ISSN 1808-3765

VARIATIONS OF LAND USE AND IRRIGATION FOR NEXT DECADES UNDER DIFFERENT SCENARIOS

MOHAMMAD VALIPOUR[1]

[1]Young Researchers and Elite Club, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran. Email: vali-pour@hotmail.com

1 ABSTRACT

The goal of this paper is 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 Food and Agriculture Organization of the United Nations (FAO) and was checked using The World Bank Group (WBG). Among all presented data in the FAO database, 10 indexes were selected (due to more importance and more availability for all the regions in Americas). 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/yr), value added to gross domestic product (GDP) by agriculture (%), irrigation water requirement (mm/yr), percent of total cultivated area drained (%), difference between NIR and irrigation water requirement (mm/yr), and area equipped for irrigation per cultivated area (%). These indexes were analyzed for all 5 regions in the study area and amount of area equipped for irrigation per cultivated area (10th index) was estimated by three different scenarios and using the other 9 indexes.

Keywords: agricultural water management, Americas, FAO, irrigation, macroeconomic policies, optimum decision, sustainable development

VALIPOUR, M.
VARIAÇÕES DO USO DA TERRA E IRRIGAÇÃO PARA AS PRÓXIMAS DÉCADAS EM DIFERENTES CENÁRIOS

2 RESUMO

O objetivo do presente trabalho é estimar a área equipada para irrigação nas Américas nos anos de 2035 e 2060 através do estudo da gestão da água agrícola no período de 1962 a 2011. Para isso, todas as informações necessárias foram obtidas da Organização das Nações Unidas para Agricultura e Alimentação (FAO) e foram verificado através do Grupo Banco Mundial (WBG). Entre todos os dados apresentados na base de dados da FAO, foram selecionados 10 índices (devido à maior importância e maior disponibilidade para todas as regiões das Américas). Estes índices correspondem a culturas permanentes por área cultivada (%), população rural com relação à população total (%), população economicamente ativa na agricultura com relação à população economicamente ativa total (%), índice de desenvolvimento humano (IDH), índice nacional de pluviosidade (NRI) (mm/ano), valor agregado ao Produto Interno Bruto (PIB) pela agricultura (%), necessidade de água de irrigação (mm/ano), porcentagem da área cultivada drenada total (%) diferença entre NRI e

Recebido em 16/04/2015 e aprovado para publicação em 15/08/2016

necessidade de água de irrigação e área equipada para irrigação por área cultivada (%). Estes índices foram analisados para todas as 5 regiões da área de estudo e a quantidade de área equipada para irrigação por área cultivada (10º índice) foi estimada através de três cenários diferentes, utilizando os outros 9 índices. Os resultados mostram que as mudanças da área equipada para irrigação são de 9,1% a 26,3% e de 17,6% a 51,3% em 2035 e 2060, respectivamente.

Palavras-chave: gestão agrícola da água, Américas, FAO, irrigação, políticas macroeconômicas, decisão ideal, desenvolvimento sustentável

3 INTRODUCTION

Considering limitation of renewable water resources, role of macroeconomic policies in land use change and irrigation is vital and undeniable. The 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 and Central America and the Caribbean, respectively (FAO, 2012).

Therefore, studying agricultural water management is still reasonable for Americas. The different aspects of irrigation in agricultural water management such as irrigation efficiency (VALIPOUR, 2013a,b,c,d; VALIPOUR; MONTAZAR 2012), soil salinity (DU PLESSIS, 1985), water-saving (RAHIME et al., 2015; REZAEI; VALIPOUR; VALIPOUR, 2016; MONTENEGRO; MONTENEGRO; RAGAB, 2010), sustainable development (SCHULTZ; DE WRACHIEN, 2002; VALIPOUR, 2012a,b,c,d), soil water management (STEINER; KELLER, 1992; YANNOPOULOS et al., 2015; VALIPOUR and SINGH, 2016; VALIPOUR; BANIHABIB; BEHBAHANI, 2013), evapotranspiration (VALIPOUR and ESLAMIAN, 2014; VALIPOUR; GHOLAMI SEFIDKOUHI; RAEINI-SARJAZ, 2017; VALIPOUR; GHOLAMI SEFIDKOUHI; KHOSHRAVESH, 2017; VALIPOUR; GHOLAMI SEFIDKOUHI; 2017; VALIPOUR, 2013a,b,c,d,e,f,g,h,i,j), and crop yield (WU; BARRAGAN; BRALTS, 2013) have been investigated in previous works. Also, FAO (2011a, 2011b) showed that pressure to water resources due to irrigation would be increased to 2050. TURRAL, SVENDSEN and FAURES (2010) showed that investment is one of the most factors on area equipped for irrigation per 2050. NEUMANN et al. (2011) cited that area equipped for irrigation per be expanded by 40 million ha, by 2030.

PLUSQUELLEC (2002) claimed that area equipped for irrigation would be increased by 15% to 22% for 2025. SCHALDACH et al. (2002) underlined the importance of considering both the change of equipped area and agricultural management as well as hydrology aspects in regional water use analysis. KNOX, KAY and WEATHERHEAD (2012) claimed demonstrating efficient or ‘best’ use of water is not straightforward 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. NAMARA et al. (2010) mentioned role of agricultural water management to reduce poverty in the world as three pathways.

Those are 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. They preferred improving the management of existing systems as selected strategy in Asia. VALIPOUR (2014a,b,c; 2016a,b) 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 showed that 46% of cultivated areas in the world are not suitable for rainfed agriculture because of climate changes and other meteorological conditions.

FRANKS, GARCES-RESTREPO and PUTUHENA (2008) studied developing capacity for agricultural water management in current practice and future directions. They suggested increased attention to monitoring and evaluation of capacity development, and closer links to emerging work on water governance. Ferreyra, DE LOE and KREUTZWISER (2008) 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. DE LOE, KREUTZWISER and IVEY (2001) studied agricultural water use in Ontario. 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, HANJRA and MU (2009) reviewed water management and crop production for food security. 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 are about a limited area and cannot apply them for other regions or did not consider role of all important indexes for estimation of agricultural water management. Thus, the goal of this study is estimation of area equipped for irrigation using to establish a link for more important parameters in agricultural water management based on available data for Americas.

4 METHODOLOGY

Irrigation controls global yield variability heavily (MUELLER et al., 2012). 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 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 (FAO, 2013), 10 main indexes were selected to assessment of agricultural water management in Americas and values of them were checked using WBG database (WBG, 2013). Then, values of area equipped for irrigation were estimated in 2035 and 2060 using three different scenarios.

4.1 Main indexes

4.1.1 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 pastures. This index is determined as

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

4.1.2 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

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

4.1.3 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

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

4.1.4 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.

4.1.5 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.

4.1.6 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. But 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.

4.1.7 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.

4.1.8 Difference between NIR and irrigation water requirement (mm/yr)

This index shows water deficit and is determined as

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

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

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

4.1.10 Area equipped for irrigation per cultivated area (%)

Area equipped 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 indexes 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

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

4.2 Estimation of equipped area in 2035 and 2060

To estimate area equipped for irrigation in 2035 and 2060, in the first step, 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 obtained equations and three different scenarios. In the first scenario, the author assumed that values of the main indexes would be changed by the 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 the second and third scenarios, the author assumed that the slopes would be decreased by 30% and 50% respectively. Therefore new values of the indexes (in 2035 and 2060) were computed using these new slopes. In the second step, variations of area equipped for irrigation versus the other main indexes were surveyed and a linear equation with related R^2 was computed for each indexes. 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 the second step. Finally, a relationship has been established among calculated data (for area equipped for irrigation) as:

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

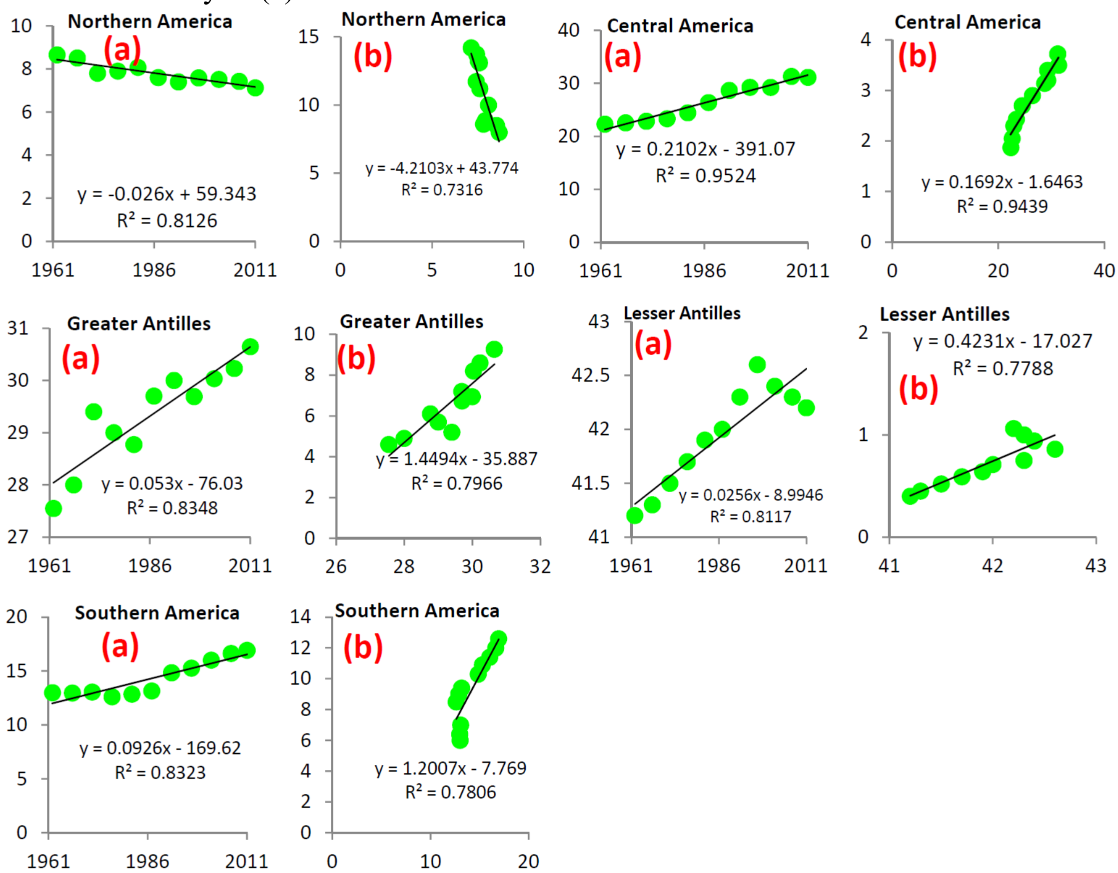
Where, y is obtained value for area equipped for irrigation in the second step (Figs. 1-9b) and values of R^2 have been showed in the Figs 1-9b.

4.3 Evaluation of the main indexes of agricultural water management in the past half of century

According to the 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 helped to better scheduling for allocation of required water, it is dependent to climate conditions (DE SALVO; RAFFAELLI; MOSER, 2013), tendency of farmers (BOLLIGER et al., 2006), and government's policy (SUKHWAL, 1991).

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

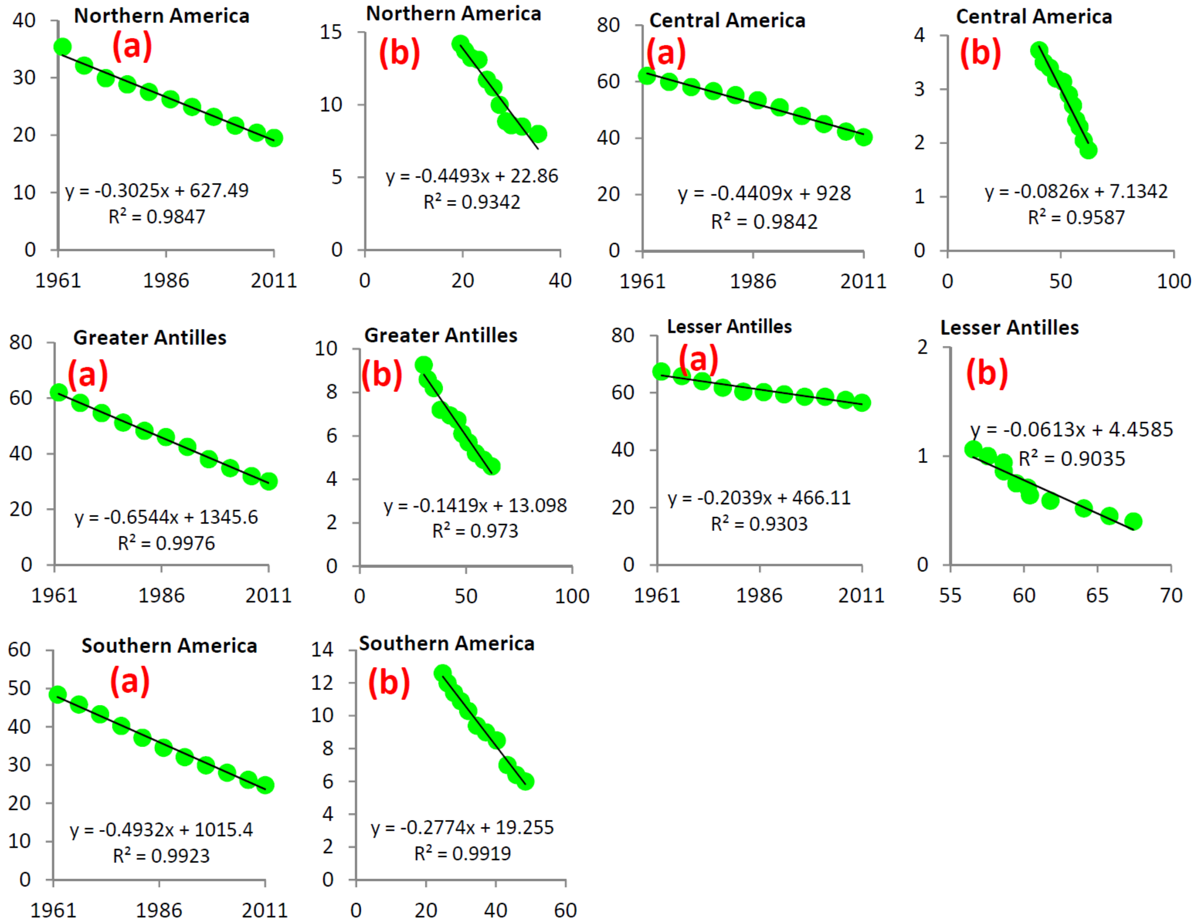
Figure 1. Variations of permanent crops per cultivated area versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is permanent crops per cultivated area (%) and (b) horizontal axis is permanent crops per cultivated area (%) and vertical axis is area equipped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



According to the 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 water management and sustainable agriculture (EVANS; GIORDANO; CLAYTON, 2012).

Figure 2 shows variations of rural population per total population versus time and area equipped for irrigation.

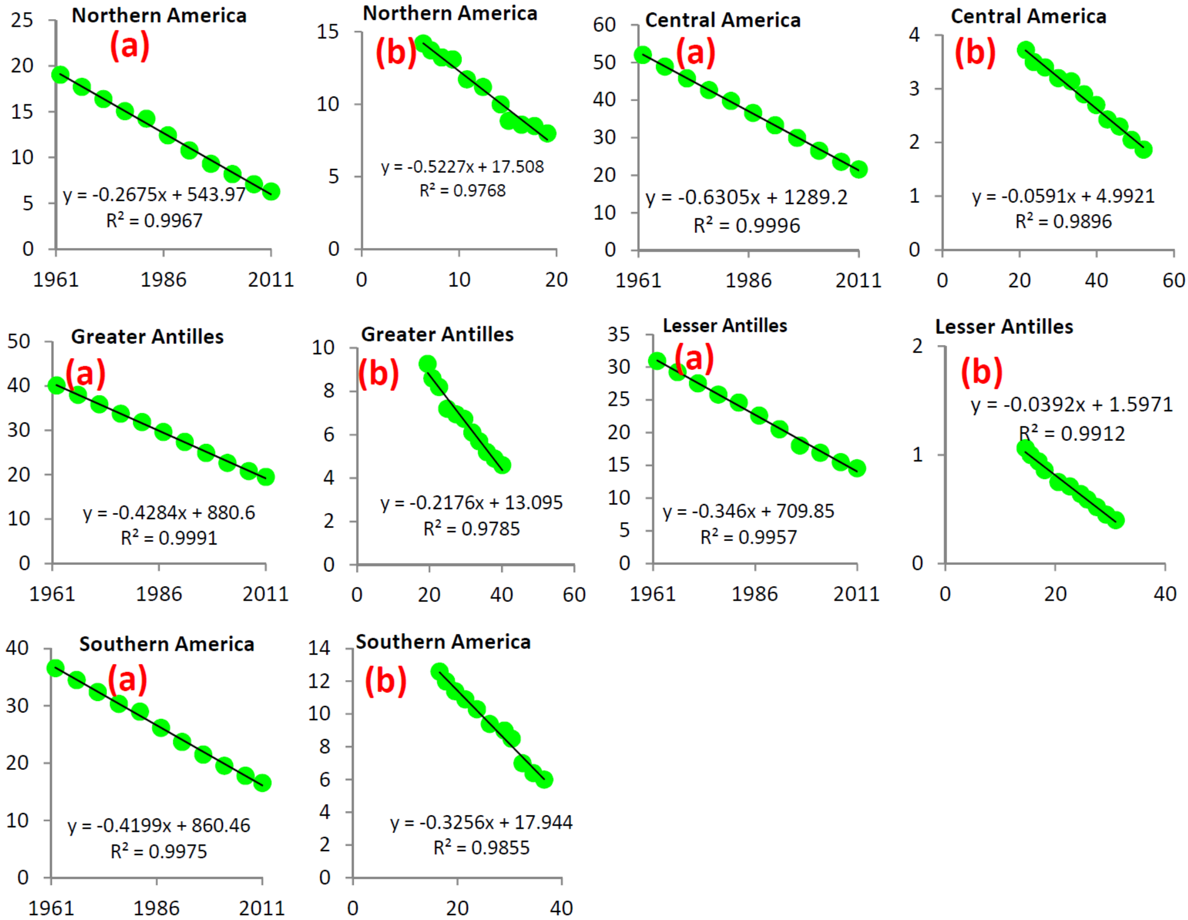
Figure 2. Variations of rural population per total population versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is rural population per total population (%) and (b) horizontal axis is rural population per total population (%) and vertical axis is area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



According to the Fig. 3a value of economically active population in agriculture is 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 in a lot of researches (NAIKEN; SCHULTE, 1976).

