FUTURE OF AGRICULTURAL WATER MANAGEMENT IN AMERICAS

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ABSTRACT

The study is aimed at estimation of area equipped for irrigation in Americas in 2035 and 2060 using study of agricultural water management during 1962 to 2011. For this purpose, all necessary information was gathered from FAO of United Nations and their values were checked using World Bank Group (WBG) data base. Among all presented data in FAO database, 10 indexes were selected for importance and more availability basis for all the regions in Americas and analyzed for all 5 regions in the study area. These indexes 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), national rainfall index (NRI) (mm/year), value added to gross domestic product (GDP) by agriculture (%), irrigation water requirement (mm/year), percent of total cultivated area drained, difference between NRI and irrigation water requirement (mm/year), and area equipped for irrigation per cultivated area (%). The amount of area equipped for irrigation per cultivated area (10th index) was estimated for three different scenarios by the other 9 indexes. The results showed that trend of permanent crops per cultivated area (with the exception of Northern America), HDI, irrigation water requirement and percentage of total cultivated area drained is increasing and trend 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 is decreasing. The results also showed changes of area equipped for irrigation as 9.1 to 26.3% and 17.6 to 51.3% in 2035 and 2060, respectively.

KEYWORDS: Agricultural water management; FAO; irrigation; macroeconomic policies; sustainable development; WBG data base; Americas.

INTRODUCTION

The world population is growing day by day and need to provide the food to meet sustainable development necessitates to make accurate decisions in

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the agricultural management. Due to scarcity of water resources, role of macroeconomic policies in agricultural water management is vital and undeniable. Although actual crop yield as percentage of potential yield is more than 60% for North America, it is less than 50% and about 30% for South America Central America and Caribbean, respectively (6). Therefore, studying agricultural WM is still reasonable for Americas. The different aspects of irrigation in agricultural WM such as irrigation efficiency (46, 47), soil salinity (12), water-saving (29), sustainable development (38), soil WM (40) and crop yield (50) have been investigated in previous works. Also, FAO (4, 5) showed that pressure to water resources due to irrigation would be increased by 2050. Neuman *et al.* cited that area equipped for irrigation purpose be expanded by 40 million ha by 2030 (34). Plusquellec claimed that area equipped for irrigation would be increased by 15 to 22% for 2025 (35).

Schaldach *et al.* underlined the importance of considering both the change of equipped area and agricultural management as well as hydrology aspects in regional water use analysis (37). Knox *et al.* claimed demonstrating efficient or 'best' use of water is not straight forward in England but farmers and the water regulator needed a rational approach that reflects the needs of the farming community whilst providing a policy framework for protecting the environment (23). Namara *et al.* mentioned role of agricultural WM to reduce poverty in the world as improvement of production, enhancement of employment opportunities and stabilization of income and consumption using access to reliable water, increasing high-value products, and finally its role to nutritional status, health, societal equity and environment (32). They preferred improving the management of existing systems as selected strategy in Asia. Valipour mentioned status of irrigated and rainfed agriculture in the world, summarized advantages and disadvantages of irrigation systems, and paid attention to update irrigation information to make optimum decisions. (46). His results showed that 46% of cultivated areas in the world are not suitable for rainfed agriculture because of climate changes and other meteorological conditions. Franks *et al.* studied developing capacity for agricultural WM in current practice and future directions (16). They suggested increased attention to monitoring and evaluation of capacity development and closer links to emerging work on water governance. Ferreyra *et al.* concluded that, instead of forcing watershed-based governance structures, the exploration and examination of more creative and flexible ways of linking watershed imperatives to existing socially and politically meaningful scales in agricultural areas of Ontario and elsewhere was warranted (15). De Loe *et al.* studied agricultural water use in Ontario (10). They have claimed that future water allocation decisions must take account of the distribution of agricultural water withdrawals, especially those for irrigation, which are strongly seasonal. Khan *et al.* reviewed WM and crop production for food security (20). According to their study, links between water and other development-related sectors such as population, energy, food, and environment, and the interactions among them require reckoning, as they together will determine future food security and poverty reduction. The previous researches confine to limited area and cannot be applied to other regions or did not consider role of all important indexes for estimation of agricultural WM. Thus, the objective of this study is estimation of area equipped for irrigation using to establish a link for more important parameters in agricultural WM based on available data for Americas.

MATERIALS AND METHODS

Many variables are required to obtain amount of area equipped for irrigation 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 (7), 10 main indexes were selected for the assessment of agricultural water management (WM) in Americas and their values were checked using World Bank Group (WBG) database (3). Then, values of area equipped for irrigation were estimated in 2035 and 2060 using three different scenarios.

1. Main indexes

1.1 Permanent crops per cultivated area (%)

This index is determined as:

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

1.2 Rural population per total population (%)

This index is determined as:

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

1.3 Total economically active population in agriculture per total economically active population (%)

This index is determined as:

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

1.4 Human development index (HDI)

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

1.5 National rainfall index (NRI) (mm/year)

The NRI is defined as the national average of the total annual precipitation weighted by its long-term average. The calculation of NRI is different in the northern and southern hemisphere. In the northern hemisphere the indices were calculated based on January-December rainfall; the rainfall indices coincide with the calendar year. But in the southern hemisphere, crops are planted at the end of a year to be harvested in the first half of following calendar year. Consequently, the index of a special year is calculated July of 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.

1.6 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.

1.7 Irrigation water requirement (mm/year)

The quantity of water exclusive of precipitation and soil moisture (quantity of irrigation water) required for normal crop production. It consists of water to ensure that the crop receives its full crop water requirement 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.

