Article

Asian water resources development considering irrigation management

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Abstract: In this paper, irrigated agriculture has been estimated in Asia Pacific using three different scenarios by 2035 and 2060. The number of 10 indices (as the main indices) was selected to assess agricultural water management based on their importance and other indices were not studied due to lack of adequate data. These indices are permanent crops per cultivated area, rural population per total population, total economically active population in agriculture per total economically active population, human development index (HDI), value added to gross domestic product (GDP) by agriculture, national rainfall index (NRI), irrigation water requirement, difference between NRI and irrigation water requirement, percent of total cultivated area drained, and irrigated agriculture per cultivated area. The changes of the main indices in the previous half of century indicated that they had similar values in some regions and had very different values in other regions due to the nature of the indices and conditions of the regions. In the first step, the author studied variations of the main indices during the previous half of the century using linear regression and R^2 value then amount of each index was estimated in 2035 and 2060 by obtained equations and three different scenarios. The results show that trends of permanent crops per cultivated area (with the exception of Caucasus, Maritime Southeast Asia, and Oceania), HDI, irrigation water requirement, and percent of total cultivated area drained are increasing and trends of rural population per total population, total economically active population in agriculture per total economically active population, value added to GDP by agriculture, and difference between NRI and irrigation water requirement (with the exception of East Asia Pacific) are decreasing. The maximum value of irrigated agriculture is related to Central Asia; 69.2% and 81.8% by 2035 and 2060, respectively.

Keywords: sustainable agriculture; water management; Asia

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1. Introduction

The world population is growing day by day and need to provide the food according to meet sustainable development distinguishes necessity of accurate decision in the agricultural management. The role of macroeconomic policies in agricultural water management is vital and undeniable due to limitation of water resources. Asia Pacific has more than 60 percent of the world population and they need to more attention than other areas. The different aspects of irrigation in agricultural water management such as irrigation efficiency [1-18], soil salinity, water-saving, sustainable development, soil water management, and crop yield have been investigated in previous works. Valipour [19-28] determined critical area of Iran for agricultural water management according to the climate conditions. He considered annual rainfall and introduced areas with drastic rainfall variations as critical areas. Tan et al. [29] surveyed irrigated agriculture in the face of the nation's changing water resource policy and developing economy in Taiwan. They cited that efficient use and water saving appeared as the keys to balancing supply and demand to help secure the water economy, increase domestic food reserves, and contribute to social justice. Valipour [30-34] mentioned status of irrigated and rainfed agriculture in the world, summarized advantages and disadvantages of irrigation systems, and attend to update of irrigation information to choose optimum decision. His results show that 46% of cultivated areas in the world are not suitable for rainfed agriculture because of climate changes and other meteorological conditions. The value of irrigation-equipped areas as share of cultivated areas was 33.6% and the value of water-managed areas as share of cultivated areas was 34.3% for Asia. Yakubov and Manthrithilake [35] provided conclusions and recommendations as to how further scenarios could be better optimized given the trans-boundary nature of most water resources in Uzbekistan. The previous researches are about a limited area and cannot apply them for other regions or they did not consider role of all important indices for prediction of agricultural water management. Thus, the goal of this study is prediction of irrigated agriculture by finding a link between more important parameters in agricultural water management based on the available data for Asia Pacific.

2. Materials and Methods

Although irrigation efficiency is a proper index to show status of agricultural water management, we cannot increase irrigation efficiency until obtain value of equipped area and encourage farmers to use irrigation systems instead of rainfed agriculture. Many variables are required to obtain amount of irrigated agriculture per cultivated area for cropping pattern design, microeconomic decisions, and allocation of water resources. However, we cannot consider all parameters due to lack of adequate data. In this study, using AQUASTAT database [36], 10 main indices were selected to assessment of agricultural water management in Asia Pacific. Then, values of irrigated agriculture were estimated in 2035 and 2060 using three different scenarios.

2.1. Main indices

2.1.1. Permanent crops per cultivated area (%)

Crops are divided into temporary and permanent crops. Permanent crops are sown or planted once, and then occupy the land for some years and need not be replanted after each annual harvest, such as cocoa, coffee and rubber. This category includes flowering shrubs, fruit trees, nut trees and vines, but excludes trees grown for wood or timber, and permanent meadows and previousures. This index is determined as

$$I_1 = 100 \times \frac{permanent\ crops\ (ha)}{cultivated\ area\ (ha)} \quad (1)$$

2.1.2. Rural population per total population (%)

Usually the rural population is obtained by subtracting the urban population from the total population. In practice, the criteria adopted for distinguishing between urban and rural areas vary among regions. However, these criteria can be roughly divided into three major groups: classification of localities of a certain size as urban; classification of administrative centres of minor civil divisions as urban; and classification of centres of minor civil divisions on a chosen criterion which may include type of local government, number of inhabitants or proportion of population engaged in agriculture. Thus, the rural population estimates in this domain are based on the varying national definitions of urban areas. This index is determined as

$$I_2 = 100 \times \frac{rural\ population\ (inhabitant)}{total\ population\ (inhabitant)} \quad (2)$$

2.1.3. Total economically active population in agriculture per total economically active population (%)

Part of the economically active population engaged in or seeking work in agriculture, hunting, fishing or forestry (agricultural labour force). The economically active population refers to the number of all employed and unemployed persons (including those seeking work for the first time). It covers employers, self-employed workers, salaried employees, wage earners, unpaid workers assisting in a family or farm or business operation, members of producers' cooperatives, and members of the armed forces. The economically active population is also called the labour force. This index is determined as

$$I_3 = 100 \times \frac{total\ economically\ active\ population\ in\ agriculture\,(inhabitant)}{total\ economically\ active\ population\,(inhabitant)} \quad (3)$$

2.1.4. Human development index (HDI)

The HDI (I_4) is a composite statistic of life expectancy, education, and income indices used to rank regions into different tiers of human development.

2.1.5. Value added to gross domestic product (GDP) by agriculture (%)

Agriculture corresponds to International Standard Industrial Classification (ISIC) divisions 1-5 and includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. This index (I_6) is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources.