Figure 3 shows variations of total economically active population in agriculture per total economically active population versus time and area equipped for irrigation.

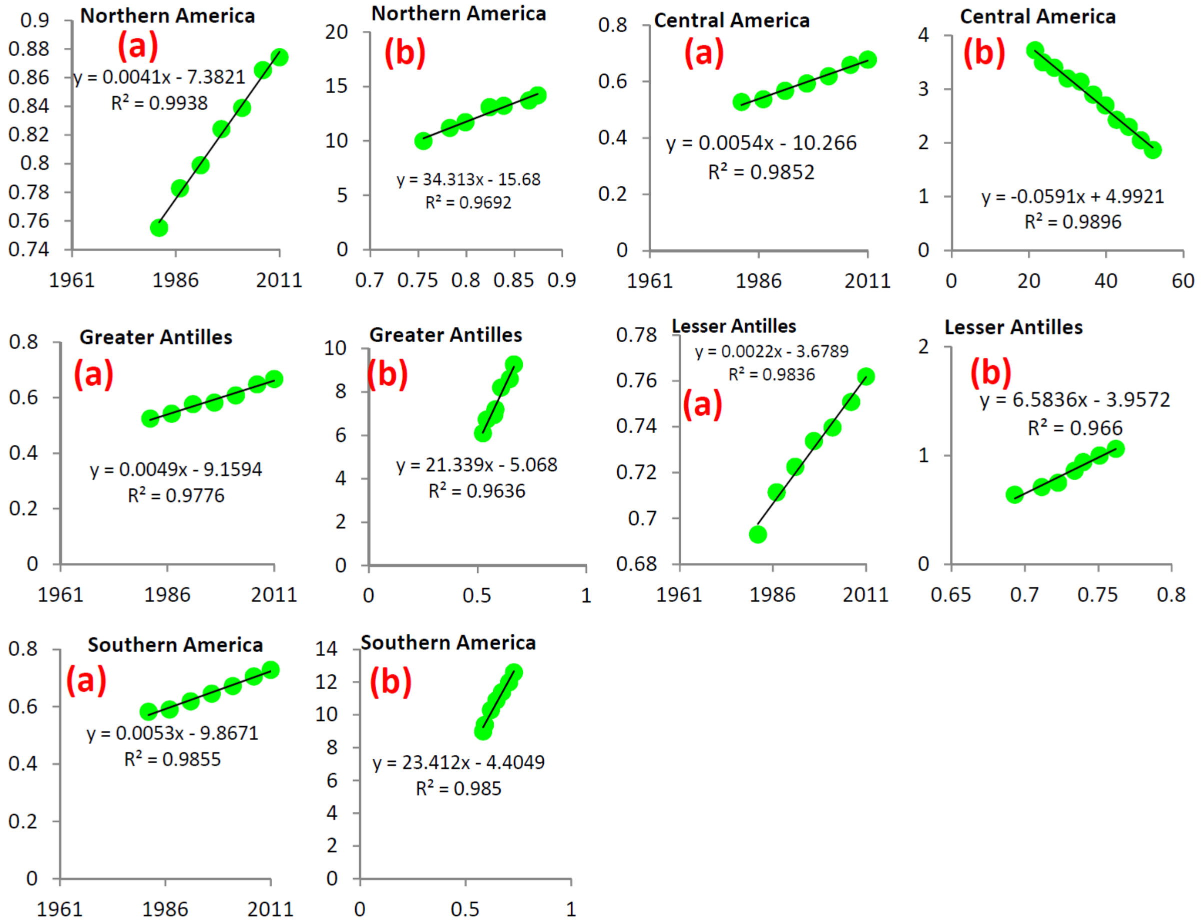
Figure 3. Variations of total economically active population in agriculture per total economically active population versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is total economically active population in agriculture per total economically active 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 and 3) is more than increasing slope of HDI in Americas. It is a big warning (HUSSAIN, 2007) because although mechanization and use of new technologies have an important role in enhancement of agricultural knowledge and increasing productivity (KIRPICH; HAMAN; STYLES, 1999), labor force has a vital and irreplaceable role in agricultural scheduling and macroeconomic perspectives (HENDRICKSON; JAMES Jr.; HEFFERNAN, 2008). The HDI index as a weighted measure of the Falkenmark indicator (FALKENMARK, 1989) in order to account for the ability to adapt to water stress is termed the Social Water Stress Index.

Figure 4 shows variations of human development index (HDI) versus time and area equipped for irrigation.

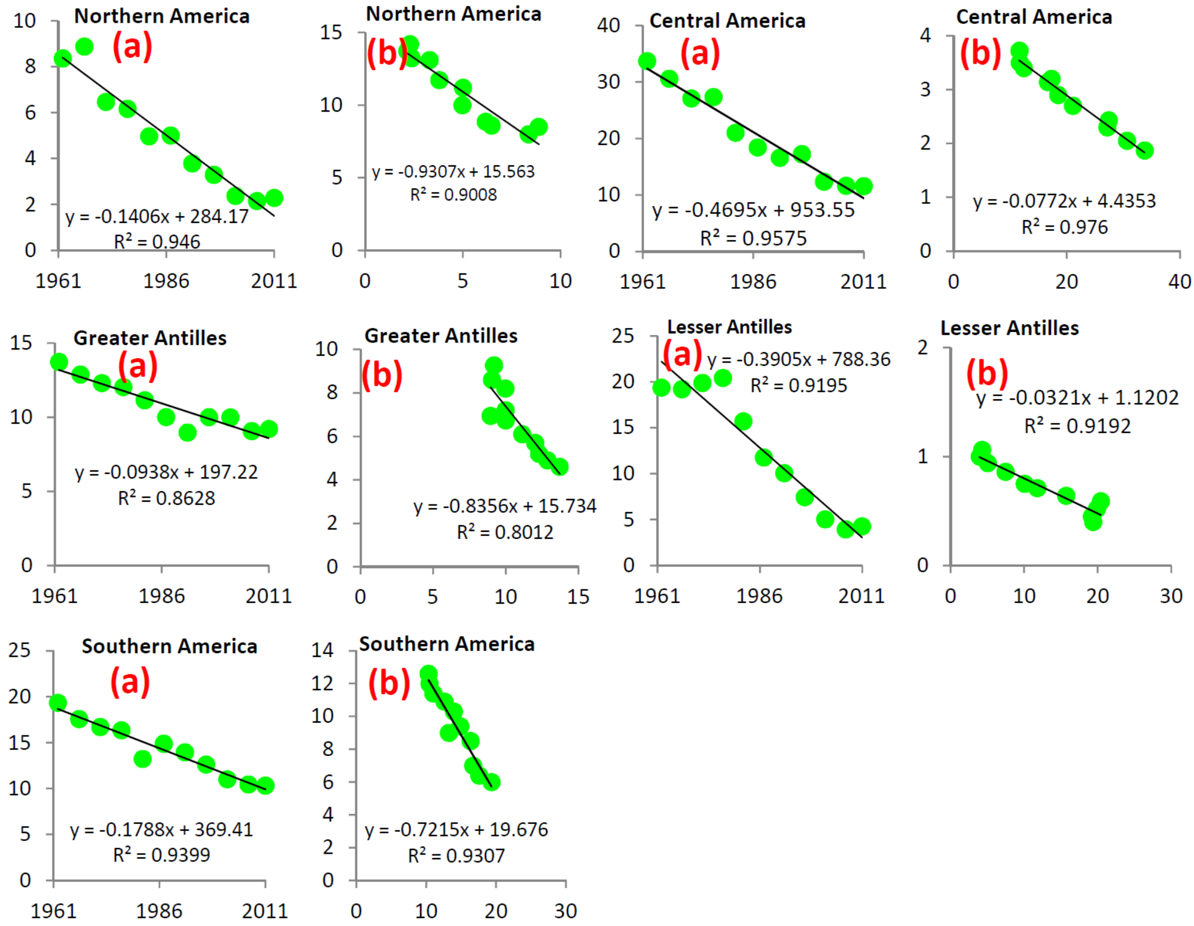
Figure 4. Variations of HDI versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is HDI and (b) horizontal axis is HDI and vertical axis is area equipped for irrigation (%), value of x in (b) is equal to value of y in (a), value of this index is not available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



According to the Fig. 5a, value of this index has been decreased in the all 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. (2011) mentioned effect of GDF on irrigation.