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

This index shows water deficit and is determined as:

$$I_8 = NRI\ (mm/year) - irrigation\ water\ requirement\ (mm/year) \qquad (4)$$

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:

$$I_9 = 100 \times \frac{total\ drained\ area\ (ha)}{cultivated\ area\ (ha)} \qquad (5)$$

1.10 Area equipped for irrigation per cultivated area (%)

This index is determined as:

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

2. Estimation of equipped area in 2035 and 2060

To estimate area equipped for irrigation in 2035 and 2060, the author studied variations of the main indexes during the past half of century using linear regression and R^2 value then amount of each index was estimated in 2035 and 2060 by obtaining equations in three different scenarios. In the first scenario, the author assumed that values of main indexes would be changed by same slope of the past half of century (Figs. 1-9a). However, changes of the indexes show that rate of increase or decrease has been reduced in the current years. Hence, in second and third scenarios, the author assumed that the slopes would be decreased by 30 and 50%, respectively. Therefore new values of indexes (in 2035 and 2060) were computed using these new slopes. In the second step, variations of area equipped for irrigation versus other main indexes were surveyed and a linear equation with related R^2 was computed for each index. In the next step, values of area equipped for irrigation (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 second step. Finally, a relationship has been established among calculated data (for area equipped for irrigation) as:

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

Where, *y* is obtained value for area equipped for irrigation in the second step (Figs. 1-9b) and values of R^2 have been shown in Figs 1-9b.

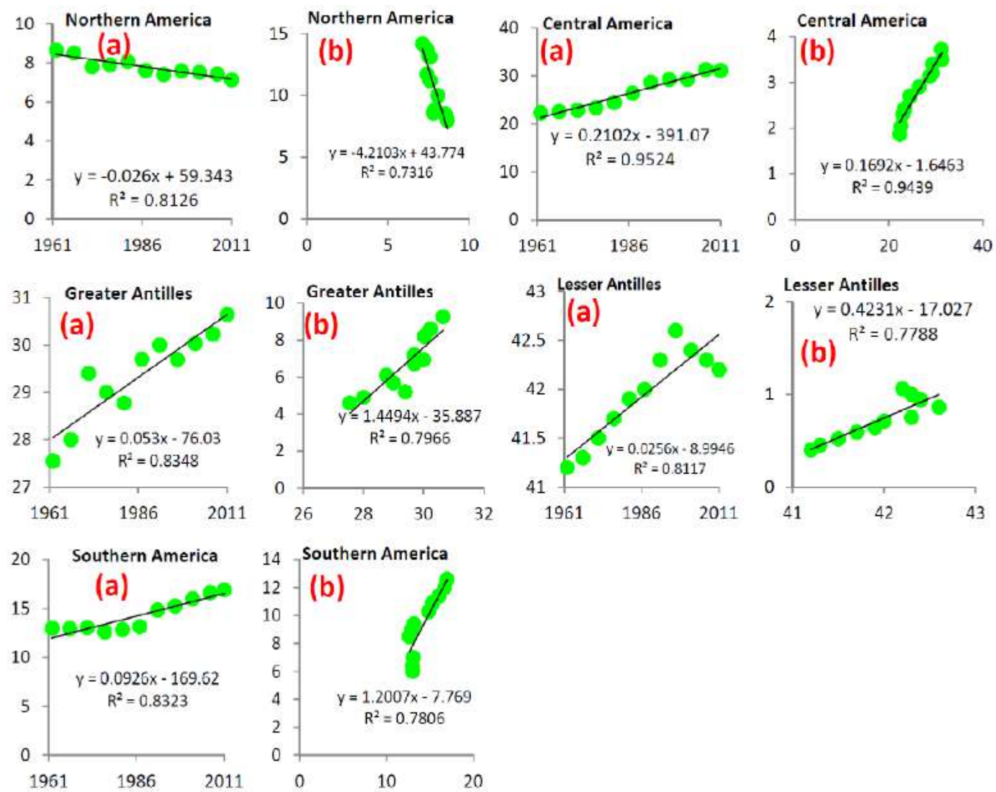

Fig.1. Variations of permanent crops per cultivated area versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is permanent crops per cultivated area (%) and (b) horizontal axis is permanent crops per cultivated area (%) and vertical axis is area equipped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

3. Evaluation of the main indexes of agricultural WM in the past half of century

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

According to Fig. 1a value of permanent crops per cultivated area has been decreased in Northern America and this index has been increased in the other regions. Thus, role of permanent crops per cultivated area is decreasing for area equipped for irrigation in Northern America and it is increasing for the other regions (Fig. 1b). Although more values of this index can be helpful to better scheduling for allocation of required water, it is dependent on climatic conditions (11), tendency of farmers (9) and government's policy (41). Fig. 2 shows variations of rural population per total population versus time and area equipped for irrigation.

