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The nexus of agricultural water use and economic development level

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ABSTRACT

For many countries in the world, especially developing countries, the agricultural sector contributes low income to the country. However, this sector consumes the largest amount of water. Water is essential for the production of agricultural goods and services, which generate income and create national wealth. Therefore, this paper studied the relationship of water use for agricultural purposes in 154 countries and their economic development. In this study, the economic development in a country, as indicated by per capita GNI, was separated into 4 income groups, based on the World Bank criteria: (1) high income; (2) upper-middle income; (3) lower-middle income; and (4) low income. The results of the study revealed that water use for agricultural purposes usually takes the highest proportion of water consumption in low, lower-middle, and upper-middle income countries. The study also indicated that the quantity of water used for agricultural purposes gradually increased with the income of a country; that is, the greater the income, the more agricultural water was used. On the other hand, less water was consumed in high-income countries.

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Introduction

Water resources are important to economic development, as water is essential to the production of agricultural goods and services. Globally, the major use of water (70%) is in the agricultural sector. In developing countries, whose income mainly depends on agricultural products, water use in agriculture can occupy up to 90 percent of all water withdrawals (FAO, 2010). However, these agricultural products generate only a small amount of income for these countries. In developed countries—such as the countries located in North America and Europe—approximately 40 percent of water is used in the agricultural sector, less than the amount of water used for industrial purposes (FAO, 2010). As water is a main factor in the production of agricultural products, which contribute to the national income, the hypothesis of this study is that 'there is a relationship between the agricultural water use and the level of economic development of a country'. The research question in this paper is "what kind of relationship is there between agricultural water use and the level of development?"

Although the study of the relationship between water and economic development has been extensively pursued by several researchers and international development agencies, including ADB (2013), Berry (2011), FAO (2010), Grey and Sadoff

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(2007), HSBC (2012), Musouwir (2010), and World Bank (2010), none of them focuses on the relationship between agricultural water use and the level of economic development. To fill the gap, this paper studied the relationship of water use in the agricultural sector and the level of economic development. The scope of work covered agricultural water use in 154 countries. The economic development category was divided into four levels according to economic development indices: high income, upper-middle income, lower-middle income, and low income.

The paper is divided into six sections. Section Review on water resources and development briefly reviews the empirical literature on economic growth and water resources. Section Data and methodologies provides the data and information on the methodologies adopted in the study. Section Limitations presents the limitations. Section Results analysis presents the results of the analyses, followed by conclusions and policy implications in Section Conclusion and policy implications.

Review on water resources and development

Water resources are insufficient because fresh water makes up only 0.003 percent of the total amount of water resources worldwide (45,000 out of 1,400 million cubic km). Moreover, there is only 9,000–14,000 cubic km of water for human use (FAO, 2010). The global demand for water is increasing for many reasons such as population and economic growth (Ringler, 2010), and urbanization (Biswas, 2010). By 2030, the world's population is expected to grow by 2 billion people and will require approximately 50 percent more food, compared to the data for 1998 (FAO, 2010). By 2030, more than half of the world's population will be in urban areas. Urbanization is a cause of rapid economic growth, meaning that there will be an increase in water demand. Therefore, water scarcity is going to be a big issue in the near future. Approximately two-third of the world's population will encounter water stress conditions in 2025 and about 1.8 billion people will face absolute water scarcity (UN Water, 2010). The annual water supply will drop below 1,700 cubic m per person, which means that many countries are going to face a water shortage issue. Therefore, water conflicts among all types of water users—agriculture, domestic, and industrial—are going to occur and will lead to obstacles in a country's economic growth.

Water and economic development

The water issue is now of concern worldwide. Several international organizations, such as USAID, ADB, World Bank, and UN Water, have launched many projects and arranged many conferences focused on water resources and development with the objective to address the problems and ultimately come up with solutions for the issues. Due to such concern, World Water Day has been established on 22 March every year. In addition, numerous researchers have studied the relationship between water and economic development from various aspects. For example, investment in water resources generates growth (Biswas, 2010; Grey & Sadoff, 2007; Musouwir, 2010; World Bank, 2008). Access to water and sanitation generates growth (Berry, 2011; HSBC, 2012; World Bank, 2010), water disasters (floods and drought) disrupt a country's growth (GRID-Arendal, 2002) and the water available for agricultural and economic development (OECD, 2008, 2009).