Figure 5 shows variations of value added to GDP by agriculture versus time and area equipped for irrigation.

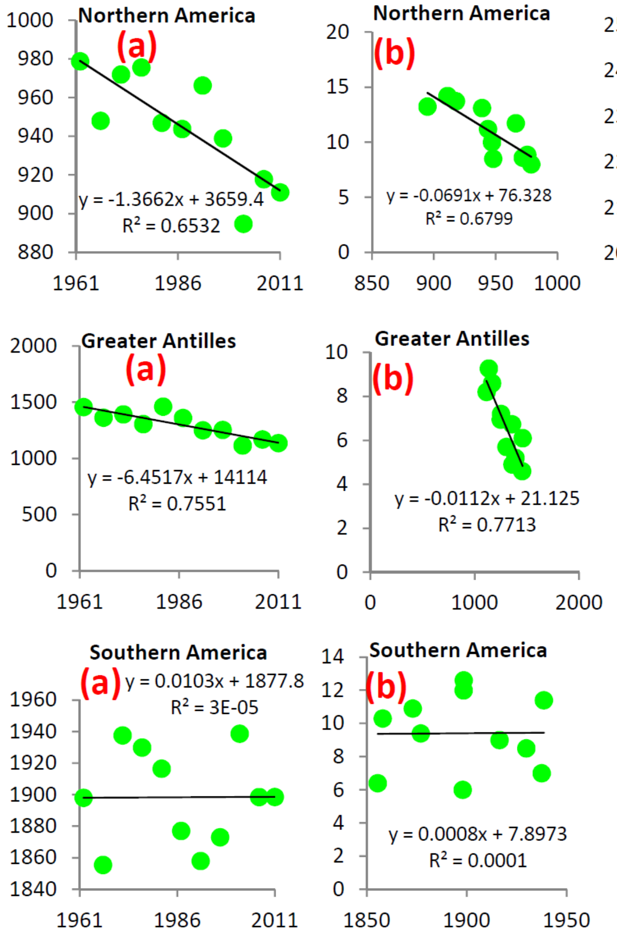
Figure 5. Variations of value added to GDP by agriculture versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is value added to GDP by agriculture (%) and (b) horizontal axis is value added to GDP by agriculture (%) and vertical axis is area equipped for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



According to the Fig. 6a, the value of NRI is variable during the past half of century due to many different factors such as greenhouse gases (LAL, 2001), global warming (MICHAELS, 1990), climate change (MUZIK, 2002) etc. and linear regression is not suitable for evaluation of its trend. Thus, there is not a 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 (1994), this index was known as a considerable factor in drought studies (MISHRA; SINGH, 2010).

Figure 6 shows variations of NRI versus time and area equipped for irrigation.

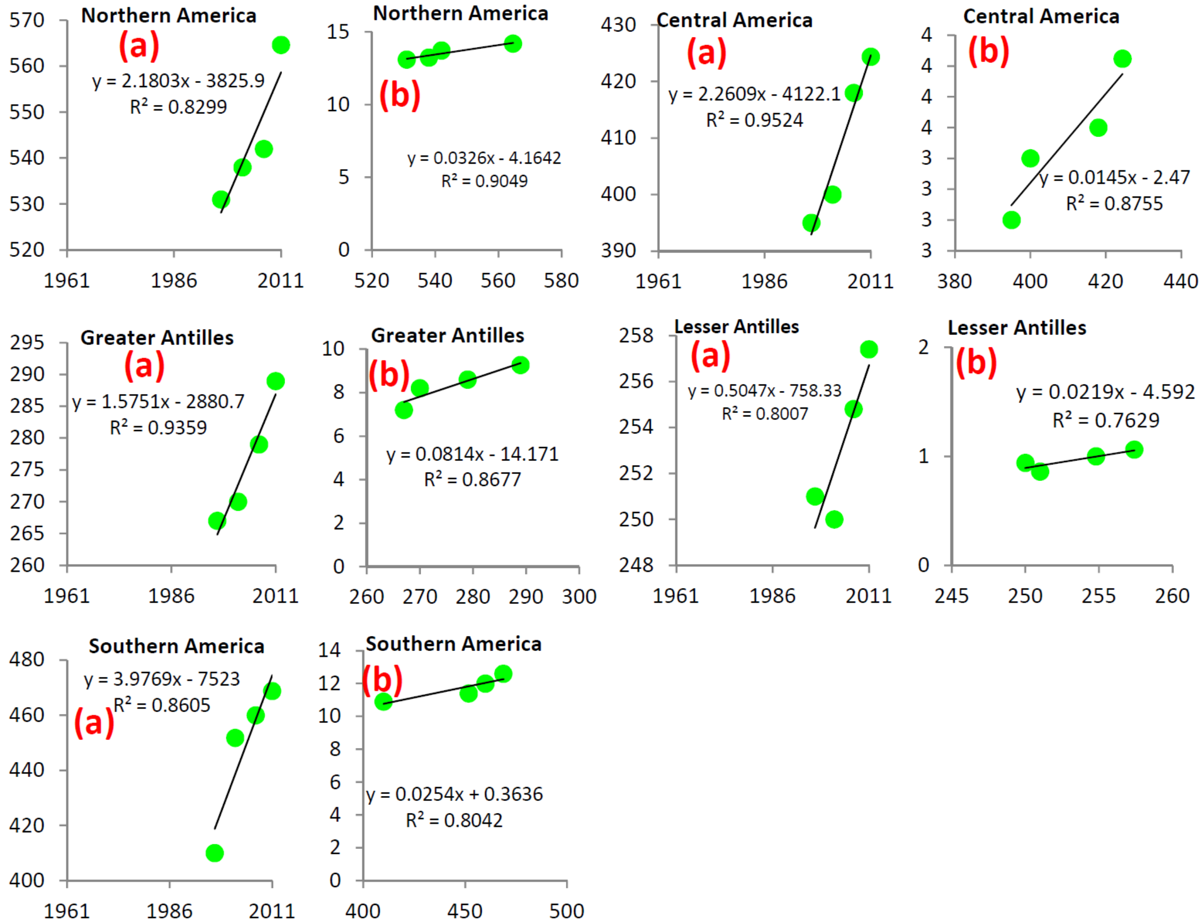
Figure 6. Variations of NRI versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is NRI (mm/year) and (b) horizontal axis is NRI (mm/year) and vertical axis is area equipped for irrigation (%), value of x in (b) is equal to value of y in (a).



According to the 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 effected on river basin management (SIMENSTAD et al., 1992), water allocation policy (KILLGORE, 2009), and agricultural expansion (MCCREADY; DUKES, 2009).