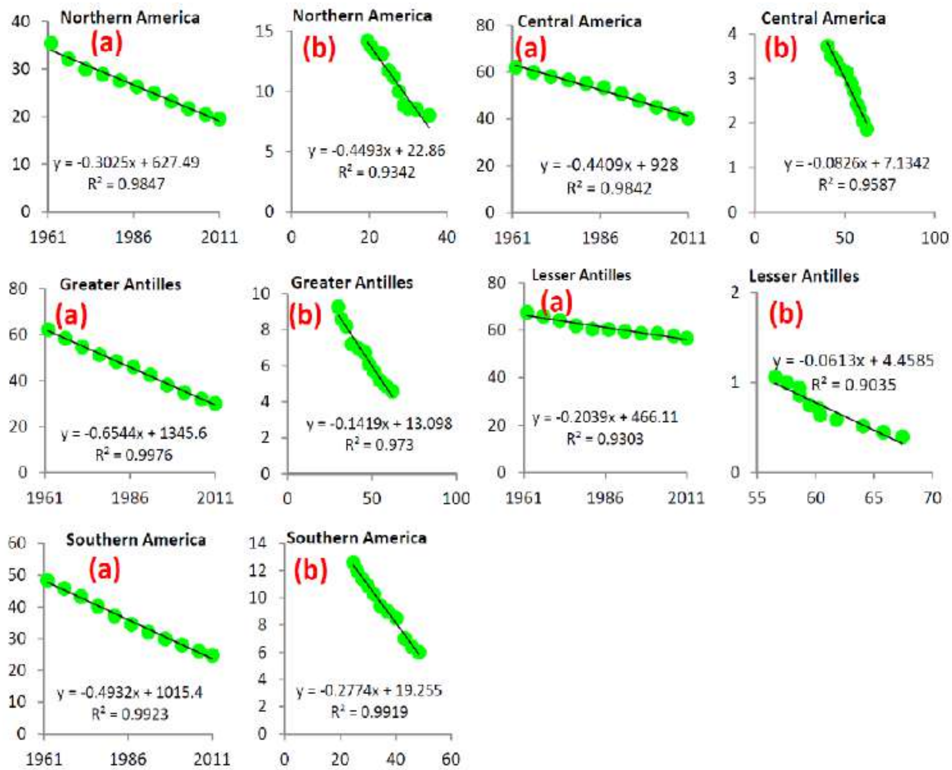

Fig.2. **Variations of rural population per total population versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is rural population per total population (%) and (b) horizontal axis is rural population per total population (%) and vertical axis is area equipped for irrigation (%), 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 Americas. Thus, role of this index is decreasing for area equipped for irrigation (Fig. 2b). Previous researches show advantages of rural development on agricultural WM and sustainable agriculture (13). Fig. 3 shows variations of total economically active population in agriculture per total economically active population versus time and area equipped for irrigation.

According to Fig. 3a value of economically active population in agriculture has been decreased in Americas. Thus, role of this index is decreasing for area equipped for irrigation (Fig. 3b). Effect of proper labour force on water management and improvement of sustainable agriculture has been studied by many researchers (33). Fig. 4 shows variations of human development index (HDI) versus time and area equipped for irrigation.

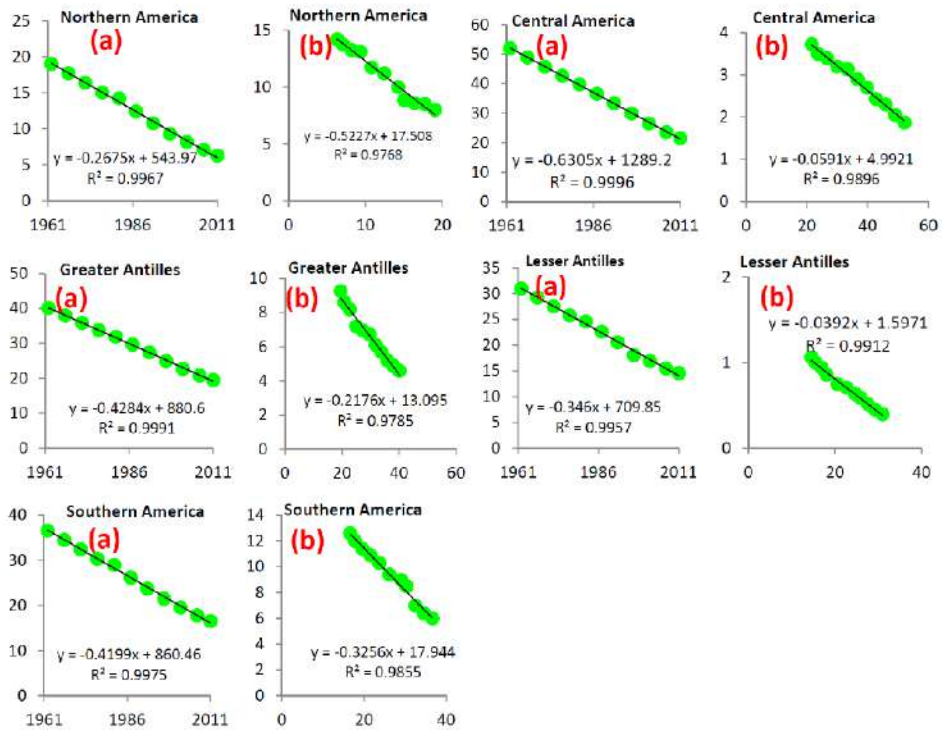

Fig. 3. Variations of total economically active population in agriculture per total economically active population versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is total economically active population in agriculture per total economically active population (%) and (b) horizontal axis is total economically active population in agriculture per total economically active population (%) and vertical axis is area equipped for irrigation (%), value of *x* in (b) is equal to value of *y* in (a).

As expected, value of HDI has been increased in Americas (Fig. 4a). Thus, role of this index is increasing for area equipped for irrigation (Fig. 4b). However, slope of reduction of rural population per total population and total economically active population in agriculture per total economically active population (Figs. 2 & 3) is more than increasing slope of HDI in Americas. It

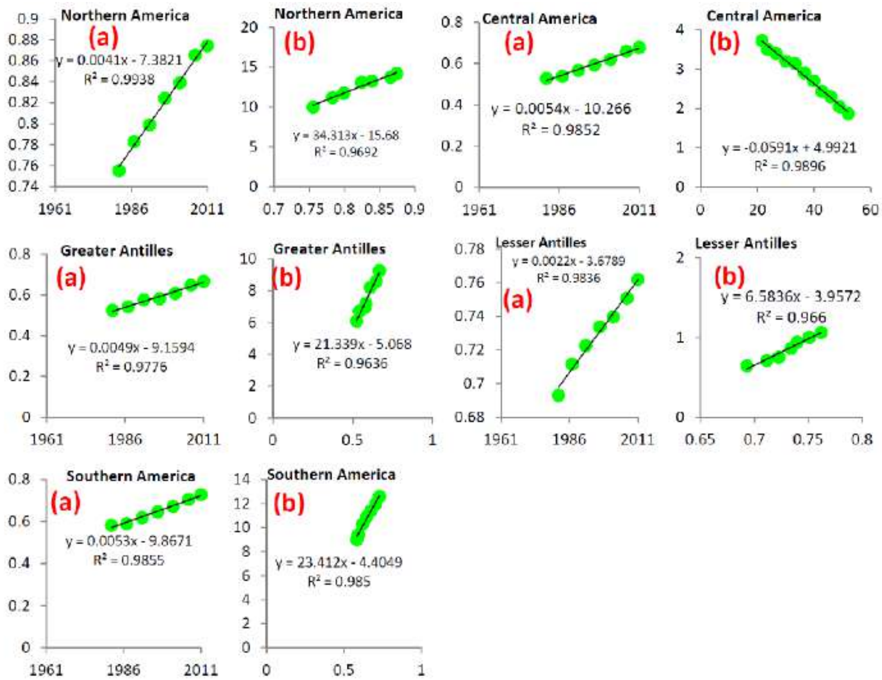

Fig. 4. Variations of HDI versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is HDI and (b) horizontal axis is HDI and vertical axis is area equipped for irrigation (%), value of *x* in (b) is equal to value of *y* in (a), value of this index is not available before 1982.

is a big warning (19) as mechanization and use of new technologies have an important role in enhancement of agricultural knowledge and increasing productivity (22), labor force has a vital and irreplaceable role in agricultural scheduling and macroeconomic perspectives (24). The HDI index as a weighted measure of the Falkenmark indicator in order to account for the ability to adapt to water stress is termed the Social Water Stress Index (14). Fig. 5 shows variations of value added to GDP by agriculture versus time and area equipped for irrigation.