Water resources infrastructure

There is a causality between economic development and investment in water resources. Investment in infrastructure for these resource helps to create national growth. Wealthy countries have higher ability to invest in such infrastructure and management. Grey and Sadoff (2007) point out that investment in and management of water resources in rich and poor countries make their economic development different. The rich have invested in water resources for a long time and now enjoy the benefit from the investment—a reduced poverty rate and increased economic growth. On the other hand, poor countries are still suffering from water shortage situations due to the lack of water infrastructure and good management systems. This issue is sometimes an obstacle to the development of the country and is one of the causes of poverty and famine. A report from World Bank (2008) revealed that investing in water infrastructure, especially in the agricultural sector, has resulted in poverty reduction and economic growth in the Sub-Saharan African countries. It can be seen that both water resource infrastructure and decent management support a country's growth and development. A study by Musouwir (2010) in 22 developing African countries found that there was a significant relationship between the national budget for water supply and sanitation and Gross Domestic Product (GDP) per capita, excluding rainfall. Research by Biswas (2010) illustrated the dissimilarity in the urbanization process between the mega cities in developed and developing regions. While there are effective water and wastewater infrastructure and relevant services in developed countries, those infrastructure and services in developing regions are poor. In OECD countries, the water infrastructure is usually obsolete and needs reinvestment to handle global and climate change.

Agricultural water use

Economic growth leads to high water demand (Ringler, 2010) in all sectors—agricultural, industrial, and domestic. The percentage share of use is different in different countries, depending on their economic development. For developing countries, agriculture takes the biggest proportion of water use (accounting for 70–90% of all water withdrawal). The study of agricultural water is also extensive, including various related issues, for example, the link of agricultural water use and food security (FAO, 2010) and water management in the agricultural sector (OECD, 2010). Water and food supplies have a solid connection; water is essential in agriculture, both for crop production and animal farming, which is the main resource for food supply. The process of food production requires large amounts of water, especially animal farming. For example, to produce 1 kg of daily food for a person, 2–5 cubic m (2,000–5,000 L) of water are required; to produce 1 kg of beef requires 15,500 L of water—three times the water

used for daily food (FAO, 2010). The demand for food has been steadily rising and has increased by 64 percent for meat and 31 percent for cereals, while fresh water resources are restricted. A report from the UN states that approximately three quarters of the world's population could face scarcities of freshwater by 2050 (Ringler, 2010). Therefore, the increase in food demand results in the scarcity of global water resources. Because water is essential for food production, the scarcity of water results in food shortages, leading to famine and under-nourishment. This situation takes place in low income countries, where people depend on local agriculture for food. In addition, the lack of infrastructure, including poor management of the water supply system, leads to food shortages, and finally food instability due to insufficient water supply (Grey & Sadoff, 2007).

Agricultural water management

As demand for food and water is rising, farmers need to find efficient ways to use water and to improve agricultural water management. For the OECD countries, governments have launched policies to support the agricultural sector to encourage production and water use efficiency. In addition, water management for agriculture via water-related agencies and property rights, is also promoted (OECD, 2006).

Although the study of agricultural water use is ample, no paper has focused on the relationship between such use and a country's development level. Therefore, this paper has pioneered the analysis of such a relationship. In this study, the wealth of countries is represented by the GDP. A country's economic development level is indicated by per capita GNI based on the World Bank data.

Data and Methodologies

The data and information used in the study were collected from various sources: (1) the information of water use in 154 countries was taken from Black and King (2009), and (2) economic indicators such as the per capita GNI were taken from the World Bank. These 154 countries were classified into four income levels, based on the World Bank database (World Bank, 2014), as follows: 1) high income group ($12,616 or more) consisting of 44 countries; 2) upper middle-income group ($4,086-$12,615) consisting of 38 countries; 3) lower middle-income group ($1,036-$4,085) consisting of 41 countries; and 4) low income group ($1,035 or less) consisting of 31 countries.