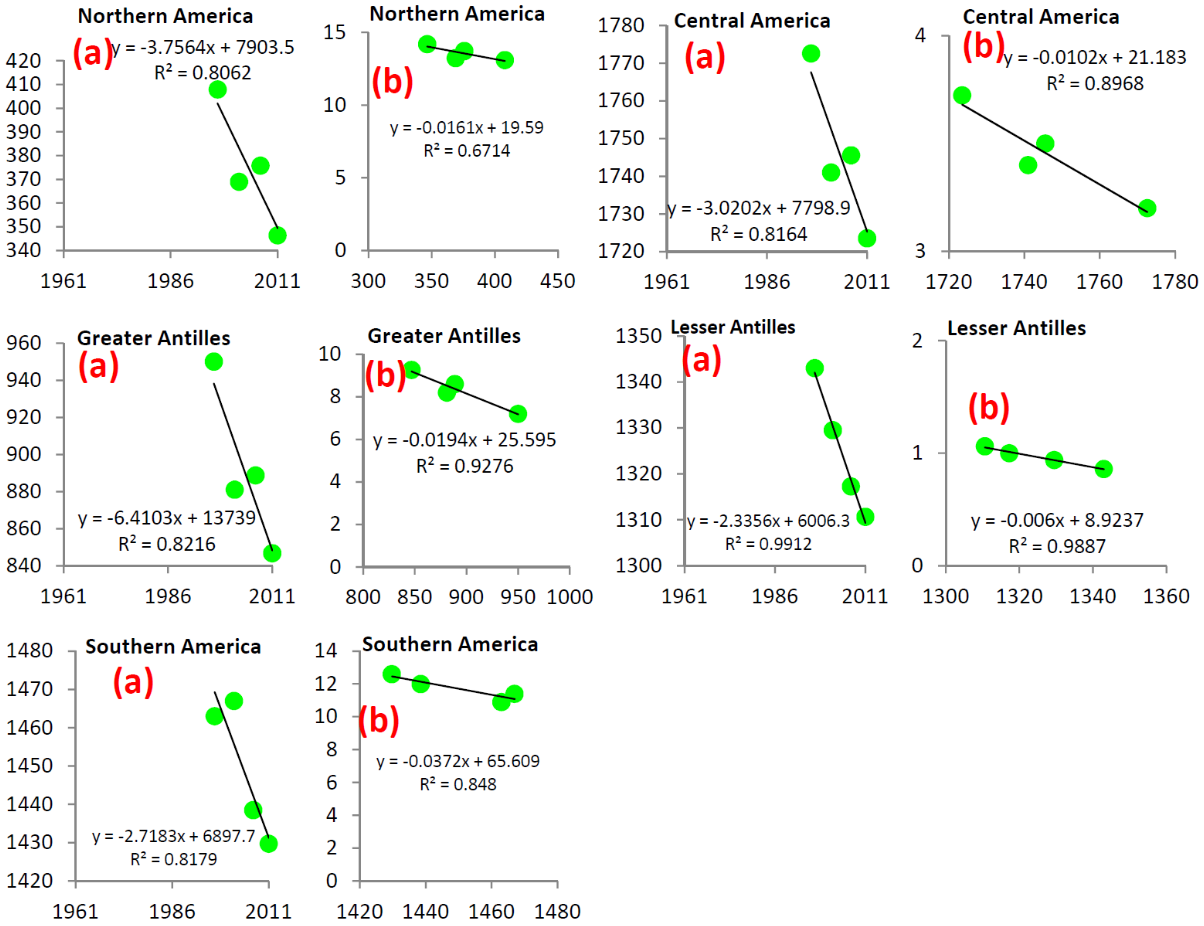
Figure 7 shows variations of irrigation water requirement versus time and area equipped for irrigation.

Figure 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.



According to the Fig. 8a, value of this index has been decreased in Americas. Thus, role of difference between NIR and irrigation water is 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 (HUSSAIN et al. 2007; QADIR et al. 2007). Figure 8 shows variations of difference between NIR and irrigation water requirement versus time and area equipped for irrigation.

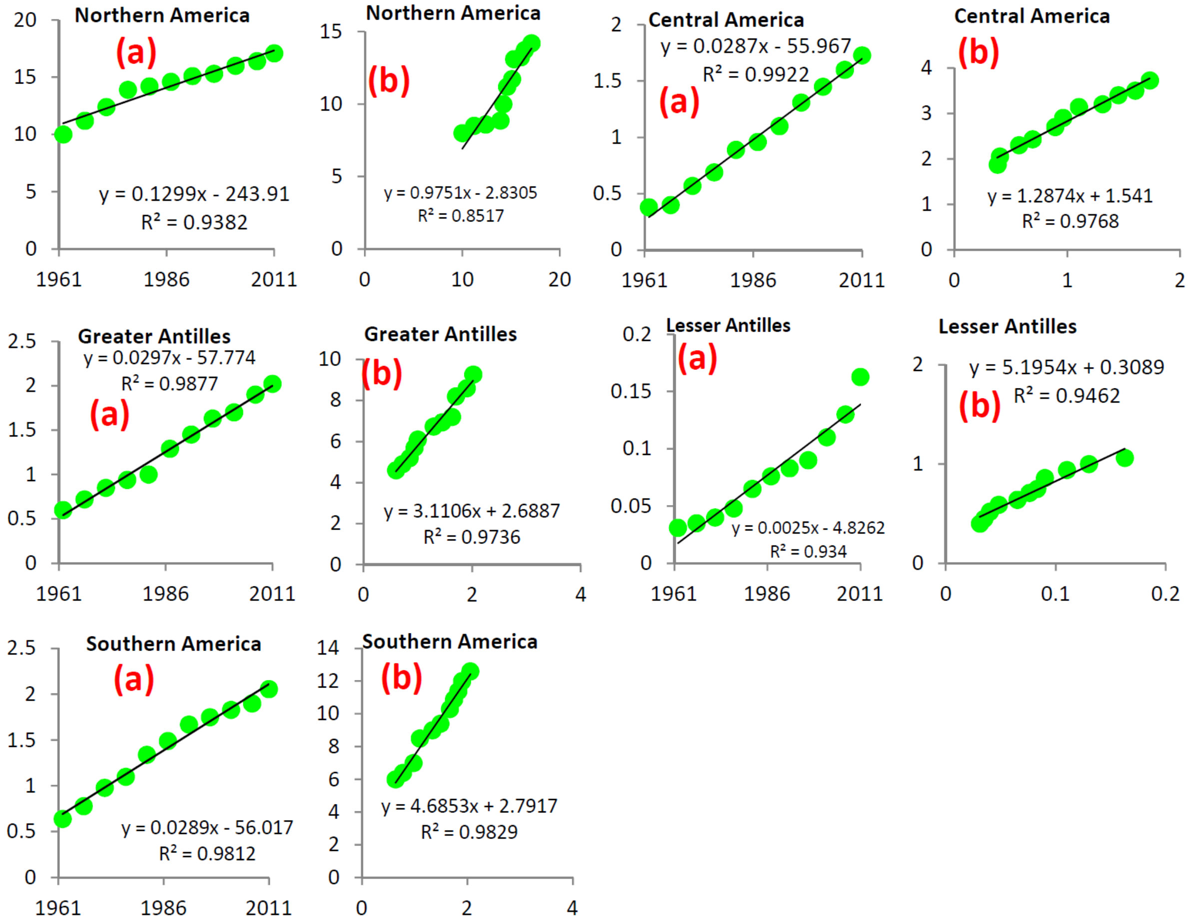
Figure 8. Variations of difference between NIR and irrigation water requirement versus time and area equipped for irrigation, (a) horizontal axis is time (year) and vertical axis is difference between NIR and irrigation water requirement (mm/year) and (b) horizontal axis is difference between NIR and 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.



In the 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 subirrigation (VALERO; MADRAMOOTOO; STAMPFLI, 2007), crop productivity (ALE et al., 2009), improving water management (AYARS; CHRISTEN; HORNBUCKLE et al., 2006), and water balance (ALE et al., 2012).

Figure 9 shows variations of percent of total cultivated area drained versus time and area equipped for irrigation.

Figure 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).

