Article

The role of different scenarios on irrigation management

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Abstract: This study aims to assess global experience on agricultural water management under different scenarios. The results showed that trend of permanent crops to cultivated area, HDI, irrigation water requirement, and percent of total cultivated area drained is increasing and trend of rural population to total population, total economically active population in agriculture to total economically active population, value added to GDP by agriculture, and the difference between NIR and irrigation water requirement is decreasing. The minimum and maximum values of pressure on renewable water resources by irrigation, are related to the third and first scenarios by 2035 (6.1%) and 2060 (9.2%), respectively.

Keywords: World agriculture; sustainable agriculture; water

PACS: J0101

1. Introduction

Due to limitation of water resources, role of macroeconomic policies in agricultural water management is vital and undeniable. According to the Fig. 1a, b, value of renewable water resources per capita is decreasing (whether based on regions or based on incomes), while value of total people undernourished is steel considerable (Fig. 1c).

Therefore, pressure on renewable water resources is influenced due to demand for the food and applying irrigation systems to increase agricultural production. In the other hand, according to the Fig. 2, total water withdrawal per capita has been decreased.

Although agricultural water withdrawal as percent of total water withdrawal has been decreased due to industries and population growth as well as applying pressurized irrigation and management strategies to increase of efficiency, but more than 40% of irrigation potential is not developed yet.

As a result, the most pressure on renewable water resources is related to the agricultural sector and irrigation has the maximum water withdrawal in agriculture. Hence, the increase of pressure on renewable water resources by irrigation is possible and important in the future.

Although actual crop yield as percentage of potential yield is more than 60% for North America, and Western and Central Europe, it is less than 50% for South America and North Africa and it is about 30% for Central America and the Caribbean, Eastern Europe, and Sub-Saharan Africa [1].

Therefore, studying agricultural water management due to its role on renewable water resources is still reasonable in the world.

