agricultural water productivity in the main river basins

4.3.2 Industrial sector

The river basin-level water productivity assessment in the inside and outside industrial estates can be considered in 9 basins where industrial estates are located. It can be classified as a river basin for factories outside industrial estates with factory location information. There are 9 types of industrial factories. When compared to river-basin data, it was discovered that there are 2 river basins, Pasak Basin and Tha Chin Basin, outside the industrial estate that have higher water productivity than the inside industrial estate, as shown in **Table 4.3.2-1**. At the provincial level, the results are different: Saraburi Province (Pasak Basin), Samut Sakhon Province (Tha Chin Basin), Prachinburi Province (Bang Pakong Basin), and Rayong Province (East Coast Gulf Basin). At the river-basin level, there are several factories and distributions, resulting in the river-basin product value increasing while the divider, which is the water consumption, has a reduced proportion.

Table 4.3.2-1 Annual water productivity inside and outside industrial estates by river basin

Basin	2015		2016		2017		2018		2019	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
Ping	790	2,019	2,080	868	2,159	752	2,323	575	2,470	679
Yom	2,614	472	2,582	495	2,710	406	7,002	333	1,115	372
Chao Phraya	2,064	1,135	2,051	1,125	1,979	983	1,865	756	1,781	833
Pasak	641	932	621	953	607	819	584	631	494	663
Tha Chin	685	790	704	797	764	746	833	583	886	641
Mae Klong	1,611	587	1,517	570	1,615	522	957	400	846	429
Bang Pakong	5,687	1,308	6,094	1,417	5,971	1,331	5,974	1,089	5,719	1,235
East Coast Gulf	1,274	951	1,315	994	1,364	898	1,248	673	1,231	738
Thale Sap Songkla	1,373	1,019	1,357	1,004	1,256	822	1,253	602	1,205	654

Source: Assessed by consultants

From the analysis of water productivity of major categories in the industrial sectors B, C, D, and E, to find the industrial water productivity of each river basin, the Bang Pakong Basin (1,097 THB/m^3) has the highest water productivity; after that, there are the East Coast Gulf Basin (931 THB/m^3), the Pasak Basin (645 THB/m^3), the Chao Phraya Basin (629 THB/m^3), the Tha Chin Basin (591 THB/m^3), and the last one is the Lower Part of Peninsula-East Coast Basin (116 THB/m^3) as shown in **Table 4.3.2-1**. This is consistent with the national overview data, which shows that the majority of the country's industrial factories are located in the top five river basins. The river basin with the highest and lowest industrial water productivity differs approximately 10-fold.

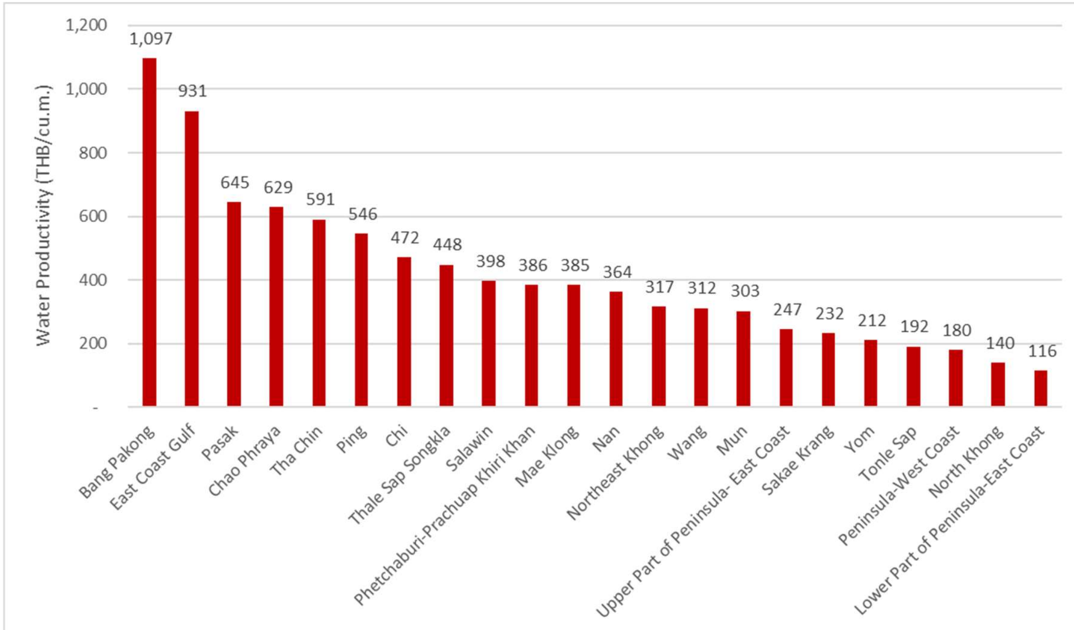


Figure 4.3.2-1 Industrial water productivity in major river basins

4.3.3 Service sector

From the analysis of service sector water productivity data, the river basin with the highest service sector water productivity is the Chao Phraya Basin (2,521 THB/m^3); followed by the Peninsula-West Coast Basin (1,540 THB/m^3), the Bang Pakong Basin (1,446 THB/m^3), the East Coast Gulf Basin (1,169 THB/m^3), Upper Part of Peninsula- East Coast Basin (843 THB/m^3), the last one is Salawin Basin (443 THB/m^3). In **Figure 4.3.3-1**, the group with the highest water productivity ranked 1 - 4 is the river basin in provinces that generate high service income for the country. From the 5th to the bottom ranks, water productivity is arranged by economic growth.

4.3.4 Water productivity in major river basins

The assessment of average water productivity in river basins is calculated as the sum of water productivity in the agricultural, industrial, and service sectors. The Chao Phraya Basin has the highest water productivity (300.00 THB/m^3); the next one is the Bang Pakong Basin (145.24 THB/m^3); the East-Coast Gulf Basin (130 THB/m^3); the Tha Chin Basin (53.90 THB/m^3); Pasak Basin (46.37 THB/m^3); the last one is the Yom Basin (9.13 THB/m^3) as in **Figure 4.3.4-1**. In this figure, water productivity is classified into 3 groups. For the high-value group, there are 3 river basins, including Chao Phraya Basin, Bang Pakong Basin, and East-Coast Gulf Basin. This group has developed trade, investment, and many provinces in these river basins have the highest GPP in the country. For the middle-value group, there are 9 river basins, including Tha Chin Basin, Pasak Basin, Mae Klong Basin, Ping Basin, Salawin Basin, Wang Basin, Phetchaburi-Prachuap Khiri Khan Basin, Peninsula West Coast Basin, and Thale Sap Songkla Basin. There are 10 river basins in the low-value group, including Northeast Khong Basin, Upper Part of Peninsula- East Coast Basin, Chi Basin, the Nan Basin, Mun Basin, Northeast Khong Basin, Lower Part of Peninsula-East Coast Basin, Tonle Sap Basin, Sakae Krang Basin, and Yom Basin.