The methodologies adopted in this study are as follows.

1) Collect information on water use, especially for agricultural purposes
2) Collect economic development indicators
3) Classify the economic development level
4) Analysis of agricultural water use of each country
5) Analysis of the relationship of agricultural water use and development level
6) Discuss the relationship of agricultural water use and economic development

Limitations

The paper uses agricultural water use as the factor to investigate each country's development. In fact, there are various factors that are linked to development such as water resource infrastructure and water resource management.

Results Analysis

Percentage of agricultural water use

The following results illustrate the share of water use for agricultural purposes among all types of water use (industrial use and domestic use) of the four income groups (Tables 1–4).

High income group
Among the 28 OECD countries in the high income group, only 7 have the highest proportion of water use for agricultural purposes. For the-non OECD countries, 9 out of 16 use the largest amount of water in agriculture. This implies that agriculture is not a key sector for most OECD countries because the sector does not consume the highest share of total water use. This result supports the claim that the economic structure of a rich country is mostly industrial. It can be noticed that several rich countries, which are not members of the OECD, have a high dependence on other natural resources. For example, Qatar's GDP is dominated by oil and its byproducts (Table 1).

Upper-middle income group
The results indicated that approximately 75 percent (26) of non OECD countries with upper-middle income use a major share of water for agricultural purposes. This illustrates that agriculture is the economic foundation of these countries. They rely to a high level on water for goods and service production. Of the OECD countries, only Mexico has a major share of water use in agriculture (Table 2).

Lower-middle income group
Approximately 90 percent (37 countries) in the lower-middle income countries have a major share of water use in the agricultural sector. Similar to the upper-middle income group, the agricultural sector is important to the economy of these countries (Table 3).

Low income group
Like the lower-middle and upper-middle income countries, agriculture is very important to the economies of this group. The results showed that 84 percent (26) of the low income countries use the highest share of water for agricultural purposes (Table 4).

Quantity of agricultural water use

Considering the quantity of agricultural water use in the four income level groups, as shown in Figure 1, the average water use in the agricultural sector was 325, 489, 688, and 447 cubic

Table 1 – List of high income group countries separated into OECD (*) and non-OECD countries

No.	Country name	Per capita GDP (US$)	Total water use per person (cu.m)	Agricultural water use per person (cu.m)	% of agricultural water use	% of domestic water use	% of industrial water use
1	Greece*	26,825	702	566	81	16	3
2	Portugal*	21,393	1,090	853	78	10	12
3	Australia*	54,562	1,226	923	75	15	10
4	Spain*	31,241	856	583	68	13	19
5	Japan*	42,888	693	433	62	20	18
6	Israel*	31,377	291	168	58	36	6
7	Korea, Rep.*	21,047	393	189	48	36	16
8	Italy*	34,709	767	346	45	18	37
9	Denmark*	57,392	236	100	43	32	25
10	New Zealand*	34,085	541	228	42	48	9
11	United States*	47,239	1,654	682	41	13	46
12	Netherlands*	47,152	494	167	34	6	60
13	Hungary*	12,825	751	241	32	9	59
14	Germany*	39,455	570	113	20	12	68
15	Canada*	47,964	1,468	173	12	20	69
16	Norway*	88,884	481	51	11	23	67
17	France*	41,347	669	66	10	16	74
18	Sweden*	50,651	332	29	9	37	54
19	Poland*	12,337	420	35	8	13	79
20	Belgium*	44,617	831	10	4	11	85
21	Finland*	44,787	476	13	3	14	83
22	United Kingdom*	37,056	161	5	3	22	75
23	Switzerland*	70,775	356	7	2	24	74
24	Czech Republic*	19,397	251	6	2	41	57
25	Austria*	45,045	260	2	1	35	64
26	Luxembourg*	112,729	821	0	0	13	87
27	Ireland*	47,733	287	0	0	23	77
28	Iceland*	41,836	523	1	0	33	67
29	Oman	22,250	515	455	88	10	1
30	Saudi Arabia	18,221	963	848	88	9	3
31	United Arab Emirates	67,956	889	737	83	15	2
32	Cyprus	26,898	297	217	73	28	1
33	Chile	12,999	795	505	64	11	25
34	Qatar	151,586	546	322	59	39	2
35	Kuwait	43,631	375	202	54	44	2
36	Venezuela, RB	14,237	330	157	47	46	7
37	Bahrain	30,594	492	219	45	50	6
38	Barbados	14,171	299	75	25	38	50
39	Antigua and Barbuda	12,820	77	15	20	60	20
40	Malta	19,912	152	25	17	67	1
41	Trinidad and Tobago	15,748	240	15	6	68	26
42	Estonia	14,047	119	6	5	56	38
43	Singapore	48,008	82	3	4	45	51
44	Equatorial Guinea	28,432	230	2	1	83	16