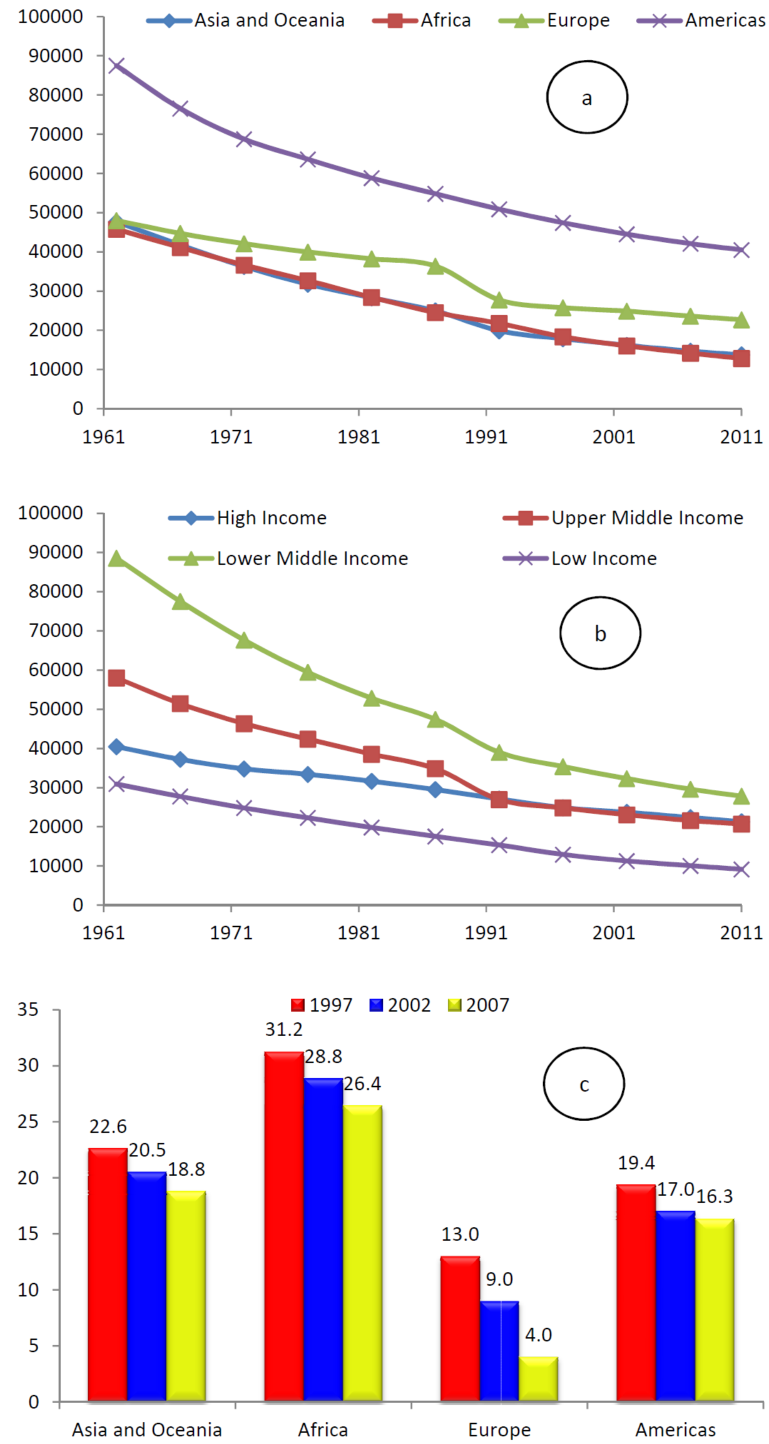

Fig.1 (a) and (b) Variations of renewable water resources per capita (m3/inhab/yr) versus time, (c) percent of total population undernourished

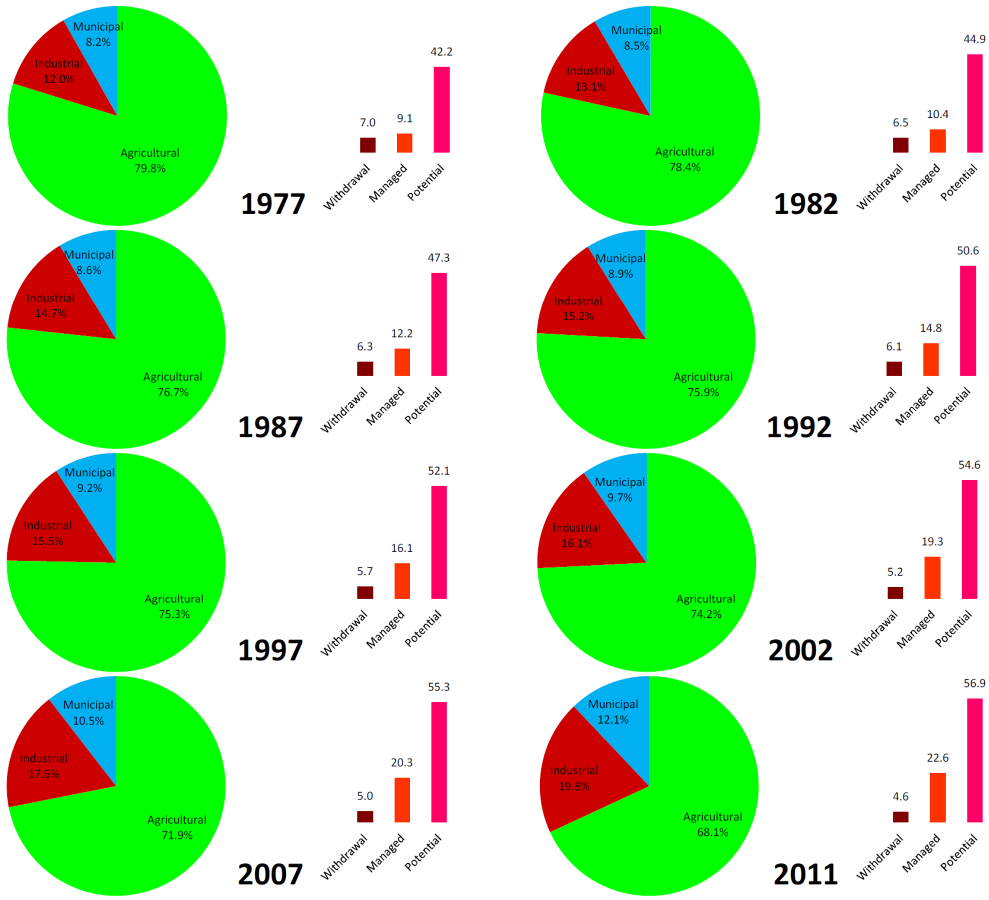

Fig.2 Status of renewable water resources and agricultural water management in the previous half of century, Agricultural indicates agricultural water withdrawal as percent of total water withdrawal (%), Industrial indicates industrial water withdrawal as percent of total water withdrawal (%), Municipal indicates municipal water withdrawal as percent of total withdrawal (%), Withdrawal indicates total water withdrawal per capita (100m3/inhab/yr), Managed indicates total agricultural water managed area to cultivated area (%), potential indicates percent of irrigation potential equipped for irrigation (%), value of these parameters are not available before 1977