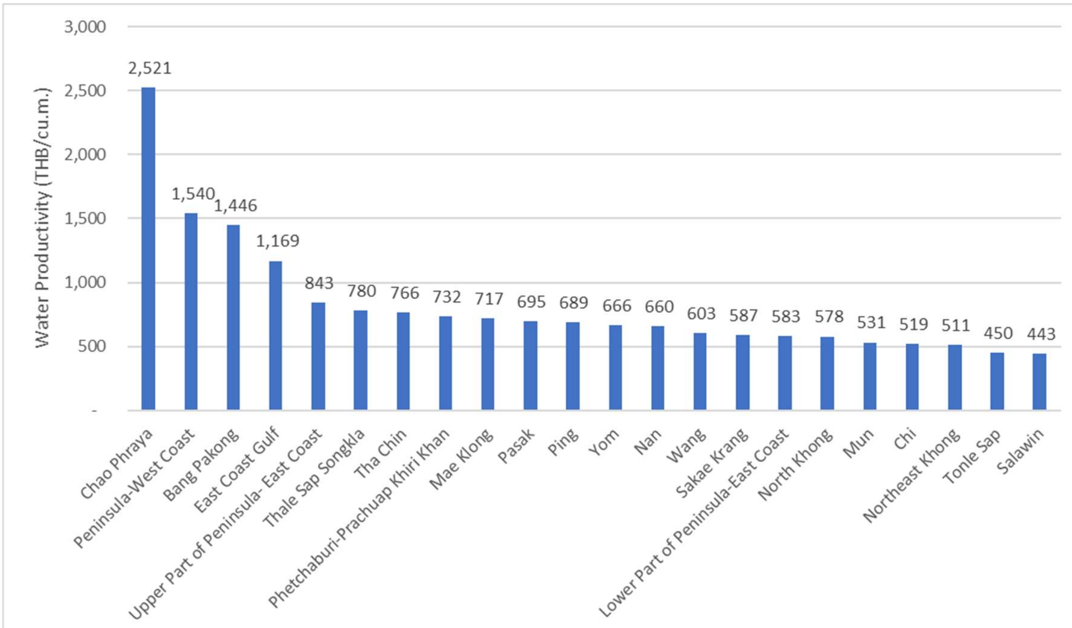


Figure 4.3.3-1 Service sector water productivity in major river basins

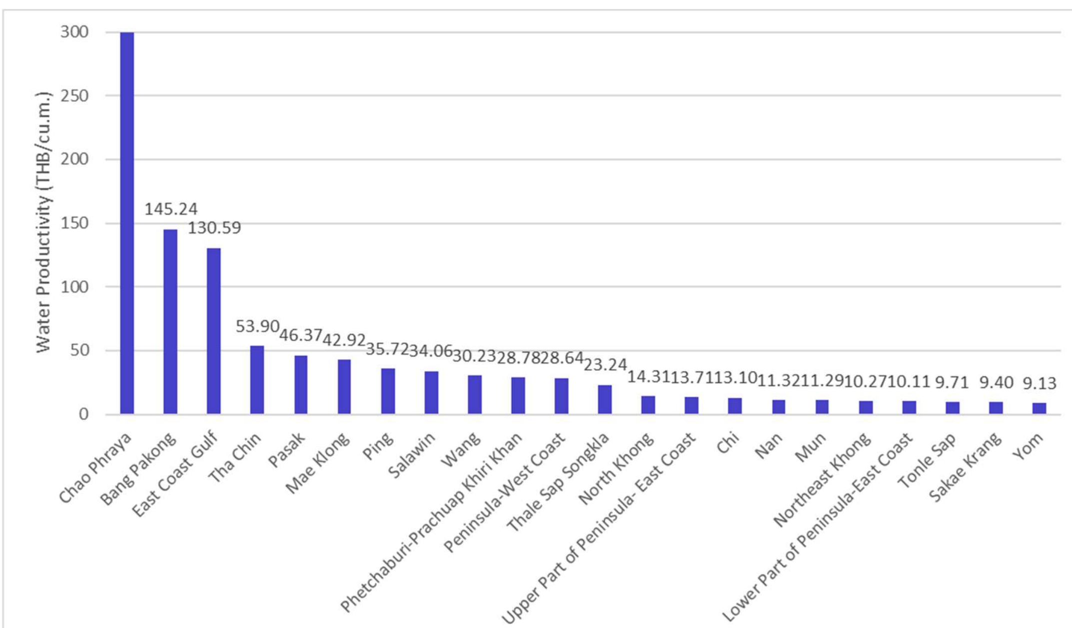


Figure 4.3.4-1 The average water productivity of the major river basins

5. Results of water productivity analysis

5.1 Limitation of using water productivity indicators

Water productivity is one of the economic indicators. Implementation requires an understanding of limitations and differences in water efficiency (see section 1 for more detail), which can be confused. This water productivity assessment study is based on internationally recognized principles of economic water productivity. However, the scope of work to determine economic water productivity in irrigated areas, rainfed agriculture areas, inside industrial estates, and outside industrial estates differs from previous studies with a national and regional assessment. Previously, there was no categorization of water usage in Thailand's service sector. Water productivity limitations can be summarized as follows:

1) Water productivity indicators are measured at the provincial to the national level of economic activity impacts. An overview of previous operations was provided by using GDP/GPP and water consumption results from each year. It was used to set feasible future objectives to be consistent with reality.

2) GPP is the provincial economic data, which is used for study at a sub-level. For example, a project requires a computational assumption and implementation requirements because greater sub-level, more error.

3) The performance data on large-scale irrigation projects is based on project evaluations or data that was studied for more than 10 years. Therefore, the theoretical plant water demand assessment is compared to the project's water supply data, as well as in-depth interviews with water delivery officers about possible values.

4) The organizations' plantation area data does not match. Choose data from organizations that are primarily related and double-check with the annual provincial plantation area.

5) There is no information about the plantation area in the electric water pumping project. As a result, the water consumption was estimated using the financial support for the pumping fee per unit of electricity and checked the plant species grown from the latest land use map and the in-depth interviews.

6) The water use pattern in rainfed areas is different because of topography, water source, and plant types. Data conducted from field trips and in-depth interviews with representatives from each region are used to categorize water consumption.

7) One of the most important methods today is the estimation of industrial water consumption with horsepower based on the industrial types and compared with relevant data such as Environmental Impact Assessment (EIA), the overview of water consumption in large factories to adjust the water usage rate. Because each factory's industrial water use rate is technical information, the factory cannot display it, which could have trade effects on competition.

8) GPP assessment in industrial estates and outside industrial estates using registered horsepower does not reflect reality, because modern manufacturing industries that use less horsepower, such as the computer chip industry and the pharmaceutical industry, may create more economic value. As a result, in some provinces, water productivity in industrial estates is lower than outside industrial estates.

9) The quantity of water used in the service sector under the Metropolitan Waterworks Authority and Provincial Waterworks Authority accounted for 50% of the country's water use by using actual storage data. Another is the assessment of water use under Local Administration.

5.2 Water productivity trend in crisis

This section shows the results that are analyzed to determine the water trend. The crisis states of study during 2015-2020 include:

1) For meteorology and hydrology, low water levels and high water levels have been considered as a national overview, and the results are clear in sample areas where drought and flood information is reported.

2) COVID-19 pandemic in 2020

5.2.1 Meteorology and Hydrology

The average annual rainfall in the country is about 1,572.5 mm. Topographical features affect the amount of rainfall. In addition to seasonal variation, Upper Thailand usually experiences dry weather and little rainfall in winter. In the summer, the amount of rainfall increases, coupled with thunderstorm rainfall. The amount of rain increases as the rainy season begins and reaches its peak in August and September. Most of the areas with heavy rainfall are those on the windward side or the side that received the Southwest monsoon winds, including the western part of the country (Thong Pha Phum District, Kanchanaburi), the Eastern region (Chanthaburi and Trat), especially in Khlong Yai District, Trat, which has a total annual rainfall more than 4,400 mm. Less rain falls on the leeward side, which includes the middle of northern Thailand (Lamphun, Lampang, and Phrae), Central Thailand, and the western part of the northeast (Chaiyaphum and Nakhon Ratchasima). Except for the summer, Southern Thailand experiences abundant rain all year. The West Coast of Southern Thailand is the side that receives the southwest monsoon. There is the highest rainfall in September. In winter, the East Coast of Southern Thailand receives the northeast monsoon, so this area will have more rainfall than the area on the west coast of Southern Thailand. It has the highest rainfall in November. The area with the most rainfall in Southern Thailand is Ranong, which has a total rainfall more than 4,000 mm throughout the year. The area that has less rainfall is located behind the Tanaosri Mountains, in Phetchaburi and Prachuap Khiri Khan[5].

Based on the study conducted by the Thai Meteorological Department during 2015 - 2020, when compared with the average rainfall data that is different from the normal (1981 - 2010), it was found that 2015, 2019, and 2020 were years with less annual rainfall than normal. In 2019, there was the greatest difference of 15% from the normal value, followed by 2015 at 11% and 2020 at 4% in the overall year. Thus, 2019 is the year of the water crisis.

Annual rainfall was higher than normal in 2016, 2018, and 2017. In 2017, there was the largest difference from normal at 27%, followed by 2016, 8%, and 2018, 5%. Overall, 2017 was a water crisis year, as shown in **Figure 5.2.1-1**.