2.1.6. National rainfall index (NRI) (mm/yr)

The NRI is defined as the national average of the total annual precipitation weighted by its long-term average. The calculation of the NRI is different in the northern and the southern hemisphere. In the northern hemisphere the indices were calculated based on the January-December rainfall; the rainfall indices coincide with the calendar year. However, in the southern hemisphere, crops are planted at the end of a year to be harvested in the first half of the following calendar year. Consequently, the index of a special year is calculated on July of the previous year to June data of the year of interest for a crop harvested in this year. In fact, this index (I_5) is a type of effective rainfall.

2.1.7. Irrigation water requirement (mm/yr)

The quantity of water exclusive of precipitation and soil moisture (i.e. quantity of irrigation water) required for normal crop production. It consists of water to ensure that the crop receives its full crop water requirement (i.e. irrigation consumptive water use, as well as extra water for flooding of paddy fields to facilitate land preparation and protect the plant and for leaching salt when necessary to allow for plant growth). This index (I_7) corresponds to net irrigation water requirement.

2.1.8. Difference between NRI and irrigation water requirement (mm/yr)

This index shows water deficit and is determined as

$$I_8 = NIR\,(mm/yr) - irrigation\ water\ requirement\,(mm/yr) \quad (5)$$

2.1.9. Percent of total cultivated area drained (%)

The irrigated and non-irrigated cultivated area that is drained as percentage of the total cultivated area. This index is determined as

$$I_9 = 100 \times \frac{total\ drained\ area\,(ha)}{cultivated\ area\,(ha)} \quad (4)$$

2.1.10. Irrigated agriculture per cultivated area (%)

Equipped area to provide water (via irrigation) to crops. It includes areas equipped for full/partial control irrigation, equipped lowland areas, and areas equipped for spate irrigation. Although irrigated area and irrigation potential are better indices than equipped area, available values for them are less than equipped area, on the other hand, difference between irrigated area and equipped area is not significant in the most of regions, hence equipped area has been selected in this study. This index is determined as

$$I_{10} = 100 \times \frac{area\ equipped\ for\ irrigation\,(ha)}{cultivated\ area\,(ha)} \quad (6)$$

2.2. Prediction of equipped area in 2035 and 2060

To estimate irrigated agriculture in 2035 and 2060, in the first step, the author studied variations of the main indices during the previous half of century using linear regression and R2 value then amount of each index was estimated in 2035 and 2060 by obtained equations and three different scenarios. In the first scenario, the author assumed that values of the main indices would be changed by the same slope of the previous half of century (Figs. 1-9a). However, changes of the indices show that rate of increase or decrease has been reduced in the current years. Hence, in the second and third scenarios, the author assumed that the slopes would be decreased by 30% and 50% respectively. Therefore new values of the indices (in 2035 and 2060) were computed using these new slopes. In the second step, variations of irrigated agriculture versus the other main indices were surveyed and a linear equation with related R2 was computed for each indices. In the next step, values of irrigated agriculture (for each index and each scenario) were determined using replacement of obtained values for each index in 2035 and 2060 (the first step) in linear equation of the second step. Finally, a relationship has been established among calculated data (for equipped area for irrigation) as:

$$I_{10} = \frac{\sum\left(y \times R^2\right)}{\sum R^2} \quad (7)$$

Where, y is obtained value for irrigated agriculture in the second step (Figs. 1-9b) and values of R2 have been showed in Table 1.

3. Evaluation of the main indices of agricultural water management in the previous half of century

Fig. 1 shows variations of permanent crops per cultivated area versus time and equipped area for irrigation.