According to Fig. 5a, value of this index has been decreased in all the regions. Thus, role of permanent crops per cultivated area is decreasing for Americas (Fig. 5b). In addition, a significant fall is observable in the beginning of 1980s Neumann *et al.* (34) mentioned effect of GDF on irrigation. Fig. 6 shows variations of NRI versus time and area equipped for irrigation.

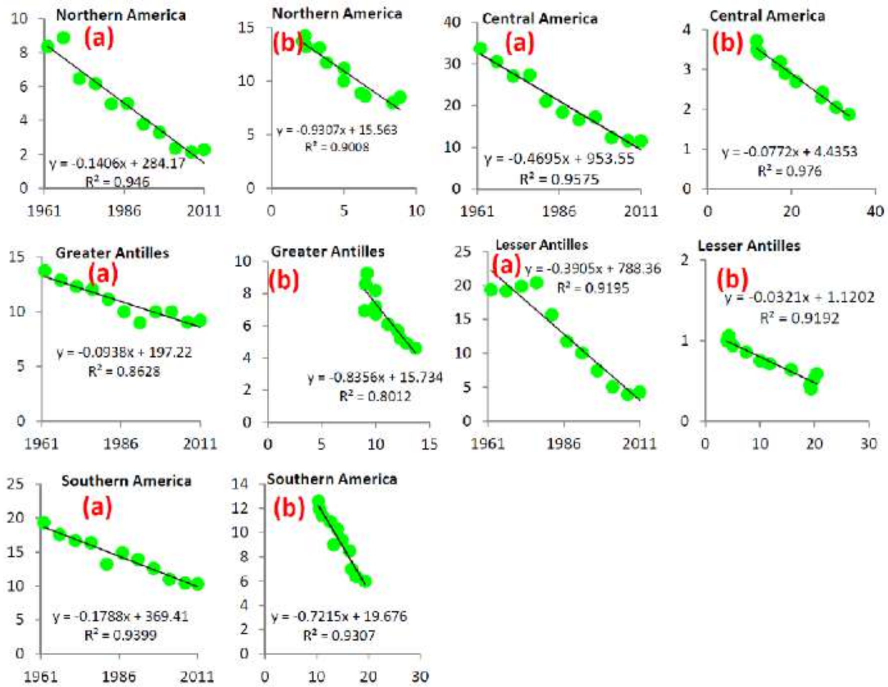

Fig. 5. Variations of value added to GDP by agriculture versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is value added to GDP by agriculture (%) and (b) horizontal axis is value added to GDP by agriculture (%) and vertical axis is area equipped for irrigation (%), value of *x* in (b) is equal to value of *y* in (a).

According to Fig. 6a, the value of NRI is variable during the past half of century due to many different factors such as green house gases (25), global warming (27), climate change (31) etc. And linear regression is not suitable for evaluation of trend. Thus, there is no significant trend between variations of NRI and area equipped for irrigation (Fig. 6b). Due to the mentioned cases, role of this index has not been considered in estimation of area equipped for irrigation in 2035 and 2060. After Gommes and Petrassi (17) this index was known as a considerable factor in drought studies (28). Fig. 7 shows variations of irrigation water requirement versus time and area equipped for irrigation.

According to Fig. 7a, value of irrigation water requirement has been increased in Americas. Thus, role of this index is increasing for area equipped for irrigation (Fig. 7b). Variation of this index can be affected on river basin management (39), water allocation policy (21) and agricultural expansion (26). Fig. 8 shows variations of difference between NRI and irrigation water requirement versus time and area equipped for irrigation.

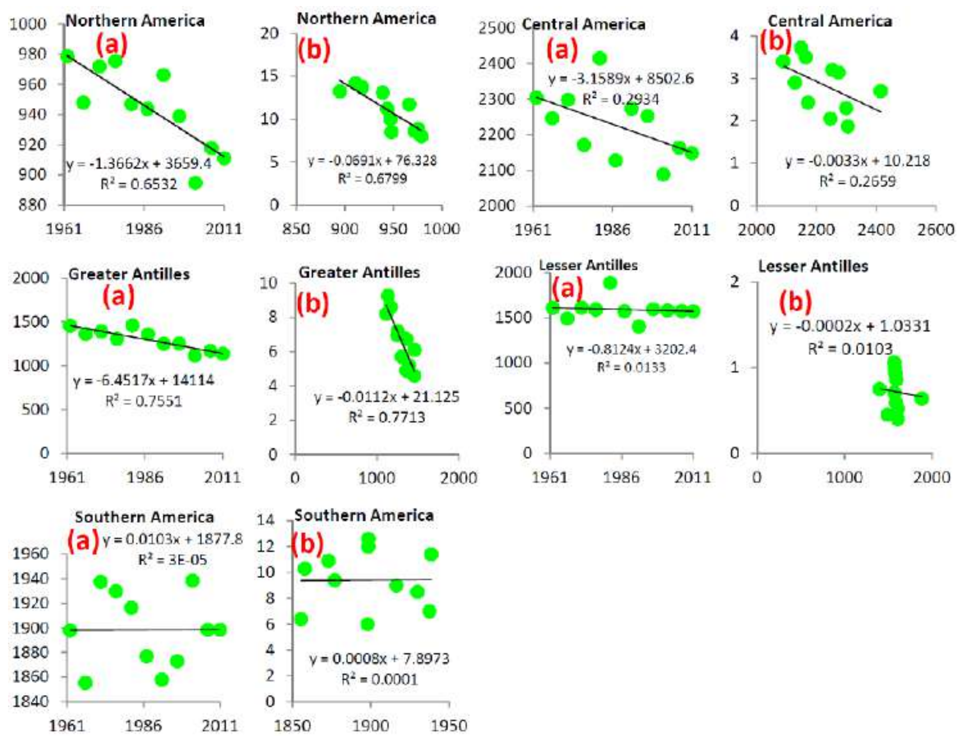

Fig. 6. Variations of NRI versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is NRI (mm/year) and (b) horizontal axis is NRI (mm/year) and vertical axis is area equipped for irrigation (%), value of *x* in (b) is equal to value of *y* in (a).