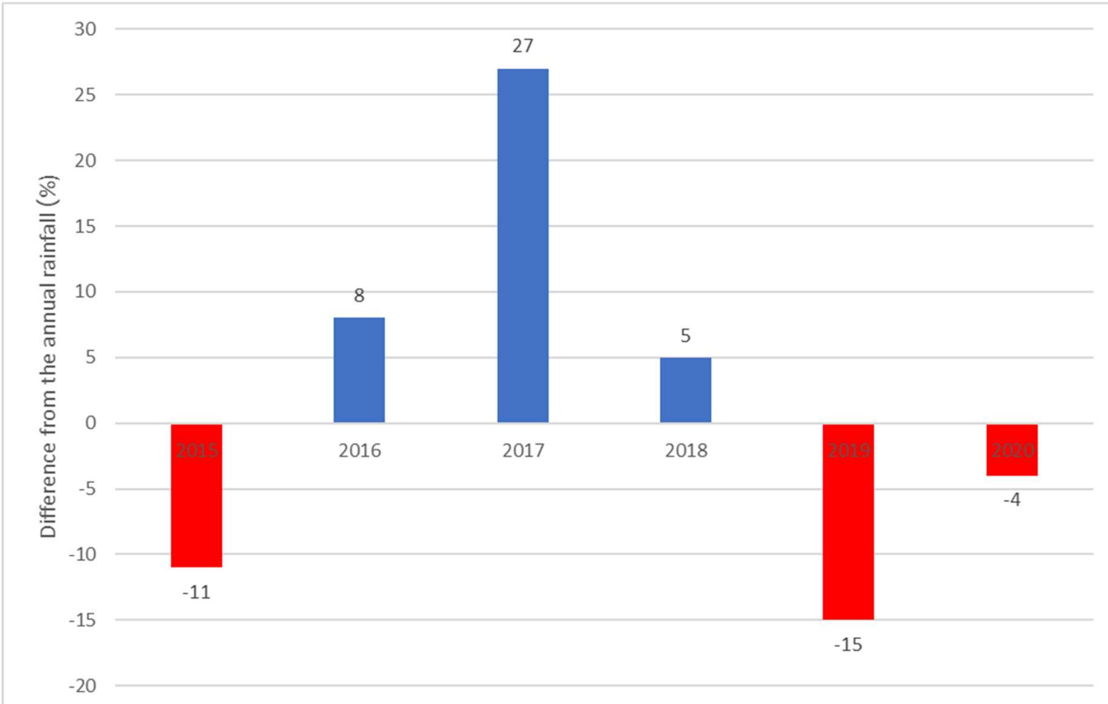
Overall water productivity **-** it is compared with the difference in annual rainfall; as a result, there is no relationship between overall water productivity and low or high water level year (**Figure 5.2.1-2**).

Water productivity in the agricultural sector - it is compared with the difference in annual rainfall. Drought years have much higher water consumption than wet years, which is consistent with water-use behavior when the amount of water is limited. Water will be used more economically, and the wasted water will be reduced (**Figure 5.2.1-3**).

Water productivity in the industrial sector– it is compared with the difference in annual rainfall; as a result, the obtained values are not related (**Figure 5.2.1-4**).

Water productivity in the service sector – it is compared with the difference in annual rainfall; as a result, the obtained values are not related (**Figure 5.2.1-5**).

[5] Thai Meteorological Department, The amount of rainfall https://www.tmd.go.th/info/info.php?FileID=55



Source: Thai Meteorological Department

Figure 5.2.1-1 Difference in annual rainfall from 1981 to 2010

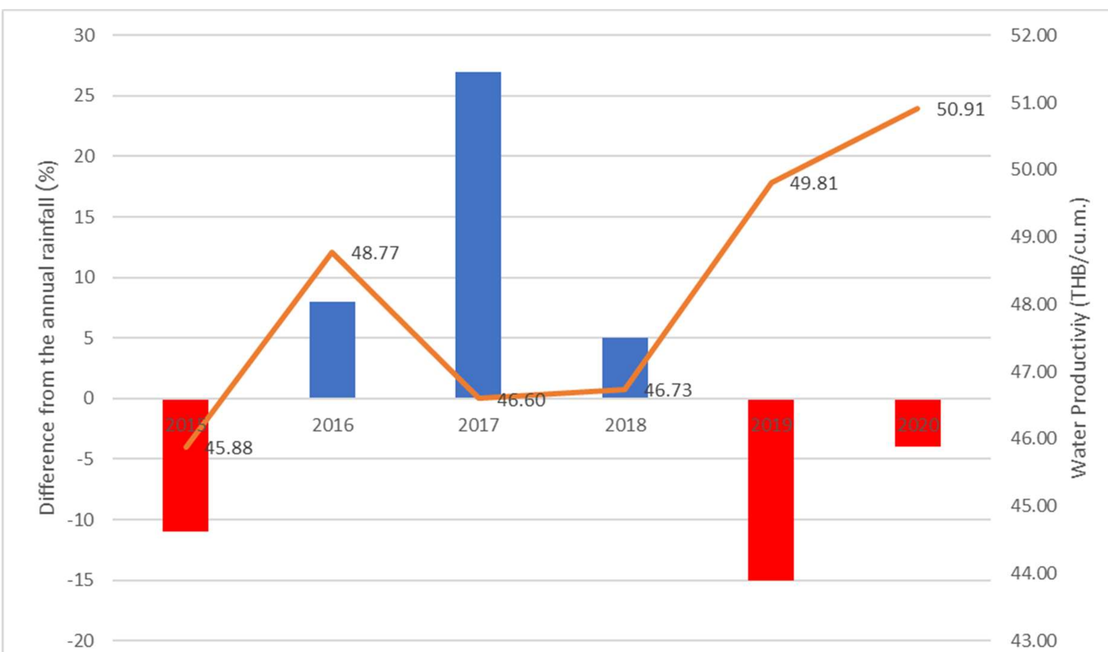


Figure 5.2.1-2 Comparison of overall water productivity and the difference in annual rainfall

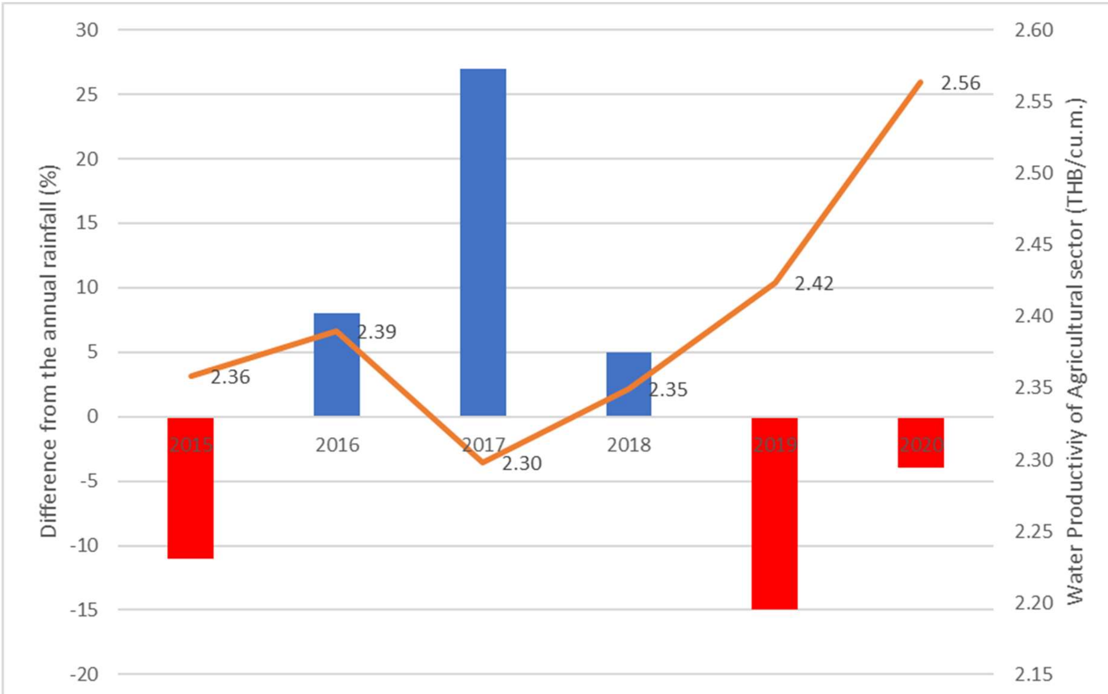


Figure 5.2.1-3 Comparison of water productivity in the agricultural sector and the difference in annual rainfall