The different aspects of irrigation in agricultural water management, such as irrigation efficiency (Rahimi et al., 2014; Valipour, 2013d, e, f, g, h; Valipour & Montazar, 2012a, b, c), soil salinity (du Plessis, 1985), water-saving (Montenegro et al., 2010), sustainable development (Valipour 2014a, b, c, d, e, f), soil water management (Steiner & Keller, 1992), and crop yield (Wu et al., 2013) have been investigated in previous works. Turral et al., (2010) showed that investment is one of the most effective factors on area equipped for irrigation to 2050. Neuman et al., (2011) cited that area equipped for irrigation to 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. Knox et al., (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 the 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 a selected strategy in Asia. Valipour, (2013a, b, c) mentioned the status of irrigated and rainfed agriculture in the world, summarized the advantages and disadvantages of irrigation systems, and attended to update of irrigation information to choose an 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 et al., (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 et al., (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 et al.. (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. The previous researches are about a limited area and cannot apply them to other regions or did not consider role of all important indexes for estimation of agricultural water management and the value of pressure on renewable water resources. Thus, the goal of this study is an estimation of pressure on renewable water resources by irrigation using to establish a link for more important parameters in agricultural water management based on available data in the world.

2. Materials and Methods

Many variables are required to obtain the amount of area equipped for irrigation to cultivated area for cropping pattern design, macroeconomic 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 the world and values of them were checked using WBG database (WBG, 2013). Then, values of area equipped for irrigation and pressure on renewable water resources by irrigation were estimated in 2035 and 2060 using three different scenarios.

Estimation of equipped area and its pressure on renewable water resources 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 R2 value, then the 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 the values of the main indexes would be changed by the same slope of the past half of century (Figs. 3a). 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 R2 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 the second step. Finally, a relationship has been established between calculated data (for area equipped for irrigation) as:

$$I_{10} = \frac{\sum\left(y \times R^2\right)}{\sum R^2} \quad (1)$$

Where, y is obtained value for area equipped for irrigation in the second step (Fig. 3b) and values of R2 showed in the Figs 3b. Finally, pressure on renewable water resources by irrigation estimates using trend between renewable water resources and equipped area.

3. Results and Discussion

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

Fig. 3 shows variations of the main indexes versus time and area equipped for irrigation. According to the Fig. 3a values of permanent crops to cultivated area, HDI, irrigation water requirement, and percent of total cultivated area drained have been increased and values of rural population to total population, economically active population in agriculture, value added to GDP by agriculture, and the difference between NIR and irrigation water requirement have been decreased in the previous half of the century. Thus, role of permanent crops to cultivated area, HDI, irrigation water requirement, and percent of total cultivated area drained is increasing for area equipped for irrigation and it is decreasing for the other indexes (Fig. 3b). In addition, a significant change is observable in the middle of 1980s for permanent crops to cultivated area. 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 et al., 2013; Valipour, 2012a, b, c, d, e), tendency of farmers (Bolliger et al., 2006; Valipour, 2014k, l, m, n), and government's policy (Sukhwal, 1991). Previous researches show the advantages of rural development on agricultural water management and sustainable agriculture (Evans et al., 2012). Effect of proper labor force on water management and improvement of sustainable agriculture has been studied in a lot of researches (Naiken & Schulte 1976). However, slope of reduction of rural population to total population and total economically active population in agriculture to total economically active population is more than increasing slope of HDI in the world. It is a big warning (Hussain, 2007) because although mechanization and use of new technologies have an important role in the enhancement of agricultural knowledge and increasing productivity (Kirpich et al., 1999), labor force has a vital and irreplaceable role in agricultural scheduling and macroeconomic perspectives (Hendrickson et al., 2008; Valipour, 2012f, g, h, i, j). 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. Meanwhile, Neumann et al., (2011) mentioned effect of GDF on irrigation.