According to Fig. 8a, value of this index has been decreased in Americas. Thus, role of difference between NRI and irrigation water for decreasing for area equipped for irrigation (Fig. 8b). The index is known as water deficit and the regions with negative values of that have a critical status for water resources management (19, 36). Fig. 9 shows variations of percentage of total cultivated area drained versus time and area equipped for irrigation.

In Fig. 9a, value of this index has been increased in Americas. Thus, role of this index is increasing for area equipped for irrigation (Fig. 9b). Previous studies notify influence of drainage on sub-irrigation (42), crop productivity (1), improving water management (8), and water balance (2). Fig. 10 is useable to summarize obtained results from Figs. 1-9b.

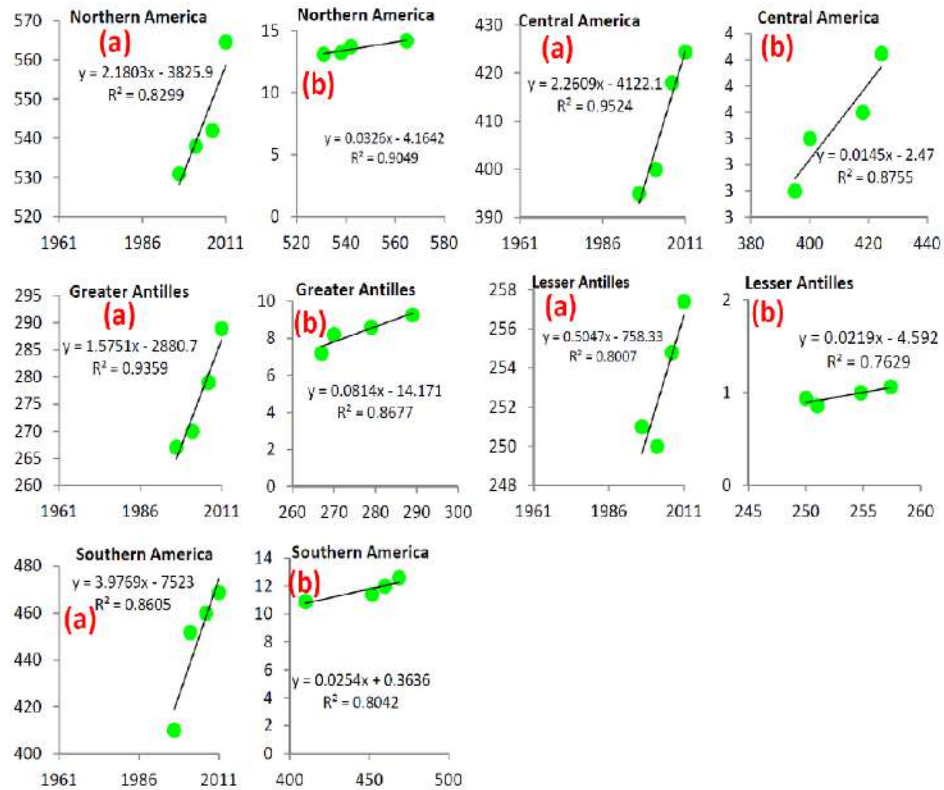

Fig. 7. Variations of irrigation water requirement versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is irrigation water requirement (mm/year) and (b) horizontal axis is irrigation water requirement (mm/year) and vertical axis is area equipped for irrigation (%), value of *x* in (b) is equal to value of *y* in (a), value of this index is not available before 1997.

In Northern America, Central America, Greater Antilles, and Lesser Antilles the most trends are related to labour force, in Southern America the most trends are related to rural development. According to Fig. 10, the observed trends are changed from 10.5 (Northern America) to 12.4% (Central America) for permanent crops per cultivated area. These changes are from 12.5 (Lesser Antilles) to 13.6% (Southern America) for rural population per total population, trends range from 13.0 (Central America) to 14.1% (Northern America) for total economically active population in agriculture per total economically active population, these are from 13.0 (Central Americas) to 14.0% (Northern America) for HDI (minimum of changes), these ranged from 11.0 (Greater Antilles) to 13.0% (Northern America) for value added to GDP by agriculture, they are from 10.5 (Lesser Antilles) to 13.0% (Northern

America) for irrigation water requirement and from 9.7 (Northern America) to 13.6% (Lesser Antilles) for difference between NRI and irrigation water requirement (maximum of changes) and from 12.3 (Northern America) to 13.4% (Greater Antilles and Southern America) for percentage of total cultivated area drained. The similar percentage of trends shows that all selected indexes are important and their selection is reasonable for study of agricultural WM and estimation of area equipped for irrigation in the future.