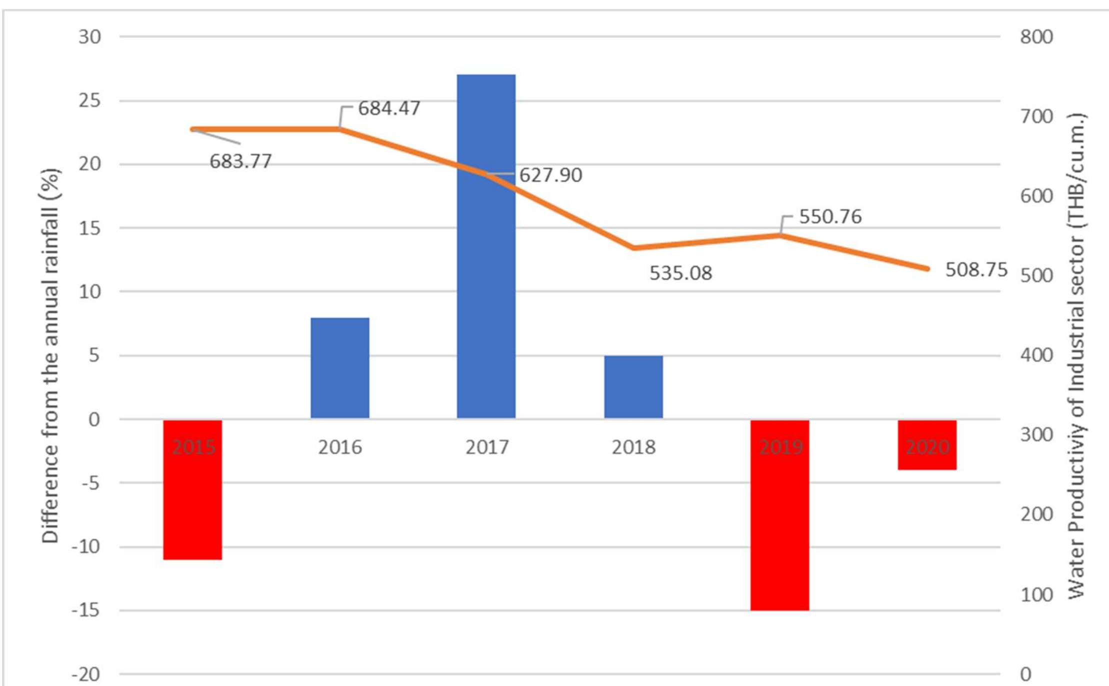


Figure 5.2.1-4 Comparison of water productivity in the industrial sector and the difference in annual rainfall

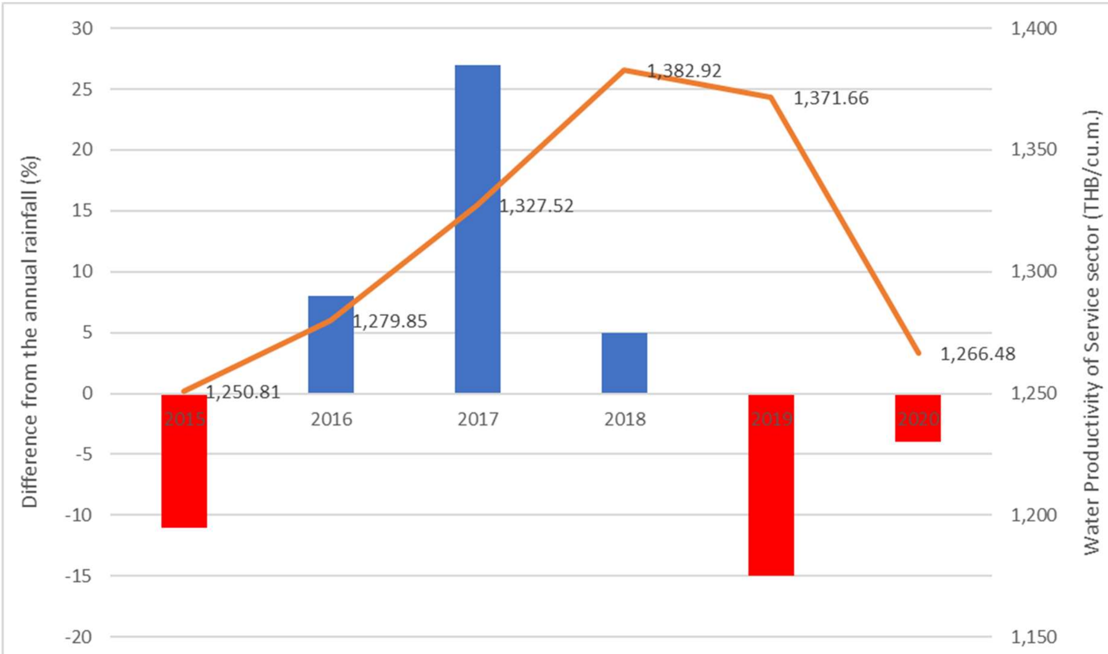


Figure 5.2.1-5 Comparison of water productivity in the service sector and the difference in annual rainfall

5.2.2 COVID-19 Pandemic

The impact analysis was made up of 3 parts: 1) water productivity value, 2) GDP, and 3) water consumption, as shown in **Tables 5.2.2-1 - 5.2.2-3**

According to water productivity assessment data, the overall water productivity increased slightly during the COVID-19 pandemic in 2020, despite the fact that the country's GDP used in the calculation was reduced by 6%. However, overall water consumption decreased by 8%, which was greater than that. The main factor was a 9% decrease in agricultural water use in 2020 compared to 2019 (**Figure 5.2.2-1**).

Since 2017, agricultural water productivity has tended to increase. In 2020, agricultural water productivity increased 6% from 2019, and it reached the highest value during the study. This was due to the 9% reduction in agricultural water consumption in 2020. The agricultural GDP decreased by 3%, which was less than the decrease in water consumption (**Figure 5.2.2-2**). When the trend of the graph in **Figure 5.2.2-2** is examined, it is clear that it has a significant impact on the overall water productivity in **Figure 5.2.2-1**.

The water productivity in the industrial sector has decreased since 2015. It was increased in 2019 and decreased again in 2020. The COVID-19 situation was one of the reasons that GDP in 2020 fell from 2019. While water consumption in the industrial sector increased in 2019, water productivity fell (**Figure 5.2.2-3**).

Table 5.2.2-1 GDP of the main economic activities

Year	GDP (million THB)			
	Agricultural sector	Industrial sector	Service sector	Overall
2015r	467,024	3,236,268	5,810,992	9,514,284
2016r	460,813	3,310,027	6,099,976	9,870,816
2017r	484,298	3,382,852	6,430,167	10,297,317
2018r	513,531	3,482,474	6,749,206	10,745,212
2019p	509,228	3,483,165	7,044,419	11,036,812
2020p1	491,506	3,276,999	6,584,648	10,353,153

Source: Analyzed from GDP CVM data, The Office of the National Economic and Social Development Council

Table 5.2.2-2 Volume of water consumption in the main economic activities

Year	Water consumption (million m^3)			
	Agricultural sector	Industrial sector	Service sector	Overall
2015	198,016	4,733	4,646	207,395
2016	192,803	4,836	4,766	202,405
2017	210,755	5,388	4,844	220,987
2018	218,551	6,508	4,880	229,940
2019	210,108	6,324	5,136	221,568
2020	191,719	6,441	5,199	203,360

Source: Assessed by consultant

Table 5.2.2-3 Water productivity

Year	Water productivity (THB/m^3)			
	Agricultural sector	Industrial sector	Service sector	Overall
2015	2.36	683.77	1,250.81	45.88
2016	2.39	684.47	1,279.85	48.77
2017	2.30	627.90	1,327.52	46.60
2018	2.35	535.08	1,382.92	46.73
2019	2.42	550.76	1,371.66	49.81
2020	2.56	508.75	1,266.48	50.91
Average	**2.40**	**598.45**	**1,313.21**	**48.12**