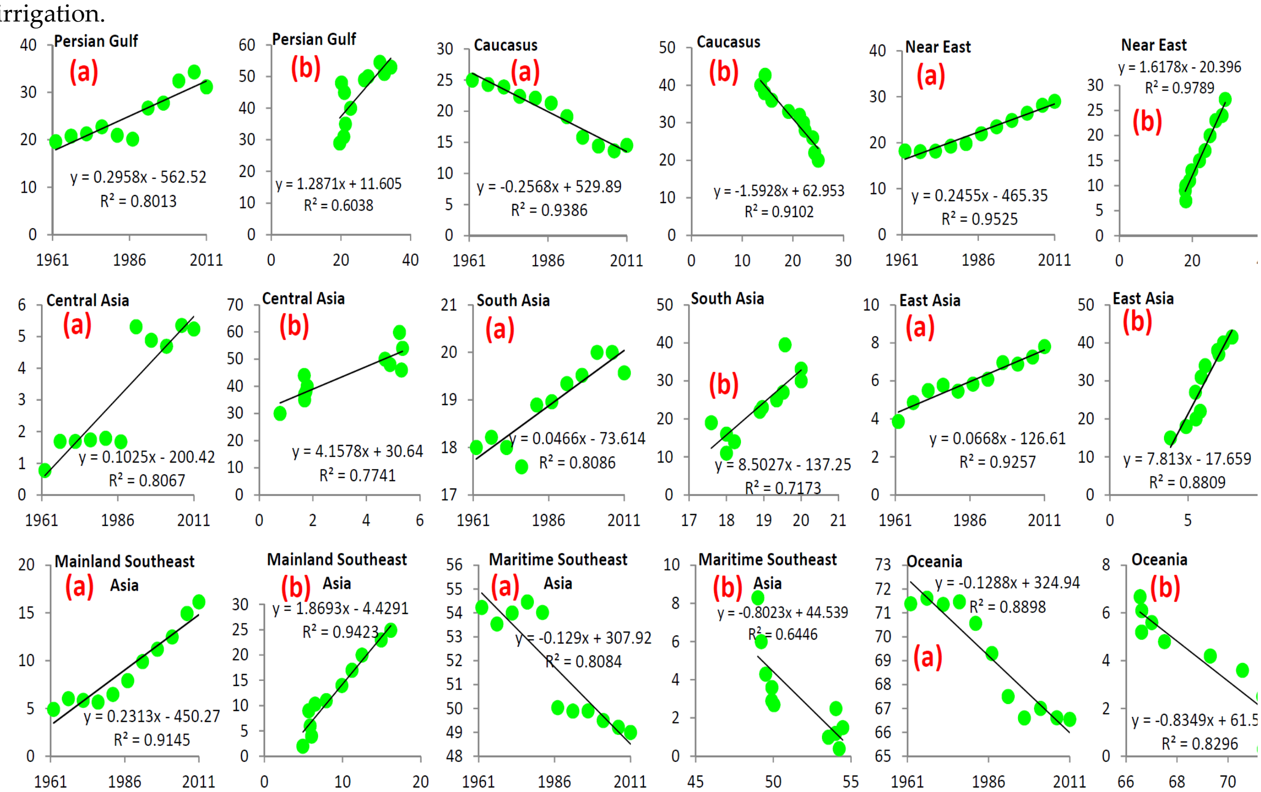

Fig.1 Variations of permanent crops per cultivated area versus time and equipped area for irrigation, (a) horizontal axis is time (year) and vertical axis is permanent crops per cultivated area (%) and (b) horizontal axis is permanent crops per cultivated area (%) and vertical axis is irrigated agriculture (%), value of x in (b) is equal to value of y in (a)

According to Fig. 1a value of permanent crops per cultivated area has been decreased in Caucasus, Maritime Southeast Asia, and Oceania and this index has been increased in the other regions. Thus, role of permanent crops per cultivated area is decreasing for irrigated agriculture in Caucasus, Maritime Southeast Asia, and Oceania and it is increasing for the other regions (Fig. 1b). In addition, a significant raise is observable in the middle of 1980s (Persian Gulf, Central Asia, South Asia, Maritime Southeast Asia, and Oceania). Although more values of this index can be helped to better scheduling for allocation of required water, it is dependent to climate conditions , tendency of farmers, and government's policy. Fig. 2 shows variations of rural population per total population versus time and equipped area for irrigation.

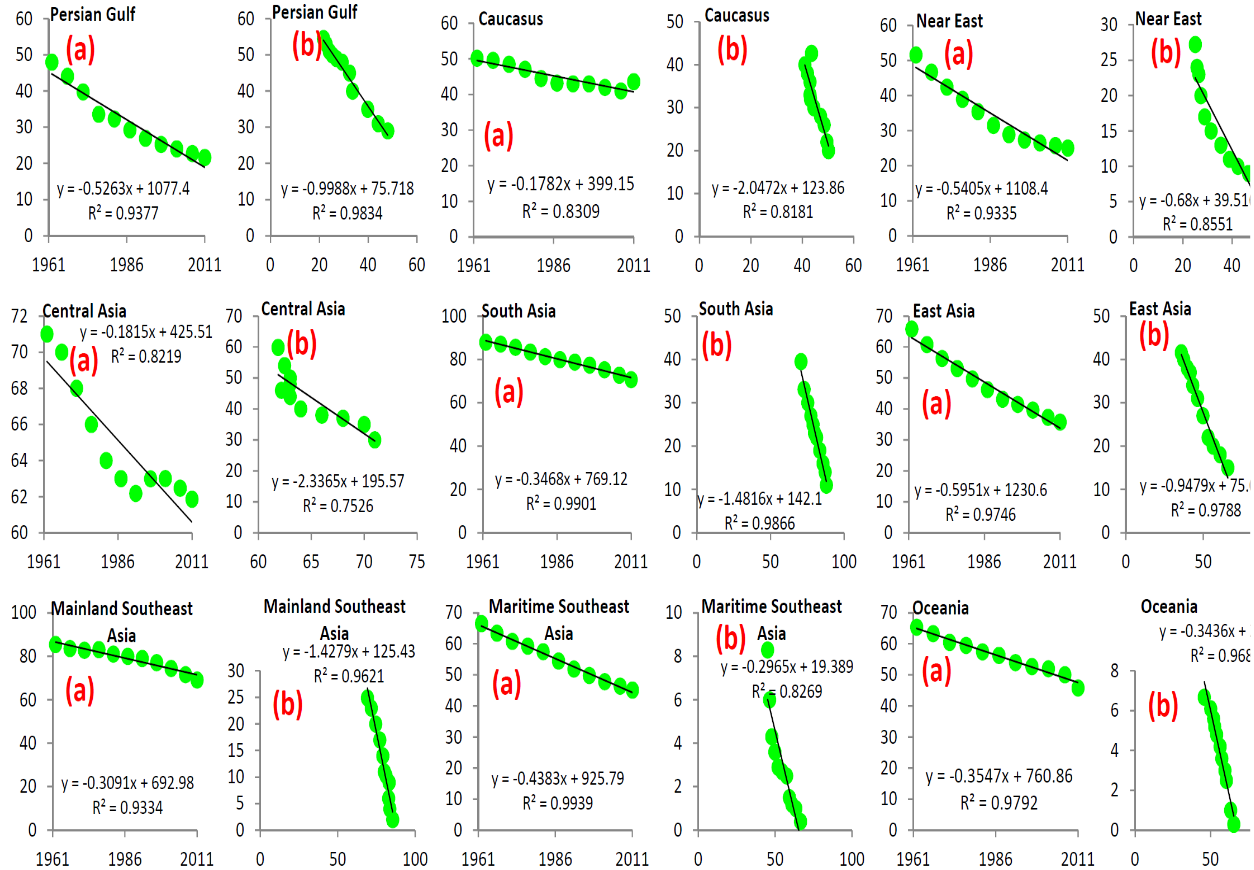

Fig.2 Variations of rural population per total population versus time and equipped area for irrigation, (a) horizontal axis is time (year) and vertical axis is rural population per total population (%) and (b) horizontal axis is rural population per total population (%) and vertical axis is irrigated agriculture (%), value of x in (b) is equal to value of y in (a)

According to Fig. 2a value of rural population per total population has been decreased in Asia Pacific. Thus, role of this index is decreasing for irrigated agriculture (Fig. 2b). Table 1 shows variations of other FAO indices versus time and equipped area for irrigation.