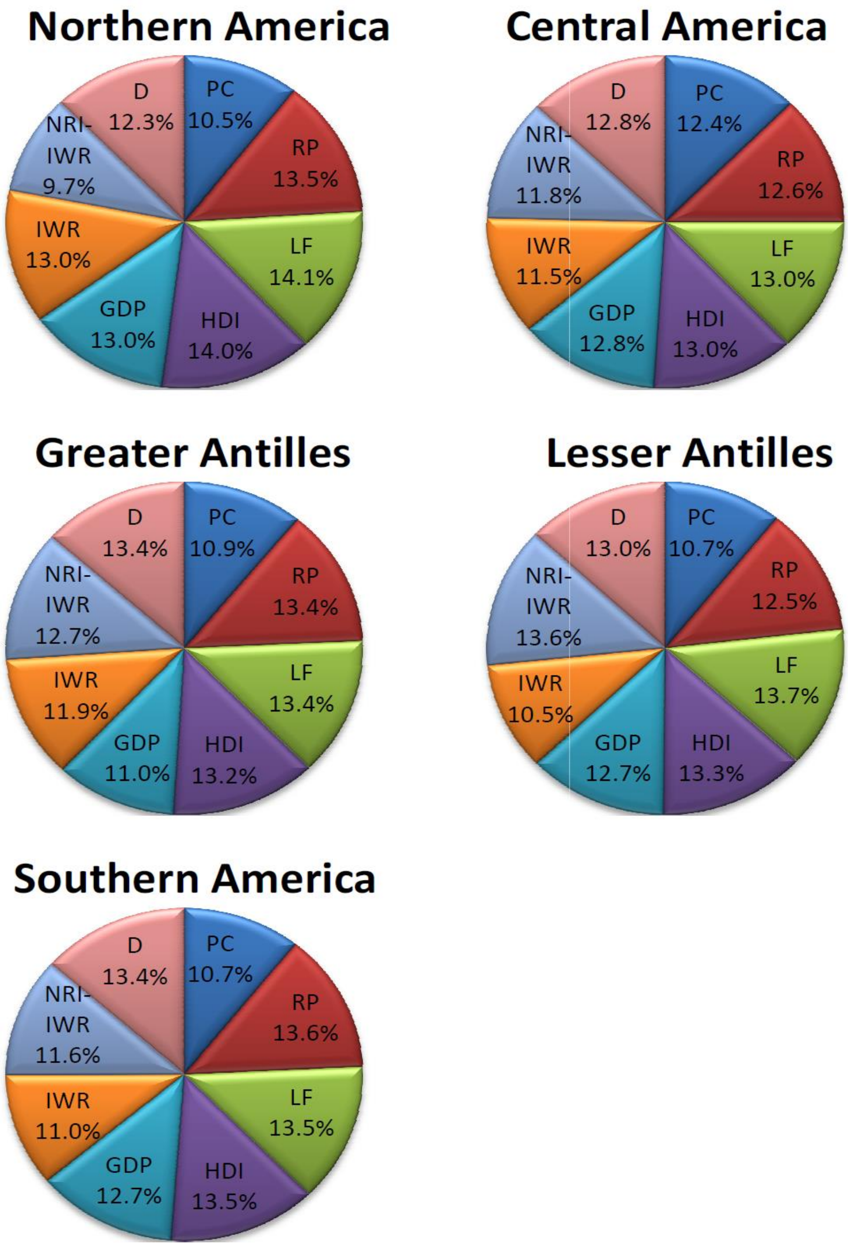


In Northern America, Central America, Greater Antilles, and Lesser Antilles the most trends are related to labour force, in Southern America the most trends is related to rural development. According to the Fig. 10, the observed trend is changed from 10.5% (Northern America) to 12.4% (Central America) 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, they are from 13.0% (Central America) to 14.1% (Northern America) for total economically active population in agriculture per total economically active population, they are from 13.0% (Central Americas) to 14.0% (Northern America) for HDI (minimum of changes), they are 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, they are from 9.7% (Northern America) to 13.6% (Lesser Antilles) for difference between NRI and irrigation water requirement (maximum of changes), and they are from 12.3% (Northern America) to 13.4% (Greater Antilles and Southern America) for percent of total cultivated area drained.

The similar percentage of the trends shows that all selected indexes are important and their selection is reasonable for study of agricultural water management and estimation of area equipped for irrigation in the future. Figure 10 is useable to summarize obtained results from Figs. 1-9b.

Figure 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 the 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 NIR-IWR indicates difference between NIR and irrigation water requirement.



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

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 decreasing 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 followed, we will meet Northern America without labour force in the future. HDI: 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 the 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 followed, 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/yr (in the third scenario by 2035) for Lesser Antilles and the maximum value is 669.4 mm/yr (in the first scenario by 2060) for Southern America. Difference between NIR and irrigation water requirement: the minimum value is 165.3 mm/yr (in the first scenario by 2060) for Northern America and the maximum value is 1689.0 mm/yr (in the third scenario by 2035) for Central America.

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

Table 1. Estimated values for the main indexes using the Equations related to the Figs. 1-9a, 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 NIR-IWR indicates difference between NIR and irrigation water requirement.

PC (%)	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern America	6.4	5.8	6.6	6.2	6.7	6.4
Central America	36.7	41.9	35.2	38.9	34.2	36.8
Greater Antilles	31.8	33.2	31.4	32.4	31.2	31.9
Lesser Antilles	43.1	43.7	42.9	43.4	42.8	43.1
Southern America	18.8	21.1	18.2	19.8	17.7	18.9
Lf(%)	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern America	0.0	0.0	1.5	0.0	2.8	0.0
Central America	6.1	0.0	10.7	0.0	13.7	5.8
Greater Antilles	8.8	0.0	11.9	4.4	13.9	8.6
Lesser Antilles	5.7	0.0	8.2	2.2	9.9	5.6
Southern America	6.0	0.0	9.0	1.6	11.0	5.8
GDB (%)	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern America	0.0	0.0	0.0	0.0	0.0	0.0
Central America	0.0	0.0	1.5	0.0	3.8	0.0
Greater Antilles	6.3	4.0	7.0	5.4	7.5	6.3

Lesser Antilles	0.0	0.0	0.0	0.0	0.0	0.0
Southern America	5.6	1.1	6.8	3.7	7.7	5.5
NRI-IWR (mm/yr)	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern America	259.2	165.3	286.3	220.5	304.3	257.3
Central America	1652.8	1577.3	1674.5	1621.7	1689.0	1651.3
Greater Antilles	694.0	533.8	740.2	628.0	771.0	690.8
Lesser Antilles	1253.4	1195.0	1270.2	1229.3	1281.4	1252.2
Southern America	1366.0	1298.0	1385.5	1338.0	1398.6	1364.6
RP (%)	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern America	11.9	4.3	14.1	8.8	15.5	11.8
Central America	30.8	19.7	33.9	26.2	36.1	30.5
Greater Antilles	13.9	0.0	18.6	7.2	21.7	13.6
Lesser Antilles	51.2	46.1	52.6	49.1	53.6	51.1
Southern America	11.7	0.0	15.3	6.7	17.7	11.5
HDI	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern America	0.961	1.000	0.932	1.000	0.912	0.963
Central America	0.723	0.858	0.684	0.779	0.658	0.726
Greater Antilles	0.812	0.935	0.777	0.863	0.753	0.815
Lesser Antilles	0.798	0.853	0.782	0.821	0.772	0.799
Southern America	0.918	1.000	0.880	0.973	0.855	0.921
IWR (mm/yr)	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern America	611.0	665.5	595.3	633.5	584.8	612.1
Central America	478.8	535.4	462.6	502.1	451.7	480.0
Greater Antilles	324.6	364.0	313.3	340.9	305.7	325.4
Lesser Antilles	268.7	281.4	265.1	273.9	262.7	269.0
Southern America	570.0	669.4	541.4	611.0	522.3	572.0
D (%)	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern America	20.4	23.7	19.5	21.8	18.9	20.5
Central America	2.4	3.2	2.2	2.7	2.1	2.5
Greater Antilles	2.7	3.4	2.5	3.0	2.3	2.7
Lesser Antilles	0.3	0.3	0.2	0.3	0.2	0.3
Southern America	2.8	3.5	2.6	3.1	2.4	2.8

Percent 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.

Data of the Table 2 have computed using the Equations related to the Figs. 1-9b and are equal to *y* value in the Eq. (7).

Table 2 shows estimated values for area equipped for irrigation using the Equations related to the Figs. 1-9b.

Table 2. Estimated values for area equipped for irrigation using the Equations related to the Figs. 1-9b, 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 NIR-IWR indicates difference between NIR and irrigation water requirement.

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

	2035	2060	2035	2060	2035	2060
Northern America	17.1	20.3	16.2	18.4	15.6	17.2
Central America	4.7	5.6	4.4	5.1	4.2	4.7
Greater Antilles	11.0	13.3	10.3	11.9	9.9	11.0
Lesser Antilles	1.7	2.0	1.6	1.8	1.5	1.7
Southern America	15.9	19.3	14.9	17.3	14.3	16.0

According to the Table 3, in the first scenario, the most changes is related to Lesser Antilles (26.3% by 2035 and 51.3% by 2060), in the second scenario, the most changes is related to Lesser Antilles (18.6% by 2035 and 37.2% by 2060), and in the third scenario, the most changes is related to Central America (13.8% by 2035) and Lesser Antilles (26.8% by 2060).

Therefore, Lesser Antilles has a better potential to increasing area equipped for irrigation in the future, however value of increasing is very low in comparison with the other regions and it needs to macroeconomic policies by governments to persuasion of farmers to using irrigation systems in the future. A considerable note is change of irrigation status in the future in comparison with the current status; although area equipped for irrigation in Northern America is more than Southern America in 2011, but they are equal for the first scenario by 2060. Although we can estimate area equipped for irrigation for after 2060, but it is advised that we update our information every year, every decade, or at least every half of century. Table 3 shows estimated values for area equipped for irrigation using the Eq. (7).

Table 3. Estimated values for area equipped for irrigation using the Eq. (7)

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

5 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) was selected to assess agricultural water management based on their importance and other indexes were not studied due to lack of adequate data. The changes of the main indexes in the past half of century argued that they had similar values in some regions and had very different values in other regions due to nature of the indexes and conditions of the regions. In the first step, 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 obtained equations and three different scenarios.

The results showed that trend of permanent crops per cultivated area (with the exception of Northern America), HDI, irrigation water requirement, and percent 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 NIR 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).

6 REFERENCES

ALE, S.; BOWLING, L. C.; BROUDER, S. M.; FRANKENBERGER, J. R.; YOUSSEF, M. A. Simulated effect of drainage water management operational strategy on hydrology and crop yield for drummer soil in the Midwestern United States. **Agricultural Water Management**, Amsterdam, v. 96, n. 4, p. 653-665, 2009.

ALE, S.; BOWLING, L. C.; OWENS, P. R.; BROUDER, S. M.; FRANKENBERGER, J. R. Development and application of a distributed modeling approach to assess the watershed-scale impact of drainage water management. **Agricultural Water Management**, Amsterdam, v. 107, p. 23-33, 2012.