Source: Assessed by consultant

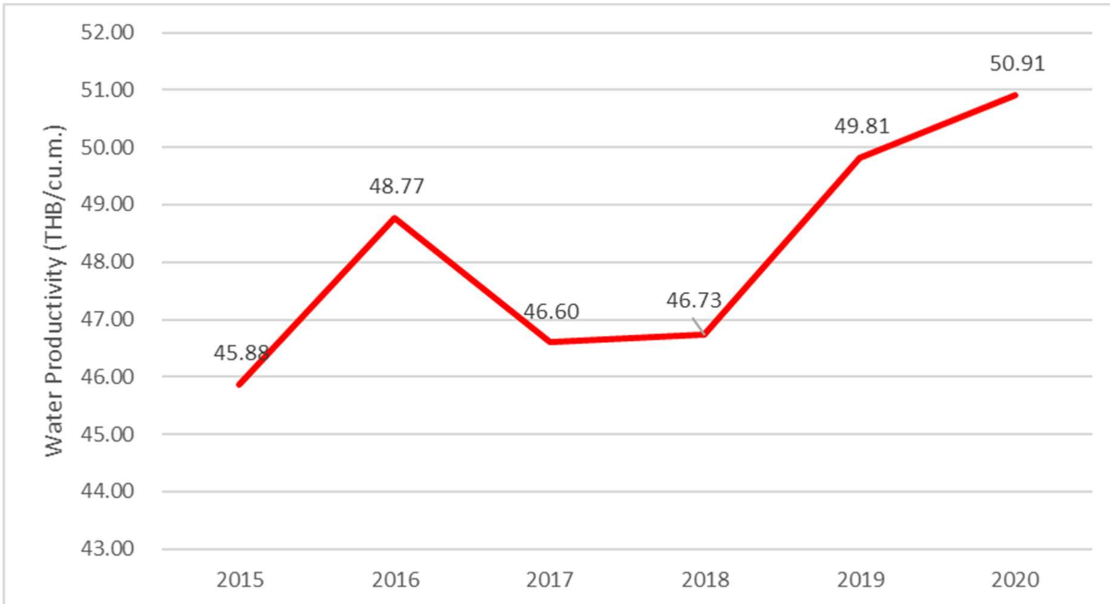


Figure 5.2.2-1 Overall water productivity in 2015 – 2020

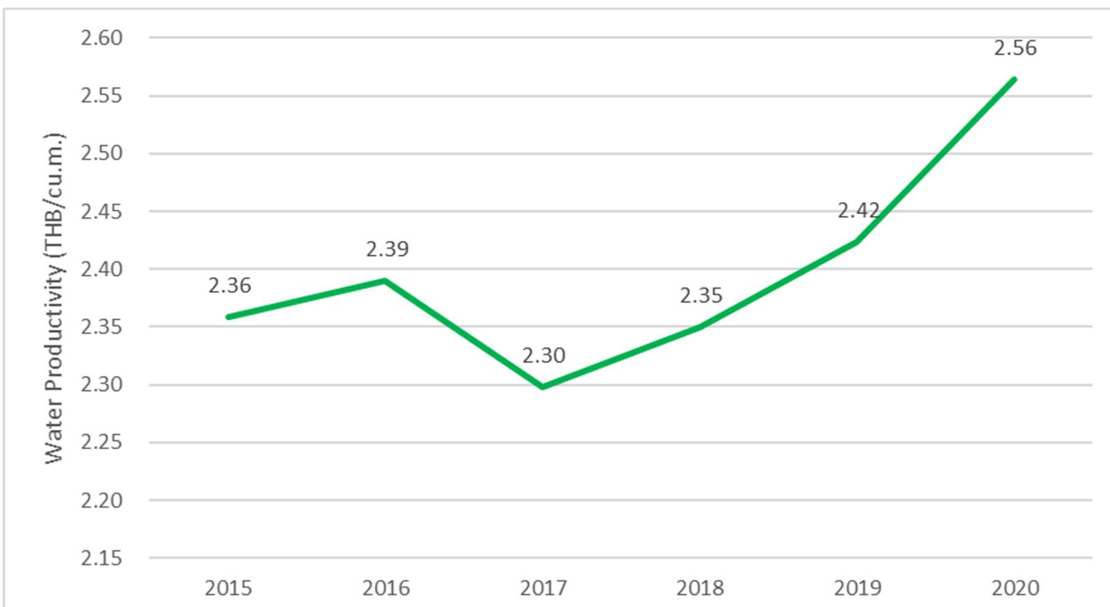


Figure 5.2.2-2 Water productivity in the agricultural sector in 2015 – 2020

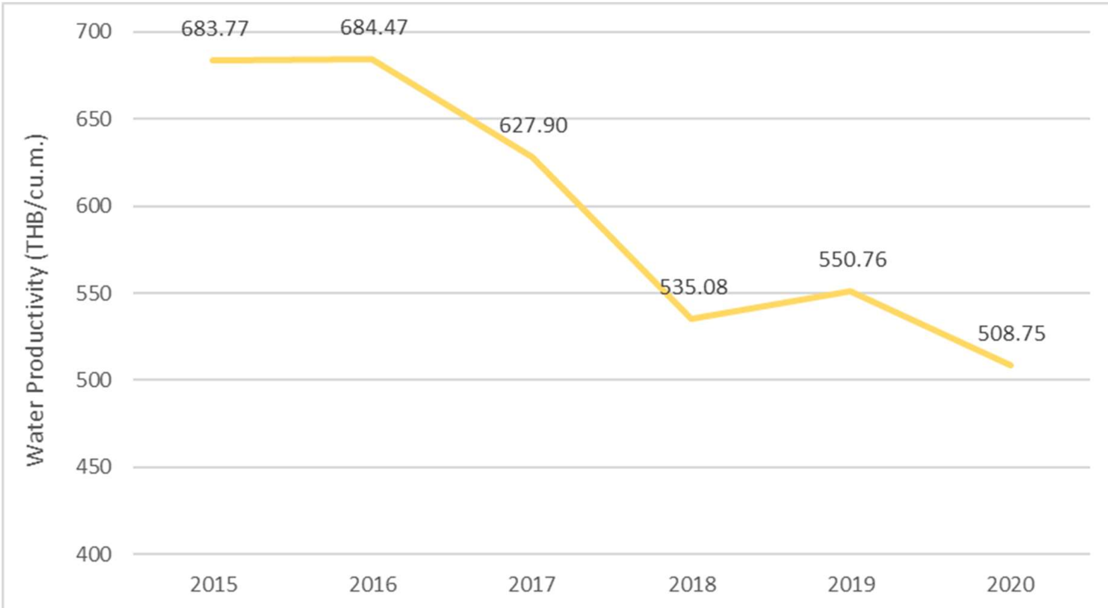


Figure 5.2.2-3 Water productivity in the industrial sector in 2015 – 2020

For water productivity in the service sector, it is clearly a result of the COVID-19 situation. The GDP in the service sector has tended to increase since 2015. There was a slight decrease in 2019 and an obvious decrease in 2020. GDP decreased by 7% from 2019, while water consumption in the services sector remained stable between 2019 and 2020 (**Figure 5.2.2-4**).

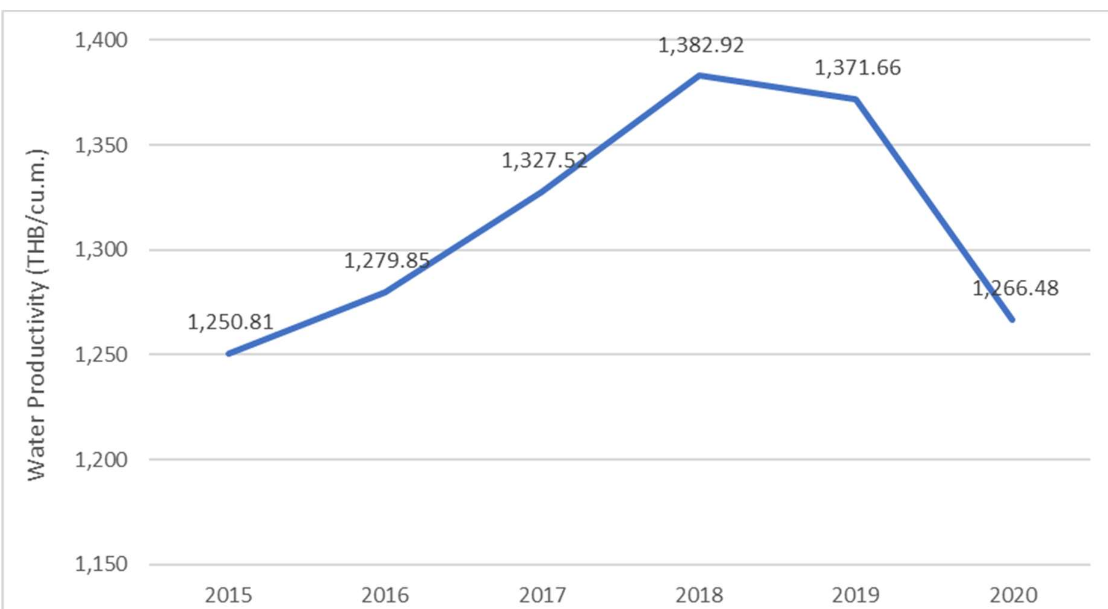


Figure 5.2.2-4 Water productivity in the service sector in 2015 – 2020

5.3 Relationship between water productivity GDP and water consumption

The results of water productivity in the agricultural sector, industrial sector, and service sector were used to analyze the relationship between water productivity GDP and water consumption during the study period (2015 - 2020) by using the information in 2015 as a base year; it can be summarized as follows:

Agricultural water productivity tends to increase, as shown in **Figure 5.3-1**. It increased by 8.7% from 2015 to 2020, with an annual growth rate of 1.74%. It fell 2.57% in 2017 compared to 2015, and it fell 0.37% in 2018. In both years, water consumption was increased because there was more water budget than the previous year. Although, both years have increased GDP, as well as water consumption. It is different from 2019 and 2020, which had decreased water consumption because there was less water budget. The changes in GDP growth and the changes in water consumption have a large gap, so water productivity increases. Considering the external factors at present, Russo-Ukrainian War and climate change cause drought and flooding in many food-producing areas of the world. As a result, the trend of the food crisis and the price of agricultural products are on an upward trend. It is predicted that in the next 3 years, agricultural products will still be in demand in the world market. Thus, the GDP growth is an upward trend. If water can be used effectively in irrigated areas, it will increase agricultural water productivity. However, Thailand exports agricultural products such as rice, rubber, and oil palm, which are similar to competitors. If they are unable to add value to produce as premium products or high-value products, agricultural GDP will be fall. In addition, fruits, especially durians, are also produced in other Southeast Asian countries, which will affect the prices of domestic products in the long term. Non-tariff barriers, such as resolved current coastal fisheries issues and exported coconuts and products that allegedly used monkeys to pick coconuts, in the future the similar issues will be more increasing. For example, using groundwater for agriculture with low-value crops; at an international level, groundwater is the last source of water for consumption.

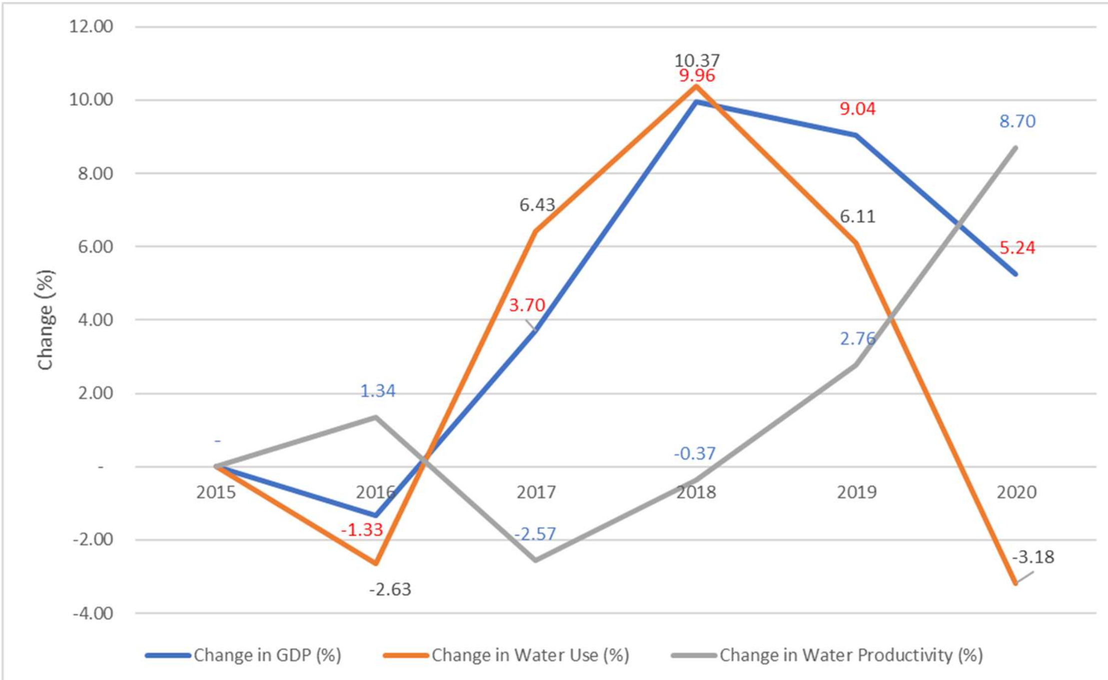


Figure 5.3-1 Relationship between water productivity, GDP, and water consumption in the agricultural sector

Water productivity in the industrial sector was in a downward trend during the study period, as shown in **Figure 5.3-2**. Water productivity in 2020 was 25.60% lower than in 2015. Even though the GDP of the industrial sector has risen, water use has increased by a higher proportion. When considering water consumption during 2018 - 2020, the volume of water increased similarly from 2015. Even though there will be a COVID-19 crisis in 2020, water consumption in the industrial sector tends to be high. There was still export production. Long-term water consumption in the industrial sector increased slightly. Modern machines have been improved to use less energy and water as a result of water reuse and recycling in the industrial sector to reduce costs. These included promoting the BCG industry, which is eco-friendly. When EEC can move at full speed ahead, it is predicted that the industrial sector will have increased GDP growth. "In the next 3 – 4 years, investment in Eastern Economic Corridor (EEC) will be worth at least 3 - 4 hundred billion THB/year, which is an important engine driving the Thai economy to expand at least 1.5%[6]."

[6] Thansettakij 19 May 2022 https://www.thansettakij.com/economy/525507

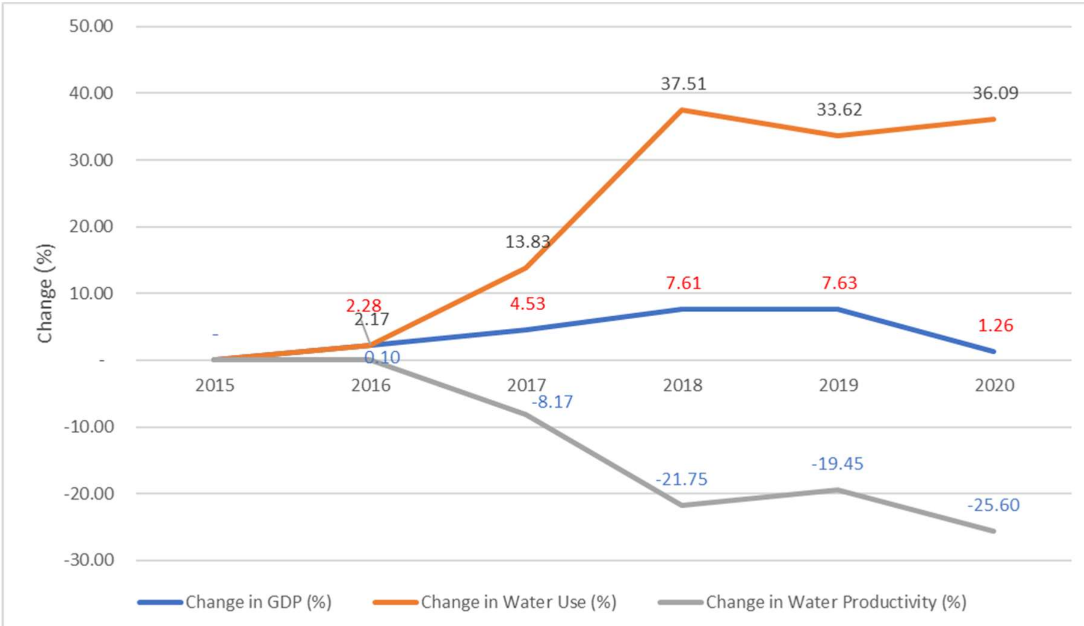


Figure 5.3-2 Relationship between water productivity, GDP, and water consumption in the industrial sector

Water productivity in the service sector was on an upward trend during 2016 - 2018 when compared to 2015. In 2019, it was down 0.9% from 2018. In 2020, it was also down because of the impact, as shown in **Figure 5.3-2**. GDP in the service sector has been increasing steadily. In 2019, it fell 8.41 % from 2018. While the water consumption in the service sector was on an upward trend, it has risen 11.91 % in 2020 from 2015. It is expected that service sector water consumption will increase in the future based on the expansion of the city. This increases water demand per capita (per person). Thus, water conservation measures promote a campaign to increase the conscious use of water; it must be continued. It also includes reducing the loss in the water supply system and seeking alternative water supply sources in case of a costly water shortage crisis. Water for consumption is the first priority, so it should be in sufficient quantities and meet international standards.