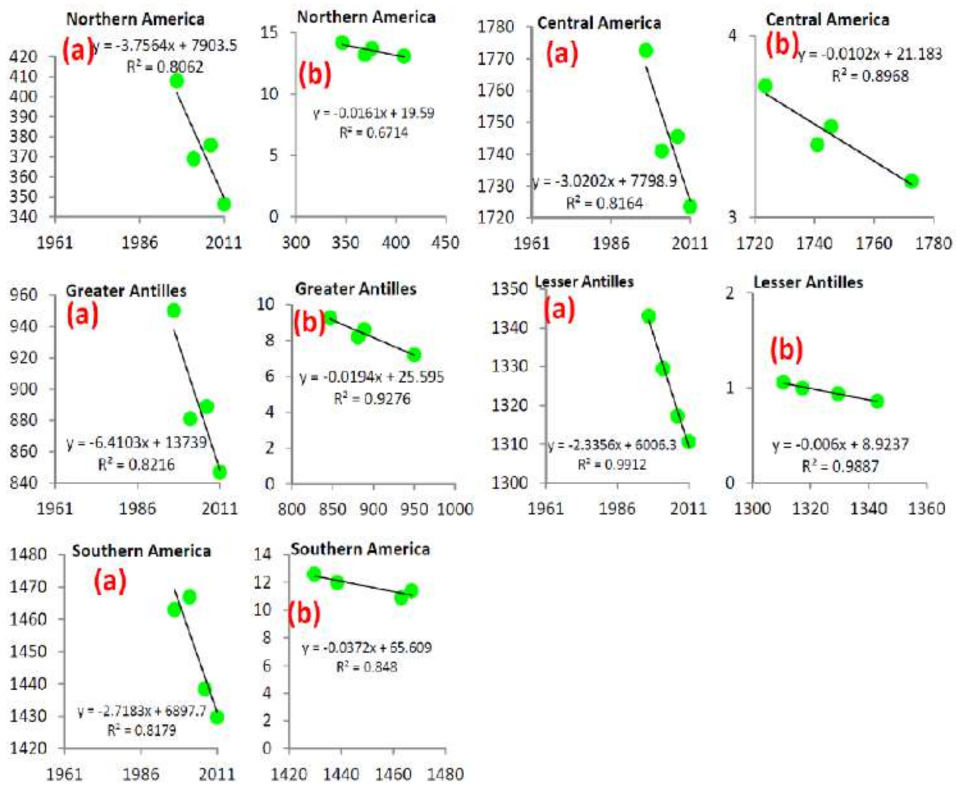

Fig. 8. Variations of difference between NIR and irrigation water requirement versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is difference between NIR and irrigation water requirement (mm/year) and (b) horizontal axis is difference between NIR and irrigation water requirement (mm/year) and vertical axis is area equipped for irrigation (%), value of *x* in (b) is equal to value of *y* in (a), value of this index is not available before 1997.

4. Estimation of area equipped for irrigation per cultivated area using the other main indexes of agricultural water management

Table 1 shows estimated values for the main indexes using the equations related to Figs. 1-9a.

Table No. 1. Estimated values for the main indexes using the equations related to Figs. 1-9a.

Region	PC (%)						RP (%)					
	Scenario (I)		Scenario (II)		Scenario (III)		Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060	2035	2060	2035	2060	2035	2060
Northern America	6.4	5.8	6.6	6.2	6.7	6.4	11.9	4.3	14.1	8.8	15.5	11.8
Central America	36.7	41.9	35.2	38.9	34.2	36.8	30.8	19.7	33.9	26.2	36.1	30.5
Greater Antilles	31.8	33.2	31.4	32.4	31.2	31.9	13.9	0.0	18.6	7.2	21.7	13.6
Lesser Antilles	43.1	43.7	42.9	43.4	42.8	43.1	51.2	46.1	52.6	49.1	53.6	51.1
Southern America	18.8	21.1	18.2	19.8	17.7	18.9	11.7	0.0	15.3	6.7	17.7	11.5
	LF (%)						HDI					
Northern America	0.0	0.0	1.5	0.0	2.8	0.0	0.961	1.000	0.932	1.000	0.912	0.963
Central America	6.1	0.0	10.7	0.0	13.7	5.8	0.723	0.858	0.684	0.779	0.658	0.726
Greater Antilles	8.8	0.0	11.9	4.4	13.9	8.6	0.812	0.935	0.777	0.863	0.753	0.815
Lesser Antilles	5.7	0.0	8.2	2.2	9.9	5.6	0.798	0.853	0.782	0.821	0.772	0.799
Southern America	6.0	0.0	9.0	1.6	11.0	5.8	0.918	1.000	0.880	0.973	0.855	0.921
	GDP (%)						IWR (mm/yr)					
Northern America	0.0	0.0	0.0	0.0	0.0	0.0	611.0	665.5	595.3	633.5	584.8	612.1
Central America	0.0	0.0	1.5	0.0	3.8	0.0	478.8	535.4	462.6	502.1	451.7	480.0
Greater Antilles	6.3	4.0	7.0	5.4	7.5	6.3	324.6	364.0	313.3	340.9	305.7	325.4
Lesser Antilles	0.0	0.0	0.0	0.0	0.0	0.0	268.7	281.4	265.1	273.9	262.7	269.0
Southern America	5.6	1.1	6.8	3.7	7.7	5.5	570.0	669.4	541.4	611.0	522.3	572.0
	NRI-IWR						D (%)					
Northern America	259.2	165.3	286.3	220.5	304.3	257.3	20.4	23.7	19.5	21.8	18.9	20.5
Central America	1652.8	1577.3	1674.5	1621.7	1689.0	1651.3	2.4	3.2	2.2	2.7	2.1	2.5
Greater Antilles	694.0	533.8	740.2	628.0	771.0	690.8	2.7	3.4	2.5	3.0	2.3	2.7
Lesser Antilles	1253.4	1195.0	1270.2	1229.3	1281.4	1252.2	0.3	0.3	0.2	0.3	0.2	0.3
Southern America	1366.0	1298.0	1385.5	1338.0	1398.6	1364.6	2.8	3.5	2.6	3.1	2.4	2.8