AYARS, J. E.; CHRISTEN, E. W.; HORNBUCKLE, J. W. Controlled drainage for improved water management in arid regions irrigated agriculture. **Agricultural Water Management**, Amsterdam, v. 86, n. 1/2, p. 128-139, 2006.

BOLLIGER, A.; MAGID, J.; AMADO, J. C. T.; RIBEIRO NETO, F. S. M.; CALEGARI, A.; RALISCH, R.; NEERGAARD, A. Taking stock of the brazilian “Zero-Till Revolution”: A Review of Landmark Research and Farmers' Practice. **Advances in Agronomy**, Maryland Heights, v. 91, p. 47-110, 2006.

DE LOE, R.; KREUTZWISER, R.; IVEY, J. Agricultural water use in Ontario. Can. **Water Resources**, Moscow, v. 26, n. 1, p. 17-42, 2001.

DE SALVO, M.; RAFFAELLI, R.; MOSER, R. The impact of climate change on permanent crops in an Alpine region: a Ricardian analysis. **Agricultural Systems**, Amsterdam, v. 118, p. 23-32, 2013.

DU PLESSIS, H. M. Evapotranspiration of citrus as affected by soil water deficit and soil salinity. **Irrigation Science**, Heidelberg, v. 6, n. 1, p. 51-61, 1985.

EVANS, A. E. V.; GIORDANO, M.; CLAYTON, T. (Ed.). **Investing in agricultural water management to benefit smallholder farmers in Ethiopia**: AgWater Solutions Project country synthesis report. Colombo: International Water Management Institute, 2012. 35 p. (IWMI Working Paper, 152). doi: 10.5337/2012.215.

FALKENMARK. M. The massive water scarcity threatening Americas-why isn't it being addressed. **Ambio**, Stockholm, v. 18, n. 2, p. 112-118, 1989.

FAO. **The state of the world's land and water resources for food and agriculture (SOLAW) –** Managing systems at risk. Rome, 2011a.

FAO. **Climate change, water and food security.** Rome, 2011b. (FAO WATER REPORTS, 36).

FAO. **The state of food and agriculture.** Rome, 2012.

FAO. Aquastat database. Rome, 2013. Avaiable on: <http://fao.org>. Accessed in: 25 November 2013.

FERREYRA, C.; DE LOE, R. C.; KREUTZWISER, R. D. Imagined communities, contested watersheds: Challenges to integrated water resources management in agricultural areas. **Journal of Rural Studies**, London, v. 24, n. 3, p. 304–321, 2008.

FRANKS, T.; GARCES-RESTREPO, C.; PUTUHENA, F; Developing capacity for agricultural water management: current practice and future directions. **Irrigation and Drainage**, London, v. 57, p. 255–267, 2008.

GOMMES, R.; PETRASSI, F. Rainfall variability and drought in Sub-Saharan Americas Since 1960. Rome, Food and Agriculture Organization, 1994. (Agro-meteorology Series Working Paper, 9)

HUSSAIN, I. Pro-poor intervention strategies in irrigated agriculture in Asia: issues, lessons, options and guidelines. Irrig. and Drain. 56, 119–126. 2007.

HUSSAIN, I.; TURRAL, H.; MOLDEN, D.; Ahmad M.-ud-D. Measuring and enhancing the value of agricultural water in irrigated river basins. **Irrigation Science**, Heidelberg, v. 25, n. 3, p. 263-282, 2007.

KHAN, S.; HANJRA, M.A.; MU, J. Water management and crop production for food security in China: A review. **Agricultural Water Management**, Amsterdam, v. 96, n. 3, p. 349–360, 2009.

KILLGORE, M. Recent developments in water policy in the americas. In: WORLD ENVIRONMENTAL AND WATER RESOURCES CONGRESS, 2009, Kansas City. Proceedings…Reston: ASCE, 2009. p. 1-8.

KIRPICH, P.; HAMAN, D.; STYLES, S. Problems of irrigation in developing regions. **Journal of Irrigation and Drainage Engineering**, California, v. 125, n. 1, p. 1–6, 1999.

KNOX, J.W.; KAY, M.G.; WEATHERHEAD, E.K. Water regulation, crop production, and agricultural water management—Understanding farmer perspectives on irrigation efficiency. **Agricultural Water Management**, Amsterdam, v. 108, p. 3–8, 2012.
HENDRICKSON, M.K.; JAMES Jr. H.S.; HEFFERNAN, W.D. Does the world need U.S. farmers even if americas don't?. **Journal of Agricultural and Environmental Ethics**, Amsterdam, v. 21, n. 4, p. 311-328, 2008.

LAL, R. Potential of desertification control to sequester carbon and mitigate the greenhouse effect. **Climatic Change**, Amsterdam, v. 51, n. 1, p. 35-72, 2001.

MCCREADY, M., DUKES, M. Evaluation of irrigation scheduling efficiency and adequacy by various control technologies compared to theoretical irrigation requirement. WORLD ENVIRONMENTAL AND WATER RESOURCES CONGRESS, 2009, Kansas City. Proceedings… Reston: ASCE, 2009. p. 1-19.

MICHAELS, P. J. The greenhouse effect and global change: review and reappraisal. **International Journal of Environmental Studies**,London, v. 36, n. 1-2, p. 55-71, 1990.

MISHRA, A.K.; SINGH, V.P. A review of drought concepts. **Journal of Hydrology**, Amsterdam, v.391, n.1-2, p.202–216, 2010.

MONTENEGRO, S.G.; MONTENEGRO, A.; RAGAB, R. Improving agricultural water management in the semi-arid region of Brazil: experimental and modelling study. **Irrigation Science**, Heidelberg, v.28, n.4, p.301-316, 2010.

MUELLER, N.D.; GERBER, J.S.; JOHNSTON, M.; RAY, D.K.; RAMANKUTTY, N.; FOLEY, J.A. Closing yield gaps through nutrient and water management. **Nature**, London, v.490, p.254–257, 2012.

MUZIK, I. A first-order analysis of the climate change effect on flood frequencies in a subalpine watershed by means of a hydrological rainfall–runoff model. **Journal of Hydrology**, Amsterdam, v.267, n.1-2, p.65–73, 2002.

NAMARA, R.; MUNIR, E.; HANJRA, A.; CASTILLO, G.E.; RAVNBORG, H.M.; SMITH, L.; VAN KOPPEN, B. Agricultural water management and poverty linkages. **Agricultural Water Management,** Amsterdam, v.97, n.4, p.520–527, 2010.

NAIKEN, L.; SCHULTE, W. Population and labour force projections for agricultural planning. **Food Policy**, Oxford, v.1 n.3, p.192–202, 1976.

NEUMANN, K.; STEHFEST, E.; VERBURG, P.H.; SIEBERT, S.; MULLER, C.; VELDKAMP, T. Exploring global irrigation patterns: A multilevel modelling approach. **Agricultural Systems**, Amsterdam, v.104, n.9, p.703–713, 2011.

PEJIC, B.; AKSIC, M.; MACKIC, K.; SEKULARAC, G. Response of Potato to Water Stress in Southern Serbia. **Austin Journal of Irrigation**, Texas, v.1, n.1, p.1001, 2015.

PLUSQUELLEC, H. Is the daunting challenge of irrigation achievable?. **Irrigation and Drainage**, London, v.51, p.185–198, 2002.

QADIR, M.; SHARMA, B.R.; BRUGGEMAN, A.; CHOUKR-ALLAH, R.; KARAJEH, F. Non-conventional water resources and opportunities for water augmentation to achieve food security in water scarce regions. **Agricultural Water Management**, Amsterdam, v.87, n.1, p.2-22, 2007.

RAHIMI, S.; GHOLAMI SEFIDKOUHI, M.A.; RAEINI-SARJAZ M.; VALIPOUR, M., Estimation of actual evapotranspiration by using MODIS images (a case study: Tajan catchment). **Archives of Agronomy and Soil Science**. Abingdon, v.61, n.5, p.695-709, 2015.

REZAEI, M.; VALIPOUR, M.; VALIPOUR, M. Modelling Evapotranspiration to Increase the Accuracy of the Estimations Based on the Climatic Parameters, **Water Conservation Science and Engineering**, Berlin, v. 1, n. 3, p. 197-207, 2016.

SCHALDACH, R.; KOCH, J.; DER BEEK, T.A.; KYNAST, E.; FLORKE, M. Current and future irrigation water requirements in pan-Americas: An integrated analysis of socio-economic and climate scenarios. **Global and Planetary Change**, Amsterdam, v.94-95, p.33–45, 2012.

SCHULTZ, B.; De WRACHIEN, D. Irrigation and drainage systems research and development in the 21st century**. Irrigation and Drainage**, London, v.51, p.311–327, 2002.

SIMENSTAD, C.A.; JAY, D.A.; SHERWOOD, C.R. Impacts of Watershed Management on Land-Margin Ecosystems: The Columbia River Estuary. Watershed Management 266-306. ISBN 978-0-387-94232-2, 1992.