In the future, when the number of tourists returns to normal, as well as the long-term Thai visa policy has worked as expected, which target groups include 1) high-income individuals, 2) foreign pensioners, 3) people who wish to conduct their work in Thailand and 4) experts from specialist fields. It is estimated that if 1 million foreigners live in Thailand, the spending rate will increase by 1 trillion THB, the investment will increase by 800 billion THB, and tax revenue will increase by 270 billion THB[7]. This will raise the service sector's GDP.

[7] https://www.salika.co/2022/05/28/long-term-visa-for-high-quality-foreigners/

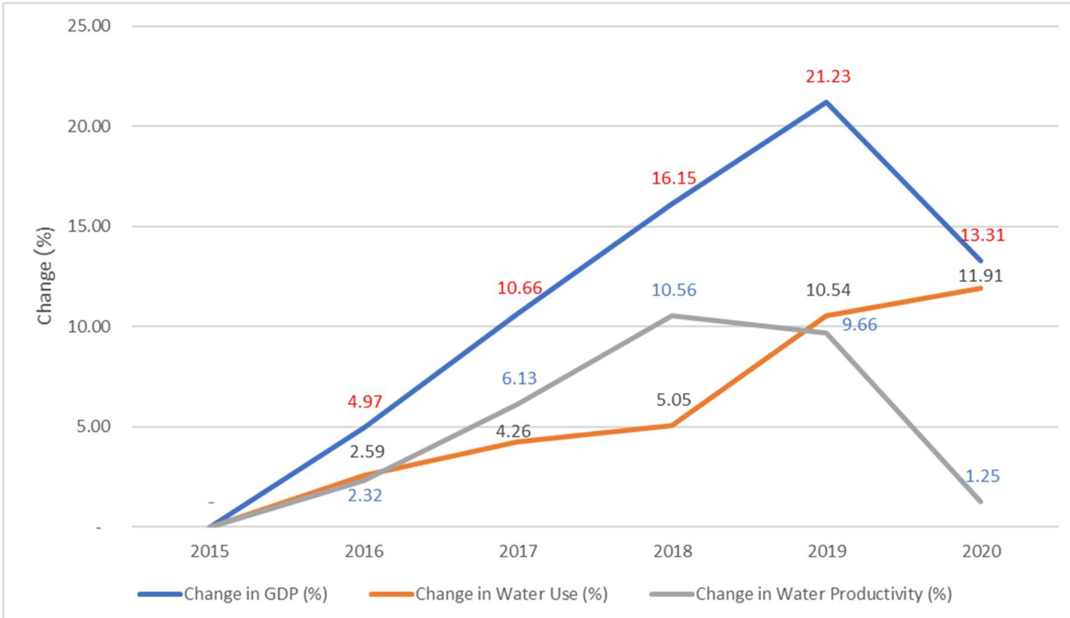


Figure 5.3-3 Relationship between water productivity, GDP, and water consumption in the service sector

6. Fieldwork and a sample of water productivity in the area

6.1 Fieldwork

The fieldwork of the project to produce information on water productivity under the 20-year national water resource management master plan (2018 - 2037) was originally planned to be implemented in August–September 2021. Due to the situation of Coronavirus outbreak (COVID-19), the fieldwork was postponed. It was implemented from December 2021 to March 2022. The plan has been adjusted based on the situation that occurred at that time with the following objectives:

1) Find suitable models and possible techniques to improve water productivity.
2) Present the example of water productivity calculation to understand the significant data in the analysis of the results.
3) Pay attention to the opinions and suggestions of staff and operators in sample areas.
4) To understand the pattern of water use in economic activities, land use management in irrigation areas, and yield per rai, as well as review the data for calculating water productivity.

Fieldwork sample areas have a continuous travel route. This program intends to expand to all regions. To represent any issues that remain unresolved as a result of the study's findings or areas that can be further developed to increase water productivity. In some issues, the sample area doesn't have to be the same in every region, including the agricultural, industrial, and service sectors, where the majority of the areas are related to agriculture. The economic sector has the highest proportion of water use; thus, reducing water consumption or the economic value in this sector will affect water productivity. The industrial and service sectors have set up specific guidelines for economic value added, which means price uncertainty in the market has less impact than in the agricultural sector.

For fieldwork patterns, a letter that provided information such as the date and time of the meeting and the detailed information to be discussed was sent. After that, local representatives and the project expert coordinate with each other for the appointment location and time. There was compliance with preventive measures against COVID-19. In practice, this will be adjusted based on the situation and ease of data collection in each area.

Information such as project objectives, results, and applied information were provided at the beginning of fieldwork in each area. Then, there was an in-depth interview by staff and experts from the Office of the National Water Resources (ONWR) based on the water productivity issues in the area, as well as other issues raised in lectures and discussions with local representatives. The beneficial data at the local level was used to expand the results and was used in the operations of ONWR. The fieldwork sample areas for creating water productivity were 37 areas, 14 provinces covering all regions of the country. It can be summarized as follows:

Date	Province
12 – 13 December 2021	Chon Buri
14 – 15 December 2021	Rayong
16 – 17 December 2021, 10 and 13 March 2022	Phetchaburi
20 – 22 December 2021	Khon Kaen
5 – 7 January 2022	Lampang
11 – 12 March 2022	Chumphon
14 March 2022	Nakhon Pathom, Ratchaburi
15 – 16 March 2022	Loei
17 – 18 March 2022	Ubon Ratchathani
22 – 23 March 2022	Chiang Rai
28 March 2022	Nonthaburi
29 March 2022	Bangkok
30 – 31 March 2022	Surat Thani

7. Suggestion

7.1 Guidelines to increase water productivity

From the results of this study, it was found that the overall water productivity of the country from 2015 to 2020, it had a small change. In 2015, there was the lowest water consumption (45.88 THB/m^3). In 2020, there was the highest water consumption (50.91 THB/m^3), which increased by 11%. Even if there were a COVID-19 epidemic situation and the country's GDP was negative, the country's water consumption would be reduced by a greater portion, and the country's water productivity would be increased.

For the suitable guidelines to increase water productivity, the significant parts are GDP and water consumption. In terms of water consumption, ONWR as a water policy organization; GDP, which is related to economic activities; government policies that promote economic growth; and many related agencies; there was mention of the policies that affect the agricultural sector, industrial sector, and service sector as follows:

1) In terms of water productivity assessment (the obtained value /1 m^3 of water), in irrigation areas, the water productivity value is less than agriculture in rainfed areas with the same conditions and the same amount of rainfall because an increase in water allocation does not increase yield proportionally (2-folds of water delivery, less than 2 folds of productivity). If implemented in water saving, it is expected to reduce water consumption by less than 20%. When calculating water productivity, it will be increased by only 16 %. Farmers must manage water consumption on their agricultural land plots and invest in it. Increasing water productivity is based on the value of production. Thus, if we need 3-folds of water productivity in the agricultural sector, we need to choose high-value plants. Geographical Indication (GI) is used to promote and control the quality of the agricultural product. Therefore, using measurement productivity does not guarantee the success of water resource development. It might be considered guidelines for assessing water efficiency (SDG 6.4.1 indicator).

2) Increase irrigation use efficiency in the rainy season by 60%. Reduce water use in rice cultivation. Promote the cultivation of crops that use less water based on the marketing-led production policy of the Ministry of Agriculture and Cooperatives. This will increase 5% of water productivity.

3) Irrigation system development to increase productivity; if the crops are still planted in the same way, the yield will not increase (productivity doesn't increase in proportion to

the amount of water allocated and delivered). As a result, increasing water productivity must be converted to high-value crops or promoted production of value-added products or industrial products.

4) Developing agricultural land has a relatively low economic cost. If there are no subsidies, including for high-value fruits and vegetables, it is necessary to find another market for supporting them.

5) Agricultural production plans must be developed for the main crops. Especially in irrigated areas where the amount of water is abundant, it can change the cultivation of crops. For the rainfed areas, it should be maintained as the same production model.

6) The budget for water resources development is very high because of compensation. The preparation (many times, conducting research and not being used for construction or study) should be adjusted to have a preliminary process first. If construction cannot be completed, it should be canceled.

7) Increase the country's GDP – there are 4 engines driving the Thai economy, including 4 parts: (1) tourism, (2) export, (3) consumption, and (4) investment.