m per person in the low income, middle income, upper-middle income, and high income countries, respectively. It can be seen that the lowest income group has the lowest amount of water use in agriculture. This is due to the fact that this group of countries has limited investment in water infrastructure, resulting in a lack of water storage. These countries have a high dependence on rainfall, and this group is somewhat vulnerable to natural disasters, including floods and droughts. This is supported by the percentage of irrigated area, the percentage of the population with access to improved sanitation and the percentage of the population with access to improved water sources (Table 5).

The amount of water use in agriculture slightly increases in the lower-middle income group where the infrastructure, including the water management system, is still inefficient. The upper-middle income group consumes the highest amount of water at 688 cubic m. The quantity of water in these countries is derived from the large investment in infrastructure in the past. However, the large amount of water use necessary to produce the agricultural goods and services of

Table 2 – List of upper-middle income group separated into OECD (*) and non-OECD countries

No.	Country name	Per capita GDP (US$)	Total water use per person (cu.m)	Agricultural water use per person (cu.m)	% of agricultural water use	% of domestic water use	% of industrial water use
1	Mexico*	9,723	760	586	77	17	5
2	Russian Federation*	10,439	528	94	18	19	63
3	Turkmenistan	4,024	5,322	5,192	98	2	1
4	Kazakhstan	9,601	2,352	1,923	82	2	17
5	Suriname	9,458	1,519	1,406	93	4	3
6	Thailand	4,992	1,391	1,322	95	2	2
7	Azerbaijan	6,246	1,452	1,109	76	4	19
8	Ecuador	4,346	1,340	1,102	82	12	5
9	Uruguay	11,800	929	894	96	3	1
10	Peru	5,516	752	614	82	8	10
11	Romania	7,539	1,056	602	57	9	34
12	Argentina	9,327	772	572	74	17	9
13	Turkey	9,764	548	404	75	15	10
14	Mauritius	7,710	582	394	68	30	3
15	Costa Rica	8,102	654	349	53	29	17
16	China	4,464	485	329	68	7	26
17	Dominican Republic	5,284	398	263	66	32	2
18	Bulgaria	6,247	1,331	250	19	3	78
19	Malaysia	8,950	376	234	62	17	21
20	Tunisia	4,283	270	221	82	14	4
21	Lebanon	9,514	366	218	60	29	11
22	Brazil	11,174	331	205	62	20	18
23	South Africa	7,483	268	168	63	31	6
24	Algeria	4,784	193	126	65	22	13
25	Belize	4,831	474	119	25	8	92
26	Colombia	6,256	246	113	46	50	4
27	Namibia	5,378	153	109	71	24	5
28	Jordan	4,464	165	107	65	31	4
29	Belarus	5,699	281	85	30	23	47
30	Jamaica	5,119	157	77	49	34	17
31	Panama	8,017	268	75	28	67	5
32	Botswana	7,928	110	45	41	41	18
33	Gabon	9,925	91	38	42	50	8
34	Latvia	10,531	124	17	14	55	34
35	Angola	4,846	24	14	60	23	17
36	Seychelles	10,700	152	11	7	65	28
37	Lithuania	10,710	78	6	7	78	15
38	Maldives	6,695	17	0	0	99	2

these countries takes place at the expense of overspending on water resources. This implies there is an inefficiency of water management that can occur at different levels of water management. Improvements in institutions and management are necessary for the group. It can also be seen that the average amount of agricultural water use in rich countries is lower than the amount in the middle income countries. The amount of water is lower there because of investment, resulting in a highly efficient water management system and the resultant economic growth.