Table 1. Variations of FAO indices versus time and equipped area for irrigation, (a) regression between time (year) and total economically active population in agriculture per total economically active population (%), (b) regression between total economically active population in agriculture per total economically active population (%) and irrigated agriculture (%), (c) regression between time (year) and vertical axis is HDI and (d) regression between HDI and irrigated agriculture (%), (e) regression between time (year) and value added to GDP by agriculture (%), (f) regression between value added to GDP by agriculture (%) and irrigated agriculture (%), (g) regression between time (year) and NRI (mm/year), (h) regression between NRI (mm/year) and irrigated agriculture (%), (i)

regression between time (year) and irrigation water requirement (mm/year), (j) regression between irrigation water requirement (mm/year) and irrigated agriculture (%), (k) regression between time (year) and difference between NRI and irrigation water requirement (mm/year) and, (l) regression between difference between NRI and irrigation water requirement (mm/year) and irrigated agriculture (%), (m) regression between time (year) and percent of total cultivated area drained (%), and (n) regression between percent of total cultivated area drained (%) and irrigated agriculture (%)

		Persian Gulf	Caucasus	Near East	Central Asia	South Asia	East Asia	Mainland Southeast Asia	Maritime Southeast Asia	Oceania
LF										
	a	0.9734	0.9853	0.9961	0.9891	0.9974	0.9938	0.9985	0.9997	0.9955
	b	0.8505	0.979	0.9818	0.965	0.9556	0.9914	0.9851	0.8665	0.9643
HDI										
	c	0.8953	0.8559	0.9798	0.9499	0.9868	0.9795	0.9448	0.9645	0.9927
	d	0.8474	0.8788	0.9676	0.8752	0.9316	0.9073	0.964	0.8232	0.9893
GDP										
	e	0.8249	0.8965	0.965	0.8175	0.9262	0.9587	0.8015	0.8623	0.8273
	f	0.8731	0.9124	0.9633	0.903	0.8889	0.9349	0.8613	0.6209	0.8851
NRI										
	g	0.813	0.8024	0.8048	0.8915	0.8775	0.8116	0.8289	0.8408	0.8065
	h	0.0016	0.0489	0.1687	0.0911	0.1198	0.0003	0.0051	0.1516	0.0046
IWR										
	i	0.9834	0.8283	0.8029	0.9208	0.8085	0.9136	0.9357	0.8171	0.9738
	j	0.9337	0.7511	0.875	0.959	0.5854	0.8257	0.9567	0.9511	0.9743
NRI-IWR										
	k	0.9716	0.8688	0.8405	0.8267	0.8085	0.8225	0.8008	0.87	0.8211
	l	0.9135	0.8602	0.9627	0.7584	0.9358	0.8911	0.8023	0.9432	0.8211
D										
	m	0.968	0.983	0.9802	0.9709	0.9689	0.9511	0.9898	0.9466	0.8905
	n	0.9055	0.9781	0.9762	0.914	0.9532	0.951	0.9866	0.9458	0.8454

According to Table 1 value of economically active population in agriculture has been decreased in Asia Pacific. Thus, role of this index is decreasing for equipped area for irrigation. As expected, value of HDI has been increased in Asia Pacific. Thus, role of this index is increasing for equipped area for irrigation. However, slope of reduction of rural population per total population and total economically active population in agriculture per total economically active population is more than increasing slope of HDI in Asia Pacific. According to Table 1, value of this index has been decreased in Asia Pacific. Thus, role of this index is decreasing for equipped area for irrigation. According to Table 1, the value of NRI is variable during the previous half of century due to many different factors such as greenhouse gases, global warming, climate change etc. and linear regression is not suitable for evaluation of its trend. Thus, there is not a significant trend between variations of NRI and equipped area for irrigation. Due to the mentioned cases, role of this index has not been considered in prediction of irrigated agriculture in 2035 and 2060. According to Table 1, value of irrigation water requirement has been increased in Asia Pacific. Thus, role of this index is increasing for equipped area for irrigation. According to Table 1, value of this index has been increased in East Asia Pacific and it has been decreased in the other regions. Thus, role of difference between NRI and irrigation water requirement is increasing for irrigated agriculture in East Asia Pacific and it is increasing for the other regions. In Table 1, value of this index has been increased in Asia Pacific. Thus, role of this index is increasing for equipped area for irrigation.