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

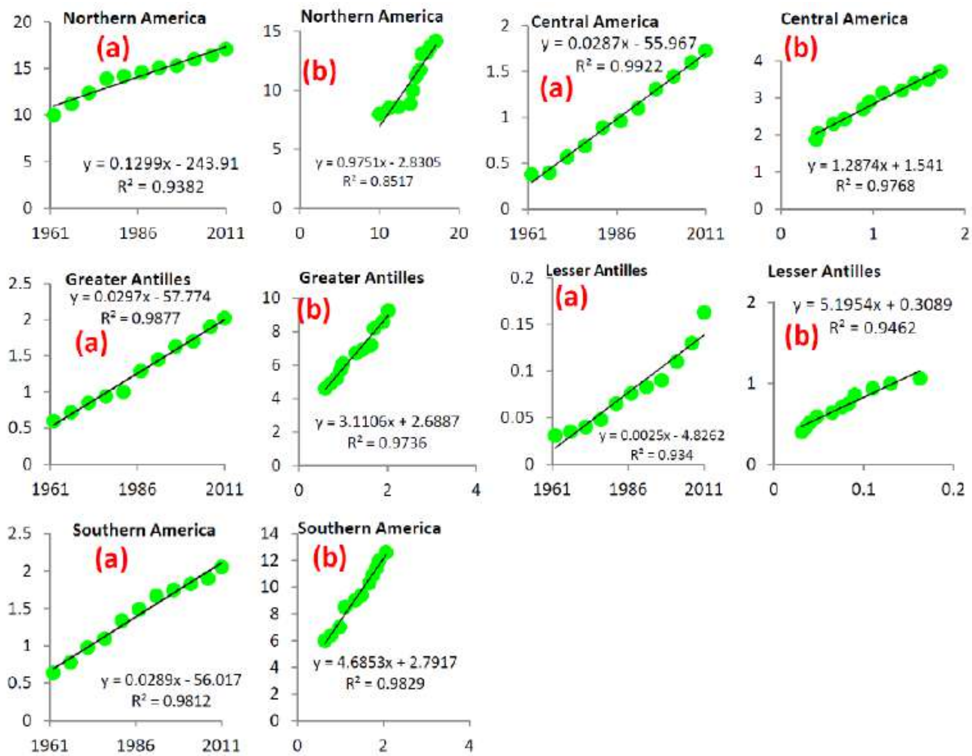

Fig.9 Variations of percent of total cultivated area drained versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is percent of total cultivated area drained (%) and (b) horizontal axis is percent of total cultivated area drained (%) and vertical axis is area equipped for irrigation (%), value of *x* in (b) is equal to value of *y* in (a).

Permanent crops per cultivated area: The minimum value is 5.8% (in the first scenario by 2060) for Northern America and the maximum value is 43.7% (in the first scenario by 2060) for Lesser Antilles. A significant decrease is considerable for Northern America in the future.

Rural population per total population: The minimum value is 0.0 (in the first scenario by 2060) for Greater Antilles and Southern America and the maximum value is 53.6% (in the third scenario by 2035) for Lesser Antilles.

Total economically active population in agriculture per total economically active population: The maximum value is 13.9% (in the third scenario by 2035) for Greater Antilles. If current decreasing trend is continued, we will meet Northern America without labour force in future. HDI.

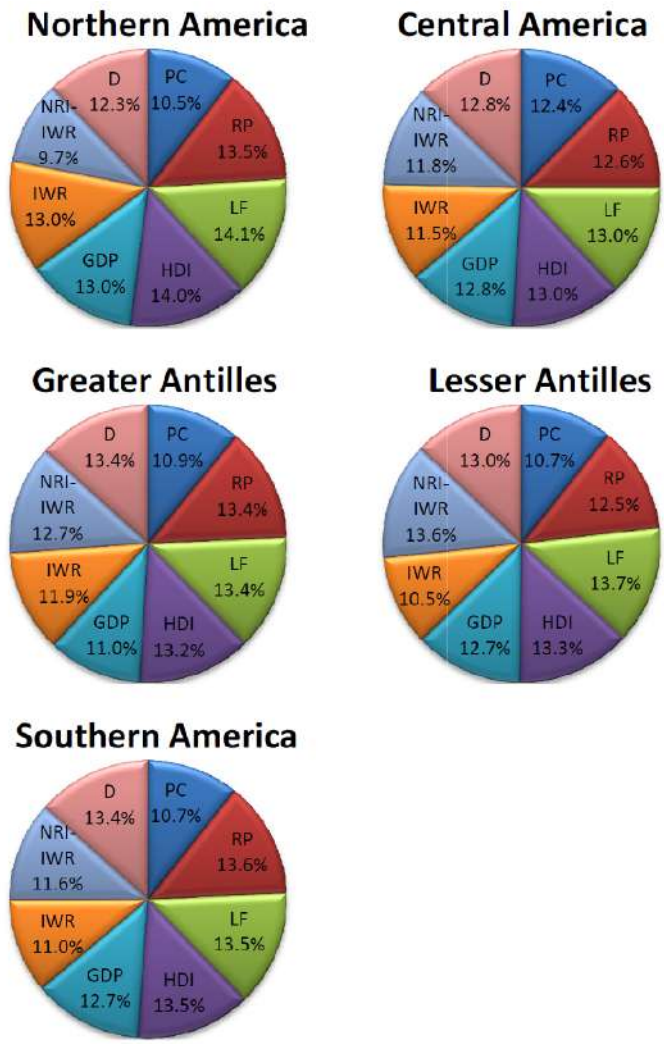

Fig. 10. Percent of observed trend between changes of the main indexes and area equipped for irrigation in the different regions of Americas (this is equivalent to role of each index to estimate area equipped for irrigation based on R^2 values in Figs. 1-9b), role of NRI has not been considered due to 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.

The minimum value in the future is related to Central America (0.658 in the third scenario by 2035), so rate of its increasing slope is less than other regions.

Value added to GDP by agriculture: The maximum value is 7.7% (in the third scenario by 2035) for Southern America. If current decreasing trend is continued we will meet Northern America, Central America, and Lesser Antilles without value added to GDP by agriculture.

Irrigation water requirement: The minimum value is 262.7 mm/year (in the third scenario by 2035) for Lesser Antilles and the maximum value is 669.4 mm/year (in the first scenario by 2060) for Southern America.

Difference between NRI and irrigation water requirement: The minimum value is 165.3 mm/year (in the first scenario by 2060) for Northern America and the maximum value is 1689.0 mm/year (in the third scenario by 2035) for Central America.

Percentage of total cultivated area drained: The minimum value is 0.2% (in the second and third scenarios by 2035) for Lesser Antilles and the maximum value is 23.7% (in the first scenario by 2060) for Northern America. Table 2 shows estimated values for area equipped for irrigation using the Equations related to the Figs. 1-9b.