Overall, it can be seen clearly that unlike the high income regions, the agriculture sector is the main sector in the lower income, lower-middle income, and upper-middle income countries. The low to upper-middle income groups have the highest share of water use in agriculture at approximately 70–90 percent. These countries use large amounts of water for the agricultural sector compared to the rich countries. This shows that countries with a high amount of water use for agriculture do not experience high economic growth, thus implying the inefficiency of water use is occurring in the process of using agricultural water. In addition, the impropriate management of water institutions is another factor.

Conclusion and Policy Implications

The relationship was studied between agricultural water use and economic development, using per capita GNI to represent economic development. The quantity of water use in the agricultural sector in the four income groups of countries surveyed revealed that agricultural water use in the three country groups—low income, lower-middle income, and upper-middle income—depends on the agricultural

Table 3 – List of lower-middle income group in non-OECD countries

No.	Country name	Per capita GDP (US$)	Total water use per person (cu.m)	Agricultural water use per person (cu.m)	% of agricultural water use	% of domestic water use	% of industrial water use
1	Guyana	3,053	2,195	2,142	98	2	1
2	Swaziland	3,244	1,009	974	97	2	1
3	Sudan	1,737	1,091	1,054	97	3	1
4	Pakistan	1,079	1,138	1,093	96	2	2
5	Sri Lanka	2,568	623	594	95	2	2
6	Bhutan	2,297	207	197	95	5	1
7	Uzbekistan	1,437	2,292	2,136	93	5	2
8	Senegal	1,038	205	190	93	4	3
9	Cape Verde	3,130	47	42	91	7	2
10	Indonesia	3,057	386	352	91	8	1
11	Yemen, Rep.	1,386	178	160	90	8	2
12	Lao PDR	1,226	541	488	90	4	6
13	Syrian Arab Republic	2,968	876	770	88	9	4
14	Mauritania	1,158	606	534	88	9	3
15	Morocco	2,908	418	366	87	10	3
16	Egypt, Arab Rep.	2,899	977	844	86	8	6
17	India	1,441	613	530	86	8	5
18	Bolivia	2,062	160	134	83	13	7
19	Nicaragua	1,177	252	209	83	15	2
20	Guatemala	3,097	171	137	81	7	14
21	Honduras	2,158	128	102	80	8	12
22	Iraq	2,798	2,486	1,959	79	7	15
23	Zambia	1,358	157	119	76	17	7
24	Philippines	2,269	362	268	74	17	9
25	Cameroon	1,212	64	47	74	18	8
26	Fiji	3,778	85	61	71	14	14
27	Paraguay	2,990	85	61	71	20	8
28	Nigeria	1,329	65	45	69	21	10
29	Vietnam	1,218	883	601	68	8	24
30	Armenia	3,124	967	636	66	30	4
31	Ghana	1,370	47	31	66	24	10
32	Georgia	2,645	362	236	65	22	13
33	Cote d'Ivoire	1,190	54	35	65	24	12
34	Albania	3,717	556	344	62	27	11
35	El Salvador	3,124	195	117	60	25	16
36	Ukraine	2,952	781	410	52	12	35
37	Mongolia	2,358	172	90	52	20	27
38	Moldova	1,533	544	179	33	10	58
39	Congo, Rep.	3,185	7	2	31	53	17
40	Lesotho	1,084	28	6	20	40	40
41	Papua New Guinea	1,498	14	0	1	50	38

sector. This sector is the main user of water. Therefore, a lack of or inadequate use of water causes water crises and finally economic stagnation. On the other hand, in the rich countries, water use in agriculture plays an insignificant role in the economy, as it can be seen that the water use in agriculture takes the second largest share of water use because the high income countries mostly rely on the industrial sector and technology. Furthermore, these countries have invested in water infrastructure and their economic structure has already shifted from an agricultural to an industrial economy, leading to lower water use in agriculture. These results imply that the difference in the level of economic development can be used to identify the amount of agricultural water use.