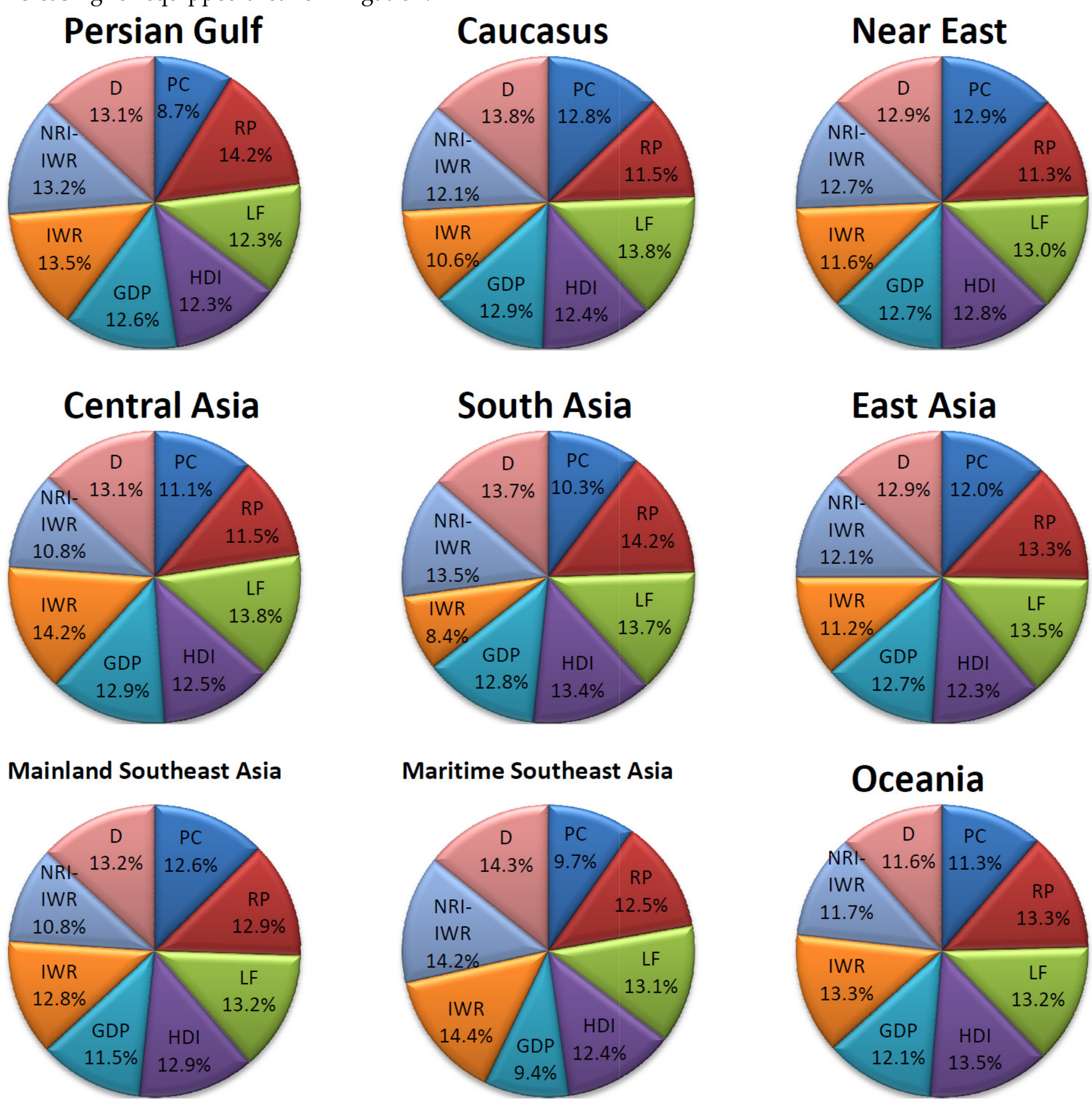

Fig. 3 Percent of observed trend between changes of the main indices and irrigated agriculture in the different regions of Asia Pacific (this is equivalent to role of each index to estimate irrigated agriculture based on R2 values in Table 1), role of NRI has not been considered due to very poor trend, PC indicates permanent crops per cultivated area, RP indicates rural population per total

population, LF (labour force) indicates total economically active population in agriculture per total economically active population, HDI indicates human development index, GDP indicates value added to gross domestic product by agriculture, IWR indicates irrigation water requirement, D indicates percent of total cultivated area drained, and NRI-IWR indicates difference between NRI and irrigation water requirement

In Persian Gulf and South Asia, the most trends is related to rural population per total population, in Caucasus, Near East, East Asia, and Mainland Southeast Asia, the most trends is related to total economically active population in agriculture per total economically active population, in Central Asia and Maritime Southeast Asia, the most trends is related to irrigation water requirement and in Oceania, the most trends is related to HDI. According to Fig. 3, the observed trend is changed from 8.7% (Persian Gulf) to 12.9% (Near East) for permanent crops per cultivated area (maximum of changes). These changes are from 11.3% (Near East) to 14.2% (Persian Gulf and South Asia) for rural population per total population, they are from 12.3% (Persian Gulf) to 13.8% (Caucasus and Central Asia) for total economically active population in agriculture per total economically active population, they are from 12.3% (Persian Gulf) to 13.5% (Oceania) for HDI (minimum of changes), they are from 9.4% (Maritime Southeast Asia) to 12.9% (Caucasus and Central Asia) for value added to GDP by agriculture, they are from 8.4% to 14.4% (Maritime Southeast Asia) for irrigation water requirement, they are from 10.8% (Central Asia and Mainland Southeast Asia) to 14.2% (Maritime Southeast Asia) for difference between NRI and irrigation water requirement, and they are from 11.6% (Oceania) to 14.3% (Maritime Southeast Asia) for percent of total cultivated area drained. The similar percentage of the trends shows that all selected indices are important and their selection is reasonable for study of agricultural water management and prediction of irrigated agriculture in the future.

4. Prediction of irrigated agriculture per cultivated area using the other main indices of agricultural water management

Table 2 shows estimated values for the main indices using the Equations related to Table 1.

Table 2 Estimated values for the main indices using the Equations related to Table 1, PC indicates permanent crops per cultivated area, RP indicates rural population per total population, LF (labour force) indicates total economically active population in agriculture per total economically active population, HDI indicates human development index, GDP indicates value added to gross domestic product by agriculture, IWR indicates irrigation water requirement, D indicates percent of total cultivated area drained, and NRI-IWR indicates difference between NRI and irrigation water requirement

PC (%)	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Persian Gulf	39.4	46.8	37.3	42.5	35.9	39.6
Caucasus	7.3	0.9	9.2	4.7	10.4	7.2
Near East	34.2	40.4	32.5	36.8	31.3	34.4
Central Asia	8	1	7	9	6	8

	.2	0.7	.4	.2	.9	.2
South Asia	21.2	22.4	20.9	21.7	20.7	21.2
East Asia	9.3	11.0	8.8	10.0	8.5	9.4
Mainland Southeast Asia	20.4	26.2	18.8	22.8	17.6	20.5
Maritime Southeast Asia	45.4	42.2	46.3	44.1	47.0	45.3
Oceania	62.8	59.6	63.8	61.5	64.4	62.8

LE (%)	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Persian Gulf	3.3	0.0	6.0	0.0	7.9	3.1
Caucasus	8.2	0.0	10.6	4.8	12.2	8.0
Near East	0.0	0.0	2.3	0.0	4.5	0.0
Central Asia	16.4	3.7	20.0	11.2	22.5	16.1
South Asia	41.9	29.4	45.5	36.8	47.9	41.6
East Asia	5.3	0.0	9.9	0.0	13.0	5.0
Mainland Southeast Asia	54.2	44.3	57.0	50.1	58.9	54.0
Maritime Southeast Asia	23.7	13.5	26.6	19.5	28.5	23.4
Oceania	15.8	7.1	18.2	12.2	19.9	15.6