STEINER, R.; KELLER, A. Irrigation Land Management Model. **Journal of Irrigation and Drainage Engineering,** California, v.118, n.6, p.928–942, 1992.

SUKHWAL, B.L. Native Americas water rights in the water scarce Western United States, its causes, consequences and probable solutions. **GeoJournal**, Berlin, v.24, n.4, p.347-354, 1991.

TURRAL, H.; SVENDSEN, M.; FAURES, J.M. Investing in irrigation: Reviewing the past and looking to the future. **Agricultural Water Management**, Amsterdam, v.97, n.4, p.551–560, 2010.

VALERO, C.S.; MADRAMOOTOO, C.A.; STAMPFLI, N. Water table management impacts on phosphorus loads in tile drainage. **Agricultural Water Management**, Amsterdam, v.89 n.1-2, p.71–80, 2007.

VALIPOUR, M., HYDRO-MODULE DETERMINATION FOR VANAEI VILLAGE IN ESLAM ABAD GHARB, IRAN. **ARPN Journal of Agricultural and Biological Science**, Islamabad, v.7, n.12, p.968-976. 2012a.

VALIPOUR, M., Critical Areas of Iran for Agriculture Water Management According to the Annual Rainfall. **European Journal of Scientific Research**, London, v.84, n.4, p.600-608. 2012b.

VALIPOUR, M., Ability of Box-Jenkins Models to Estimate of Reference Potential Evapotranspiration (A Case Study: Mehrabad Synoptic Station, Tehran, Iran). **IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)**. New Delhi, v.1, n.5, p.1-11. 2012c.

VALIPOUR, M., A Comparison between Horizontal and Vertical Drainage Systems (Include Pipe Drainage, Open Ditch Drainage, and Pumped Wells) in Anisotropic Soils. **IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)**. New Delhi, v.4, n.1, p.7-12. 2012d.

VALIPOUR, M., INCREASING IRRIGATION EFFICIENCY BY MANAGEMENT STRATEGIES: CUTBACK AND SURGE IRRIGATION. **ARPN Journal of Agricultural and Biological Science**. Islamabad, v.8, n.1, p.35-43, 2013a.

VALIPOUR, M., Necessity of Irrigated and Rainfed Agriculture in the World. **Irrigation & Drainage Systems Engineering**. Hyderabad, v.S9, p.e001. 2013b.

VALIPOUR, M., Evolution of Irrigation-Equipped Areas as Share of Cultivated Areas. **Irrigation & Drainage Systems Engineering**. Hyderabad, v.2, n.1, p.e114. 2013c.

VALIPOUR, M., USE OF SURFACE WATER SUPPLY INDEX TO ASSESSING OF WATER RESOURCES MANAGEMENT IN COLORADO AND OREGON, US. **Advances in Agriculture, Sciences and Engineering Research**. Abuja, v.3, n.2, p.631-640. 2013d.

VALIPOUR, M., Use of average data of 181 synoptic stations for estimation of reference crop evapotranspiration by temperature-based methods. **Water Resources Management**. Berlin, v.28, n.12, p.4237-4255, 2014a.

VALIPOUR, M., Application of new mass transfer formulae for computation of evapotranspiration. **Journal of Applied Water Engineering and Research**. London, v.2, n.1, p.33-46. 2014b.

VALIPOUR, M., Analysis of potential evapotranspiration using limited weather data. **Applied Water Science**, Heidelberg, 2014c, http://dx.doi.org/10.1007/s13201-014-0234-2, Assessed 27 September 2014.

VALIPOUR, M., Investigation of Valiantzas' evapotranspiration equation in Iran. **Theoretical and Applied Climatology.** Berlin, v.121, n.1-2, p.267-278. 2015a.

VALIPOUR, M., Comparative Evaluation of Radiation-Based Methods for Estimation of Potential Evapotranspiration. **Journal of Hydrologic Engineering.** California, v.20, n.5, p.04014068. 2015b.

VALIPOUR, M. Long-term runoff study using SARIMA and ARIMA models in the United States. **Meteorological Applications**. London, v.22, n.3, p.592-598, 2015c.

VALIPOUR, M., Temperature analysis of reference evapotranspiration models. **Meteorological Applications**. London, v.22, n.3, p.385-394, 2015d.

VALIPOUR, M., Evaluation of radiation methods to study potential evapotranspiration of 31 provinces. **Meteorology and Atmospheric Physics**. Berlin, v.127, n.3, p.289-303, 2015e.

VALIPOUR, M., Future of agricultural water management in Africa. **Archives of Agronomy and Soil Science**. Abingdon, v.61, n.7, p.907-927, 2015f.

VALIPOUR, M., Study of different climatic conditions to assess the role of solar radiation in reference crop evapotranspiration equations. **Archives of Agronomy and Soil Science**. Abingdon, v.61, n.5, p.679-694, 2015g.

VALIPOUR, M., Importance of solar radiation, temperature, relative humidity, and wind speed for calculation of reference evapotranspiration. **Archives of Agronomy and Soil Science**. Abingdon, v.61, n.2, p.239-255, 2015h.

VALIPOUR, M., Calibration of mass transfer-based models to predict reference crop evapotranspiration. **Applied Water Science**. Heidelberg, 2015i, http://dx.doi.org/10.1007/s13201-015-0274-2, Assessed 5 March 2015.

VALIPOUR, M., Land use policy and agricultural water management of the previous half of century in Africa. **Applied Water Science**, Heidelberg, v.5, n.4, p.367-395. 2015j.

VALIPOUR, M.; BANIHABIB, M.E.; BEHBAHANI, S.M.R., Comparison of the ARMA, ARIMA, and the autoregressive artificial neural network models in forecasting the monthly inflow of Dez dam reservoir. **Journal of Hydrology**. Amsterdam, v.476, p.433-441, 2013.

VALIPOUR, M., ESLAMIAN, S., Analysis of potential evapotranspiration using 11 modified temperature-based models. **International Journal of Hydrology Science and Technology**, Geneva, v.4, n.3, 2014.

VALIPOUR, M.; MONTAZAR, A.A. An Evaluation of SWDC and WinSRFR Models to Optimize of Infiltration Parameters in Furrow Irrigation. **American Journal of Scientific Research**, London, v. 69, p. 128-142, 2012.

VALIPOUR. M.; SINGH. V.P. Global Experiences on Wastewater Irrigation: Challenges and Prospects, Balanced Urban Development: Options and Strategies for Liveable Cities, 289-327, Berlin, Germany, 2016.

VALIPOUR, M.; GHOLAMI SEFIDKOUHI, M.A.; RAEINI-SARJAZ, M. Selecting the best model to estimate potential evapotranspiration with respect to climate change and magnitudes of extreme events, **Agricultural Water Management**, Amsterdam, v. 180, n. Part A, p. 50-60, 2017.

VALIPOUR, M.; GHOLAMI SEFIDKOUHI, M.A.; KHOSHRAVESH, M. Estimation and trend evaluation of reference evapotranspiration in a humid region, **Italian Journal of Agrometeorology**, Rome, In Press, Accepted. 2017.

VALIPOUR, M.; GHOLAMI SEFIDKOUHI, M.A. Temporal analysis of reference evapotranspiration to detect variation factors, **International Journal of Global Warmin**g, Geneva, In Press. Accepted, 2017.

VALIPOUR, M. How do different factors impact agricultural water management?, **Open Agriculture**, Berlin, In Press, Accepted, 2016a.

VALIPOUR, M. How much meteorological information is necessary to achieve reliable accuracy for rainfall estimations?, **Agriculture**, Basel, v. 6, n. 4, p. 53, 2016b.

WBG. WBG database. New Yourk, 2013. Available on: <http://www.worldbank.org/>. Accessed in: 12 October 2013.

WRACHIEN, D.D.; MAMBRETTI, S. Irrigation and Drainage Systems in Flood-prone Areas: The Role of Mathematical Models. **Austin Journal of Irrigation**, Texas, v.1, n.1, p.1002, 2015.

WU, I.P.; BARRAGAN, J.; BRALTS, V. Irrigation Systems: Water Conservation. Encyclopedia of Environmental Management , Taylor & Francis, doi: 10.1081/E-EEM-120010068, 2013.

YANG, Y.; FENG, Z.; HUANG, H.Q.; LIN, Y. Climate-induced changes in crop water balance during 1960–2001 in Northwest China. **Agriculture, Ecosystems Environment**, Amsterdam, v.127, n.1–2, p.107–118, 2008.

YANNOPOULOS, S. I.; LYBERATOS, G.; THEODOSSIOU, N.; LI, W.; VALIPOUR, M.; TAMBURRINO, A.; ANGELAKIS, A. N. Evolution of Water Lifting Devices (Pumps) over the Centuries Worldwide. **Water**, Basel, v.7, n.9, p.5031-5060, 2015.