Because the demand of water use for all purposes, especially for food production, is increasing, policy makers, especially in developing countries, should provide strategies that help these countries improve their water supply, from both the quantity and quality aspects. An increase in agricultural productivity may help developing countries escape from poverty. More efficient use of water in developing countries is vital. In addition, improvement in agricultural water management and the relevant agencies is essential for both developing and developed countries. Finally, water charges should be used to reduce wastage and this is recommended for further study. In addition, supporting measures should be introduced to encourage more innovation and better management.

Table 4 – List of low income group in non-OECD countries

No.	Country name	Per capita GDP (US$)	Total water use per person (cu.m)	Agricultural water use per person (cu.m)	% of agricultural water use	% of domestic water use	% of industrial water use
1	Central African Republic	457	6	0	80	4	16
2	Congo, Dem. Rep.	209	13	1	70	9	22
3	Togo	482	30	13	53	45	2
4	Comoros	644	14	6	48	47	5
5	Uganda	557	12	5	43	40	17
6	Benin	726	17	8	32	45	23
7	Liberia	263	34	19	27	55	18
8	Rwanda	578	17	12	24	68	8
9	Gambia, The	614	22	14	23	65	12
10	Kenya	858	80	63	17	79	4
11	Chad	792	26	22	17	83	0
12	Burundi	238	42	33	17	77	6
13	Malawi	363	84	67	15	80	5
14	Zimbabwe	560	329	260	14	79	7
15	Burkina Faso	597	67	57	13	86	1
16	Guinea-Bissau	491	121	99	13	82	5
17	Mozambique	430	34	29	11	87	2
18	Tanzania	567	143	128	10	89	0
19	Mali	764	530	477	9	90	1
20	Guinea	505	171	154	8	90	2
21	Ethiopia	357	77	72	6	94	0
22	Haiti	691	120	114	5	95	1
23	Sierra Leone	325	78	72	5	92	3
24	Tajikistan	837	1,901	1,742	4	92	5
25	Niger	380	173	165	4	95	0
26	Kyrgyz Republic	901	1,983	1,859	3	94	3
27	Bangladesh	632	592	570	3	96	1
28	Nepal	568	399	385	3	96	1
29	Madagascar	443	873	835	3	96	2
30	Afghanistan	635	898	881	2	98	0
31	Cambodia	728	308	301	1	98	0

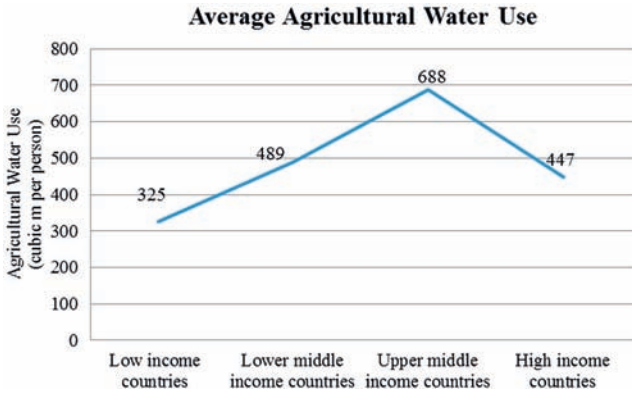


Figure 1 – Average agricultural water use of the four income groups

Table 5 – Average percentage of irrigated area, improved sanitation, and improved water resource by income group

Income group	% of irrigation	Population % with access to improved sanitation	Population % with access to improved water source
High income group	23	78	97
Upper-middle income group	17	95	92
Lower-middle income group	22	59	79
Low income group	12	33	63

Conflict of interest

No conflict of interest.

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