HDI	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Persian Gulf	0.896	1.000	0.861	[illegible]	[illegible]	[illegible]
Caucasus	0.749	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Near East	0.865	0.980	[illegible]	[illegible]	[illegible]	[illegible]
Central Asia	0.916	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
South Asia	0.843	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
East Asia	0.899	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mainland Southeast Asia	0.754	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Maritime Southeast Asia	33.8	22.9	37.0	29.3	39.1	33.6
Oceania	39.0	30.2	41.6	35.4	43.3	38.9

Southeast Asia	.905	.000	.867	.958	.842	.907
	0	0	0	0	0	0
Oceania	.821	.893	.800	.850	.786	.822

NPI IWP	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Persian Gulf	928	1041	896	975	874	931
Caucasus	1	0	2	0	3	1

GDP (%)	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Persian Gulf	4.9	3.0	4.7	4.8	4.2	4.9
Caucasus	9.1	6.0	10.0	7.8	10.6	9.0
Near East	3.6	0.0	5.5	1.0	6.7	3.5
Central Asia	16.0	11.1	17.4	14.0	18.3	15.9
South Asia	1.9	0.0	6.6	0.0	9.7	1.6
East Asia	0.0	0.0	0.0	0.0	1.9	0.0
Mainland Southeast Asia	26.2	22.0	27.4	24.5	28.3	26.1
Maritime Southeast Asia	1.4	0.0	3.9	0.0	5.7	1.2
Oceania	8.9	1.9	10.9	6.0	12.2	8.7

IWP	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Persian Gulf	985	1060	964	1016	949	987
Caucasus	219	256	209	234	202	220
Near East	584	691	554	628	533	586
Central Asia	603	682	580	635	565	605
South Asia	541	565	534	551	529	541
East Asia	571	636	552	598	539	572
Mainland Southeast Asia	566	627	548	591	537	567
Maritime Southeast Asia	902	1092	848	980	811	906
Oceania	284	347	266	310	254	285

	26	80	39	07	48	25
Near East	-224	-377	-180	-287	-150	-227
Central Asia	-438	-593	-393	-502	-363	-441
South Asia	1059	958	1088	1018	1107	1057
East Asia	645	780	606	700	580	647
Mainland Southeast Asia	1541	1520	1547	1532	1551	1541
Maritime Southeast Asia	1241	382	1488	887	1653	1224
Oceania	2709	3460	2492	3018	2348	2724

D (%)	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Persian Gulf	20.5	24.0	19.5	21.9	18.8	20.6
Caucasus	9.5	11.8	8.8	10.4	8.3	9.5
Near East	44.2	54.4	41.3	48.4	39.3	44.4
Central Asia	30.0	38.2	27.6	33.4	26.0	30.1
South Asia	43.6	52.9	41.0	47.5	39.2	43.8
East Asia	19.3	25.2	17.6	21.7	16.4	19.4
Mainland Southeast Asia	6.9	9.2	6.2	7.9	5.8	6.9
Maritime Southeast Asia	0.5	0.7	0.4	0.6	0.4	0.5
Oceania	20.5	24.0	19.5	21.9	18.8	20.6

Permanent crops per cultivated area: the minimum value is 0.9% (in the first scenario by 2060) for Caucasus and the maximum value is 47.0% (in the third scenario by 2035) for Maritime Southeast Asia. A significant decreasing is considerable for Caucasus, Central Asia, and East Asia in the future. Rural population per total population: the minimum value is 0.0% (in the first scenario by 2060) for Persian Gulf and Near East and the maximum value is 67.7% (in the third scenario by 2035) for Mainland Southeast Asia. A significant decreasing is considerable for Persian Gulf, Near East and East Asia in the future. Total economically active population in agriculture per total economically active population: the maximum value is 58.9% (in the third scenario by 2035) for Mainland Southeast Asia. If current decreasing trend is followed, we will meet Persian Gulf, Near East and East Asia without labour force in the future. HDI: the minimum value in the future is related to Mainland Southeast Asia (0.668 in the third scenario by 2035), so rate of its increasing slope is less than the other regions. Value added to GDP by agriculture: the maximum value is 28.3% (in the third scenario by 2035) for Mainland Southeast Asia. If current decreasing trend is followed, we will meet Persian Gulf, Near East, South Asia, East Asia, and Maritime Southeast Asia without value added to GDP by agriculture. Irrigation water requirement: the minimum value is 202 mm/yr (in the third scenario by 2035) for Caucasus and the maximum value is 1092 mm/yr (in the first scenario by 2060) for Maritime Southeast Asia. Difference between NRI and irrigation water requirement: the minimum value is -1041 mm/yr (in the first scenario by 2060) for Persian Gulf and the maximum value is 3460 mm/yr (in the first scenario by 2060) for Oceania. Percent of total cultivated area drained: the minimum value is 0.4% (in the second and third scenarios by 2035) for Maritime Southeast Asia and the maximum value is 54.4% (in the first scenario by 2060) for Near East. Table 3 shows estimated values for irrigated agriculture using the Equations related to Table 1.