- **Agricultural sector**: the Ministry of Agriculture and Cooperatives aims to increase GDP in the agricultural sector by 3.8% per year. Increase agricultural productivity by 1.2% per year[8]. If agricultural productivity increases at the above-mentioned rate, agricultural water consumption will approach 3 THB/m^3 in 2037, based on a 2019 base of 2.42 THB/m^3.
- **Industrial sector**: the Ministry of Industry aims to drive the Bio-Circular-Green Economy (BCG) model[9] to create economic security and increase the rate of economic growth[10]. Economic forecasts for the BCG Model in all four strategic areas are as follows: 1) agriculture and food, 2) wellness and medicine, 3) energy, materials, and biochemicals, and 4) tourism and creative economy have the potential to add value to 4.4 trillion THB, accounting for 24% of GDP[11] in

[8] Ministry of Agriculture and Cooperatives forward to the 130th year https://www.moac.go.th/news-preview-431091793857
[9] B – Bio Economy: Cost-effective utilization of biological to increase productivity and value-added
C – Circular Economy: Focus on the circularity of resources for maximum benefit and reduce the usage of limited sources.
G – Green Economy: Focus on development to achieve balance in 3 parts: The economy, society, and environment.
[10] Ministry of Industry, Promote Green Economic Model (BCG) https://www.industry.go.th/th/industrial-economy/7775
[11] Thansettakij 19 March 2021 https://www.thansettakij.com/economy/472770

2027. According to the figure, water productivity in 2027 will approach 70 THB/m^3

- **Service sector**: Thai economic value is driven by this sector with various aspects, such as Thailand's medical hub policy from the expansion of medical tourism and health. Thailand is ranked No. 1 in Asia and No. 6 in the world according to the 2019 Global Health Security Index, which collects data from 195 countries around the world. Therefore, this point is an opportunity for Thailand to increase its role in the high-value healthcare market. MICE business (Meetings, Incentive Travel, Conventions, Exhibitions) is a tourism business with the objective of organizing corporate meetings, incentive travel, international conference, and exhibitions. Thailand Convention & Exhibition Bureau: TCEB is a government agency established to promote MICE business; when the COVID-19 pandemic declines, coupled with an increase in travelers abroad, it is a big opportunity for MICE business. MICE businesses promote ecotourism and community ways of life in the country, such as traveling to national parks and learning about a community's way of life, etc.

8) Promote the adding value of agricultural products from primary agricultural commodities to be products. The Ministry of Agriculture and Cooperatives has the policy to promote learning centers to increase agricultural production efficiency and improve competitiveness and research and development in the agricultural sector of Thailand[12]. Based on issues, they should be monitored and evaluated annually in order to achieve the goals or improve operation direction to be in line with the current situation.

9) Reduce water use in the industrial sector and encourage wastewater treatment and reuse in the manufacturing process to reduce water supply costs. Regulate tax incentives to persuade entrepreneurs to reduce costs. Encourage the private sector and educational institutions to create innovations for suitable wastewater management to reduce the cost of importing high-priced equipment from abroad.

10) Promote the construction of community wastewater treatment systems. Natural treatment systems can reduce local administrative and maintenance costs. Treated

[12] Ministry of Agriculture and Cooperatives Important policies of the Ministry of Agriculture and Cooperatives https://www.moac.go.th/about-important_policy

community wastewater is used in the industry, reducing the cost of water supply in the industrial sector.

11) Reduce water use in the service sector. Continuously promote water-saving measures in all sectors. Tax measures are raised to encourage the use of water-saving equipment and indirectly generate industry from the manufacture of equipment and water-saving technology.

12) Reduce water loss in the water supply system by assessing the economic worthiness and operating costs that are appropriate and feasible.

When considering the significant policies' implementation in the past, the weakness of Thai agencies was the lack of monitoring and evaluation to improve target values and a lack of participation by involved agencies in presenting problems and solutions. In addition, frequent policy changes made it impossible to assess performance efficiently. Therefore, a performance tracking system should be produced and continuously evaluated. The evaluation agency must understand the nature of the work and have the capability to give creative opinions to assist operators in working efficiently under regulations.

7.2 Future data collection for water productivity assessment

This study adopted secondary data from relevant agencies to assess water productivity and examine the suspicious information. It had insufficient information from field trips and in-depth interviews. If the data is systematically and continuously collected, it can be used to improve water productivity assessments getting closer to reality. The additional data collections are required as follows:

1) Currently available data on large- and medium-sized projects is not updated to be consistent with the current actual water delivery due to the changes in land use in irrigated areas. If current water use efficiency is assessed, future irrigation project optimization goals can be defined.

2) Data set of cultivated areas, plant types, electric water pumping projects, and a small irrigation project with a water allocation system (including the water resources development project by ONWR) have been transferred to local administrative from the Department of Local Administrative.

3) Yields per rai of main crops in irrigated areas from the Royal Irrigation Department and provincial rainfed areas from the Office of Agricultural Economics.

4) Water use of large industrial plants from the Department of Industrial Works

5) Data on village water supply use is not submitted to the Department of Local Administration. At the local level, only some villages send water use information to the local authority. However, if there are structural and equipment damage repairs, the local authority's budget is requested. Therefore, information on water use and water bills should be submitted to the local administration every month and forwarded to the Department of Local Administration. An online system should be designed to fill out the data.

7.3 Relevant agencies' contribution to the increasing water productivity

According to the study results and field trips, there are activities to increase water productivity both directly and indirectly, as shown in **Table 7.3-1.**

Table 7.3-1 Relevant agency to increase water productivity

Department	Activity detail
Office of the National Water Resources: ONWR	● Drive a campaign and broadly promote the measures to save water and raise awareness of water use. Follow up on water savings from government agencies. ● Encourage groups of water users, registered under Water Resources Act B.E. 2561 (2018), to use water economically. ● Convince large private sectors to participate in creating a corporate image. ● Study the feasibility of tradable water rights in irrigated areas during the dry season with industrial sectors in surrounding areas. ● Prepare an annual water productivity report at the national- and provincial-level according to the main economic activities in the agricultural, industrial, and service sectors
Ministry of Agriculture and Cooperatives (Thailand)	● Marketing to lead production policy ● Promote the cultivation of high-value crops ● Preservation of native plants and biodiversity to add value to natural and environmentally friendly products

Department	Activity detail
Ministry of Industry (Thailand)	• Promote Green Economic Model (BCG)
Ministry of Commerce (Thailand)	• Find new markets and increase customer base in existing markets
Ministry of Tourism and Sports (Thailand)	• Promote eco-friendly tourism • Promote Thai sports and increase the value linked with tourism, such as Thai Boxing, extending to the production of Thai sports equipment. Create an international sporting event.
Ministry of Culture (Thailand)	• Promote value creation from Thai culture and Thai food linked to the production of music, movies, games, etc. Offer tax incentives to Thai entrepreneurs.
Ministry of Natural Resources and Environment (Thailand)	• Conserve natural resources and forests as upstream watersheds. • Good management of areas outside conservation forest areas. Promote natural tourism that generates income for the surrounding communities. Create a conservation network.
Royal Irrigation Department: RID	• Improve the efficiency of irrigation projects. • Promote the cultivation of rice and crops that use less water in the dry season. • Collect actual water delivery data. With the limitation of personnel, satellite imagery and Unmanned Aerial Vehicle (UAV) for farm surveys can be adopted. If the data is linked to the Department of Disaster Prevention and Mitigation, the same base data can be used to pay compensation to farmers in irrigated areas.
Department of Local Administration: DLA	• Collect data on water use in the village's water supply.

Department	Activity detail
Department of Intellectual Property	• Register a Geographical Indication.
Eastern Economic Corridor (EEC)	• Promote investment and enhance to develop the innovation and advanced technology in Thailand. • Facilitate business dealings and coordinate closely with government agencies and other private sectors
Industrial Estate Authority of Thailand	• Contribute wastewater treatment and reuse in industrial factories and implement tax measures to motivate entrepreneurs to reduce costs. • Employ data from representatives of various large-sized factories to collect actual water use data to use as an index of water use outside industrial estates.
Department of Groundwater Resources	• Implement groundwater projects for agriculture only in the potential groundwater zones. • Track natural groundwater levels. • Promote the economical use of groundwater for crops with economic value.
Rice Department and Department of Agriculture	• Improve rice breeding and economic crops that use less water but have high demand in the market, to resistant to climate change.
Metropolitan Waterworks Authority and Provincial Waterworks Authority	• Reduce water loss in the distributed water supply system in the service area where is economically worthwhile.
Community Development Department	• Track and evaluate the Khok Nong Na Model to generate more income for farmers.
Department of Fisheries	• Promote aquaculture in a closed system and use of circulating water.
Department of Livestock Development	• Promote the water use saving in the Zero Waste system in livestock, reducing indirect greenhouse gas emissions.