Data of Table 2 have computed using the equations related to Figs. 1-9b and are equal to *y* value in Eq. 7. Table 3 shows estimated values for area equipped for irrigation using Eq. 7.

According to Table 3, in first scenario, the most changes are related to Lesser Antilles (26.3% by 2035 and 51.3% by 2060), in second scenario, the most changes are related to Lesser Antilles (18.6% by 2035 and 37.2% by 2060) and in third scenario, the most changes related to Central America (13.8% by 2035) and Lesser Antilles (26.8% by 2060). Therefore, Lesser Antilles have a better potential to increasing area equipped for irrigation in the future, however value of increase is very low as compared to other regions and it needs macroeconomic policies by governments to persuasion of farmers for using irrigation systems in the future. A considerable change of irrigation status in the future is noted in comparison with the current status; although area equipped for irrigation in Northern America is more than Southern America in 2011 but these are equal in first scenario by 2060. Although we can estimate area equipped for irrigation after 2060, but it is advised that we should update our information every year, every decade, or at least every half of century.

Table No. 2. Estimated values for area equipped for irrigation using the equations related to Figs. 1-9b.

Region	PC						RP					
	Scenario (I)		Scenario (II)		Scenario (III)		Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060	2035	2060	2035	2060	2035	2060
Northern America	16.7	19.4	15.9	17.8	15.4	16.7	17.5	20.9	16.5	18.9	15.9	17.6
Central America	4.6	5.5	4.3	4.9	4.1	4.6	4.6	5.5	4.3	5.0	4.2	4.6
Greater Antilles	10.2	12.2	9.7	11.0	9.3	10.3	11.1	13.1	10.5	12.1	10.0	11.2
Lesser Antilles	1.2	1.5	1.1	1.3	1.1	1.2	1.3	1.6	1.2	1.5	1.2	1.3
Southern America	14.8	17.6	14.0	16.0	13.5	14.9	16.0	19.3	15.0	17.4	14.4	16.1
	LF						HDI					
Northern America	17.5	17.5	16.7	17.5	16.0	17.5	17.3	18.6	16.3	18.6	15.6	17.4
Central America	4.6	5.0	4.4	5.0	4.2	4.6	4.9	4.9	5.0	4.9	5.0	4.9
Greater Antilles	11.2	13.1	10.5	12.1	10.1	11.2	12.3	14.9	11.5	13.3	11.0	12.3
Lesser Antilles	1.4	1.6	1.3	1.5	1.2	1.4	1.3	1.7	1.2	1.4	1.1	1.3
Southern America	16.0	17.9	15.0	17.4	14.4	16.1	17.1	19.0	16.2	18.4	15.6	17.2
	GDP						IWR (mm/yr)					
Northern America	15.6	15.6	15.6	15.6	15.6	15.6	15.8	17.5	15.2	16.5	14.9	15.8
Central America	4.4	4.4	4.3	4.4	4.1	4.4	4.5	5.3	4.2	4.8	4.1	4.5
Greater Antilles	10.4	12.4	9.9	11.2	9.5	10.5	12.3	15.5	11.3	13.6	10.7	12.3
Lesser Antilles	1.1	1.1	1.1	1.1	1.1	1.1	1.3	1.6	1.2	1.4	1.2	1.3
Southern America	15.7	18.9	14.7	17.0	14.1	15.7	14.8	17.4	14.1	15.9	13.6	14.9
	NRI-IWR						D					
Northern America	15.4	16.9	15.0	16.0	14.7	15.4	17.1	20.3	16.2	18.4	15.6	17.2
Central America	4.3	5.1	4.1	4.6	4.0	4.3	4.7	5.6	4.4	5.1	4.2	4.7
Greater Antilles	12.1	15.2	11.2	13.4	10.6	12.2	11.0	13.3	10.3	11.9	9.9	11.0
Lesser Antilles	1.4	1.8	1.3	1.5	1.2	1.4	1.7	2.0	1.6	1.8	1.5	1.7
Southern America	14.8	17.3	14.1	15.8	13.6	14.8	15.9	19.3	14.9	17.3	14.3	16.0

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

Table No. 3. Estimated values for area equipped for irrigation using Eq. No. 7.

Region		Area equipped for irrigation (%)					
		Scenario (I)		Scenario (II)		Scenario (III)	
	2011	2035	2060	2035	2060	2035	2060
Northern America	14.2	16.7	18.4	16.0	17.5	15.5	16.7
Central America	3.7	4.6	5.2	4.4	4.9	4.2	4.6
Greater Antilles	9.3	11.4	13.7	10.6	12.4	10.2	11.4
Lesser Antilles	1.1	1.3	1.6	1.3	1.5	1.2	1.3
Southern America	12.6	15.7	18.4	14.8	17.0	14.2	15.8
		Scenario (I)		Scenario (II)		Scenario (III)	
	2011	2035	2060	2035	2060	2035	2060
Northern America	14.2	17.3	29.3	12.5	23.0	9.1	17.6
Central America	3.7	23.1	38.6	17.7	30.2	13.8	23.5
Greater Antilles	9.3	22.5	48.2	14.8	33.6	9.7	23.1
Lesser Antilles	1.1	26.3	51.3	18.6	37.2	13.6	26.8
Southern America	12.6	24.6	46.0	17.5	34.6	12.9	25.1

CONCLUSION

In this paper, area equipped for irrigation has been estimated in Americas using three different scenarios by 2035 and 2060. Number of 10 indexes (as the main indexes) were selected to assess agricultural water management based on their importance. The other indexes were not studied due to lack of adequate data. The changes of main indexes in the past half of century reveal that they had similar values in some regions and had very different values in other regions due to nature of indexes and conditions of the regions. In first step, the author studied variations of main indexes during the past half of century using linear regression and coefficient of variation R^2, then amount of each index was estimated for 2035 and 2060 from obtained equations for three different scenarios. The results showed that trend of permanent crops per cultivated area (with the exception of Northern America), HDI, irrigation water requirement, percentage of total cultivated area drained is increasing and trend 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 is decreasing. The maximum values for area equipped for irrigation are related to Northern America (16.7% by 2035 and 18.4% by 2060) and Southern America (18.4% by 2060).

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