Table 3 Estimated values for irrigated agriculture using the Equations related to Table 1, PC indicates permanent crops per cultivated area, RP indicates rural population per total population, LF (labour force) indicates total economically active population in agriculture per total economically active population, HDI indicates human development index, GDP indicates value added to gross domestic product by agriculture, IWR indicates irrigation water requirement, D indicates percent of total cultivated area drained, and NRI-IWR indicates difference between NRI and irrigation water requirement

	Scenar io (I)		Scenar io (II)		Scenar io (III)	
	2 035	2 060	2 035	2 060	2 035	2 060
Persian Gulf	6 2.4	7 1.9	5 9.6	6 6.3	5 7.8	6 2.5
Caucasus	5 1.3	6 1.5	4 8.4	5 5.5	4 6.4	5 1.5
Near East	3 5.0	4 4.9	3 2.1	3 9.1	3 0.2	3 5.2
Central Asia	6 4.6	7 5.3	6 1.5	6 9.0	5 9.5	6 4.8
South Asia	4 3.2	5 3.1	4 0.3	4 7.2	3 8.4	4 3.3
East Asia	5 5.2	6 8.3	5 1.5	6 0.6	4 9.0	5 5.5
Mainland Southeast Asia	3 3.8	4 4.6	3 0.6	3 8.2	2 8.6	3 4.0
Maritime Southeast Asia	8 .1	1 0.7	7 .4	9 .2	6 .9	8 .2
Oceania	9 .1	1 1.8	8 .4	1 0.2	7 .8	9 .2

	Scenar io (I)		Scenar io (II)		Scenar io (III)	
	2 035	2 060	2 035	2 060	2 035	2 060
Persian Gulf	6 9.3	7 5.7	6 5.6	7 4.8	6 3.0	6 9.6
Caucasus	4 9.1	5 8.2	4 6.5	5 2.9	4 4.7	4 9.3
Near East	3 3.7	3 9.5	3 1.1	3 7.5	2 9.3	3 3.9
Central Asia	6 5.4	7 6.7	6 2.2	7 0.1	6 0.0	6 5.7
South Asia	4 8.2	6 1.0	4 4.5	5 3.5	4 2.0	4 8.5
East Asia	5 6.5	7 0.6	5 2.4	6 2.3	4 9.7	5 6.7
Mainland Southeast Asia	3 4.1	4 5.1	3 0.9	3 8.6	2 8.8	3 4.3
Maritime Southeast Asia	9 .4	1 2.6	8 .4	1 0.7	7 .8	9 .4
Oceania	9 .8	1 2.8	8 .9	1 1.0	8 .3	9 .8

	Scenar io (I)		Scenar io (II)		Scenar io (III)	
	2 035	2 060	2 035	2 060	2 035	2 060
Persian Gulf	6 8.2	7 2.5	6 4.6	7 2.5	6 2.2	6 8.4
Caucasus	5 2.5	6 3.2	4 9.3	5 6.9	4 7.2	5 2.7
Near East	3 4.7	3 4.7	3 2.7	3 4.7	3 0.7	3 4.7
Central Asia	6 9.2	8 2.3	6 5.4	7 4.6	6 2.9	6 9.4
South Asia	4 7.9	6 0.6	4 4.3	5 3.2	4 1.8	4 8.2
East Asia	5 7.1	6 1.9	5 2.9	6 1.9	5 0.2	5 7.4
Mainland Southeast Asia	3 4.9	4 6.5	3 1.6	3 9.7	2 9.4	3 5.2
Maritime Southeast Asia	9 .5	1 2.9	8 .6	1 0.9	7 .9	9 .6
Oceania	9 .8	1 2.8	8 .9	1 1.0	8 .3	9 .8

	Scenar io (I)		Scenar io (II)		Scenar io (III)	
	2 035	2 060	2 035	2 060	2 035	2 060
Persian Gulf	6 2.3	6 7.9	6 0.4	6 5.0	5 9.2	6 2.5
Caucasus	4 3.2	5 2.5	4 0.5	4 7.0	3 8.7	4 3.4
Near East	4 0.5	5 2.4	3 7.1	4 5.4	3 4.8	4 0.8
Central Asia	6 7.0	7 0.0	6 2.9	7 0.0	6 0.2	6 7.3
South Asia	5 6.8	6 8.7	5 2.7	6 2.6	5 0.0	5 7.1
East Asia	4 9.6	5 6.8	4 6.3	5 4.3	4 4.1	4 9.8
Mainland Southeast Asia	3 8.5	5 1.4	3 4.7	4 3.8	3 2.3	3 8.7
Maritime Southeast Asia	1 4.5	1 7.8	1 3.2	1 6.3	1 2.3	1 4.6
Oceania	1 0.2	1 2.8	9 .5	1 1.3	9 .0	1 0.3

		6	7	6	7	6	6
Persian Gulf	6.3	4.4	3.0	1.1	0.7	6.5	
		5	6	4	5	4	5
Caucasus	0.9	0.9	8.0	5.0	6.1	1.1	
		3	4	3	3	3	3
Near East	5.0	0.6	2.1	9.1	0.2	5.2	
		6	7	6	7	6	6
Central Asia	5.9	7.4	2.5	0.6	0.3	6.1	
		4	4	4	4	4	4
South Asia	6.4	7.7	3.0	7.7	0.7	6.6	
		5	5	5	5	4	5
East Asia	1.9	1.9	1.9	1.9	9.3	1.9	
Mainland		3	4	2	3	2	3
Southeast Asia	1.4	1.1	8.6	5.4	6.8	1.6	
Maritime		8	8	7	8	6	8
Southeast Asia	.2	.6	.4	.6	.9	.2	
		9	1	8	1	7	9
Oceania	.1	1.7	.3	0.2	.8	.1	

[illegible]		Scenar		Scenar		Scenar	
	io (I)		io (II)		io (III)		
		2	2	2	2	2	2
	035	060	035	060	035	060	
		6	6	5	6	5	6
Persian Gulf	1.8	9.6	9.5	5.0	8.0	1.9	
		5	6	4	5	4	5
Caucasus	1.6	1.7	8.7	5.8	6.7	1.8	
		3	4	3	4	3	3
Near East	7.1	8.1	3.9	1.7	1.8	7.3	
		7	9	6	8	6	7
Central Asia	3.9	1.0	9.0	0.9	5.7	4.3	
		5	7	5	6	4	5
South Asia	5.9	5.1	0.4	3.8	6.8	6.3	
		4	5	4	5	4	4
East Asia	7.9	5.1	5.9	0.9	4.5	8.1	
Mainland		3	4	3	4	2	3
Southeast Asia	5.3	6.8	2.0	0.1	9.8	5.6	
Maritime		1	2	1	1	1	1
Southeast Asia	5.1	2.9	2.8	8.3	1.3	5.2	
		8	1	7	9	7	8
Oceania	.5	0.7	.9	.4	.5	.6	

[illegible]		Scenar		Scenar		Scenar	
	io (I)		io (II)		io (III)		
		2	2	2	2	2	2
	035	060	035	060	035	060	
		6	6	5	6	5	6
Persian Gulf	1.9	9.9	9.6	5.2	8.1	2.1	
		5	5	4	5	4	5
Caucasus	0.5	9.7	7.8	4.3	6.1	0.7	
		3	4	3	4	3	3
Near East	6.2	6.4	3.2	0.4	1.2	6.4	
		7	9	7	8	6	7
Central Asia	8.3	8.9	2.3	6.7	8.4	8.7	
		5	6	4	5	4	5
South Asia	1.1	6.2	6.7	7.3	3.8	1.4	
		4	5	4	5	4	4
East Asia	8.1	5.3	6.0	1.0	4.6	8.2	
Mainland		3	5	3	4	3	3
Southeast Asia	7.9	1.4	4.0	3.4	1.4	8.1	
Maritime		1	2	1	1	1	1
Southeast Asia	4.9	2.5	2.7	8.0	1.2	5.0	
		9	1	8	1	7	9
Oceania	.1	1.6	.3	0.1	.8	.1	

[illegible]		Scenar		Scenar		Scenar	
	io (I)		io (II)		io (III)		
		2	2	2	2	2	2
	035	060	035	060	035	060	
		6	8	6	7	6	6
Persian Gulf	9.0	1.8	5.3	4.3	2.9	9.3	
		5	6	4	5	4	5
Caucasus	2.6	3.5	9.5	7.1	7.4	2.8	
		3	4	3	3	3	3
Near East	5.3	5.4	2.4	9.5	0.5	5.5	
		6	8	6	7	6	6
Central Asia	8.2	0.9	4.6	3.5	2.1	8.5	
		4	6	4	5	4	4
South Asia	7.7	0.2	4.1	2.8	1.7	7.9	
		7	8	6	7	6	7
East Asia	3.4	7.1	9.4	9.1	6.8	3.7	
Mainland		3	4	3	3	2	3
Southeast Asia	5.0	6.5	1.7	9.8	9.5	5.3	
Maritime		9	1	8	1	8	9
Southeast Asia	.6	3.0	.6	1.0	.0	.7	
		7	1	7	8	6	7
Oceania	.8	0.5	.0	.9	.5	.8	

Data of Table 3 have computed using the Equations related to Table 1 and are equal to y value in the Eq. (7). Table 4 shows estimated values for irrigated agriculture using the Eq. (7).

Table 4 Estimated values for irrigated agriculture using the Eq. (7)

		Area equipped for irrigation (%)						Changes (%)						
			Scenar		Scenar		Scenar		Scenar		Scenar		Scenar	
		io (I)		io (II)		io (III)		io (I)		io (II)		io (III)		
		2	2	2	2	2	2	2	2	2	2	2	2	2
Region	011	035	060	035	060	035	060	035	060	035	060	035	060	

	5	6	7	6	6	6	6	1	3	1	2	1	2
Persian Gulf	4.5	5.3	3.1	2.3	9.4	0.4	5.5	9.8	4.0	4.3	7.4	0.7	0.1
	4	5	6	4	5	4	5	1	4	1	2	6	1
Caucasus	2.7	0.3	0.3	7.4	4.4	5.5	0.5	7.9	1.3	1.1	7.5	.6	8.3
	2	3	4	3	3	3	3	3	6	2	4	1	3
Near East	7.2	6.0	4.0	3.1	9.7	1.1	6.1	2.1	1.7	1.6	5.7	4.3	2.8
	5	6	8	6	7	6	6	1	3	8	2	4	1
Central Asia	9.9	9.2	1.8	5.2	4.6	2.5	9.5	5.7	6.7	.9	4.7	.4	6.1
	3	4	6	4	5	4	5	2	5	1	3	9	2
South Asia	9.5	9.8	1.7	5.9	4.9	3.3	0.0	6.0	6.2	6.1	9.0	.5	6.7
	4	5	6	5	5	4	5	3	5	2	4	2	3
East Asia	1.5	5.2	3.6	2.2	9.2	9.9	5.4	2.9	3.2	5.8	2.7	0.2	3.4
Mainland	2	3	4	3	3	2	3	4	8	2	6	1	4
Southeast Asia	4.9	5.2	6.7	1.8	9.9	9.6	5.4	1.1	7.6	7.7	0.3	8.8	2.1
Maritime Southeast	8	1	1	1	1	9	1	3	8	2	5	1	3
Asia	.3	1.4	5.7	0.1	3.3	.2	1.5	7.8	8.8	1.9	9.8	1.2	8.9
	6	9	1	8	1	7	9	3	7	2	5	1	3
Oceania	.7	.2	1.9	.4	0.3	.9	.3	7.8	8.0	6.2	4.4	8.5	8.6

According to Table 4, in the first scenario, the most changes is related to Mainland Southeast Asia (41.1% by 2035) and Maritime Southeast Asia (88.8% by 2060), in the second scenario, the most changes is related to Mainland Southeast Asia (27.7% by 2035 and 60.3% by 2060), and in the third scenario, the most changes is related to East Asia (20.2% by 2035) and Mainland Southeast Asia (42.1% by 2060). Therefore, Mainland Southeast Asia has a better potential to increasing irrigated agriculture in the future. A considerable note is change of irrigation status in the future than the current status; although irrigated agriculture in Caucasus is more than East Asia in 2011, however it is less than East Asia for the all scenarios in the future. In addition, although irrigated agriculture in South Asia is less than Caucasus in 2011, however it is more than Caucasus for the first and second scenarios in 2060. Also, although irrigated agriculture in Mainland Southeast Asia is less than Near East in 2011, however it is more than Near East for the first and second scenarios in 2060. Although we can estimate irrigated agriculture for after 2060, however it is advised that we update our information every year, every decade, or at least every half of century.

Conflicts of Interest: The authors declare no conflict of interest.

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