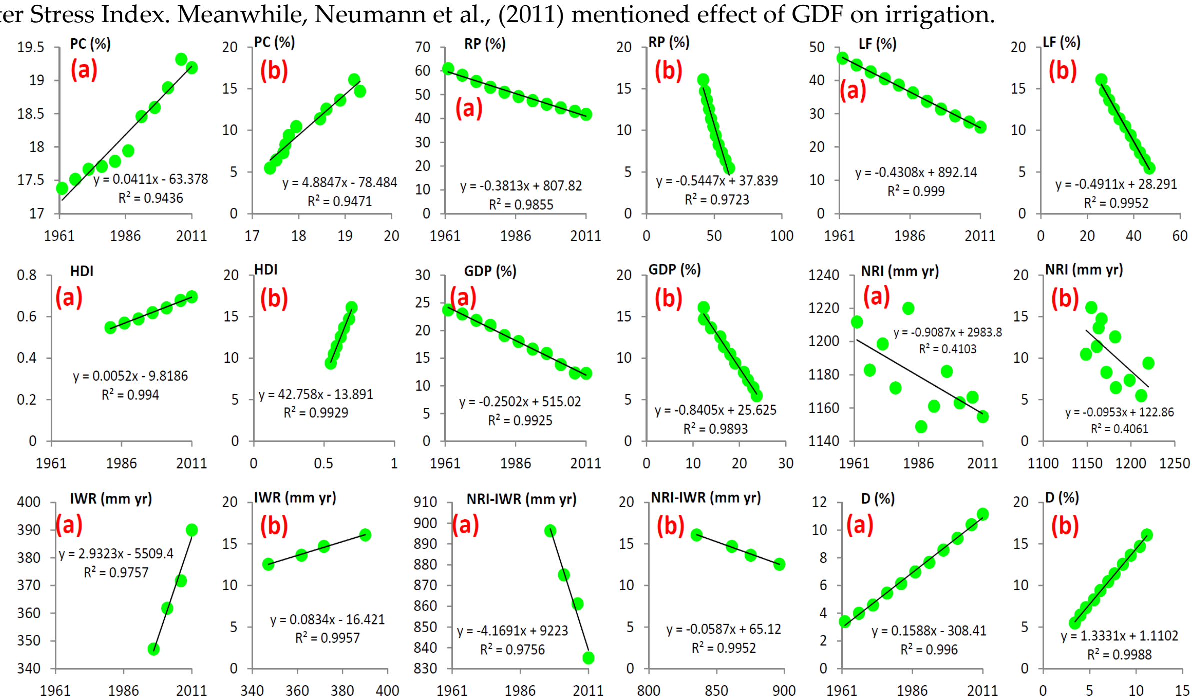

Fig.3 Variations of the main indexes versus time and area equipped for irrigation, (a) horizontal axes are time (year) and vertical axes are the indexes and (b) horizontal axes are the indexes and vertical axes are area equipped for irrigation (%), value of x in (b) is equal to value of y in (a), PC indicates permanent crops to cultivated area (%), RP indicates rural population to total population (%), LF (labor force) indicates total economically active population in agriculture to total economically active population (%), HDI indicates human development index, GDP indicates value added to gross domestic product by agriculture(%), NRI indicates national rainfall index (mm/yr), IWR indicates irrigation water requirement (mm/yr), D indicates percent of total cultivated area drained (%), and NIR-IWR indicates the difference between NIR and irrigation water requirement(mm/yr)

According to the Fig. 3a, 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; Valipour, 2014g, h, i, j) 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. 3b). Due to the mentioned cases, the role of this index has not been considered in estimation of area equipped for irrigation in 2035 and 2060.

After Gommes & Petrassi, (1994), this index was known as a considerable factor in drought studies (Mishra and Singh 2010). Variation of irrigation water management can be effected on river basin management (Simenstad et al., 1992), water allocation policy (Valipour et al., 2012a, b, c, d), and agricultural expansion (Valipour, 2014o, p, q, r).

The difference between NIR and irrigation water requirement 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).

Previous studies notify influence of drainage on subirrigation (Valero et al., 2007), crop productivity (Ale et al., 2009), improving water management (Ayars et al., 2006; Valipour et al., 2013a, b, c), and water balance (Ale et al.. 2012).

Estimation of area equipped for irrigation to cultivated area and its pressure on renewable water resources using the other main indexes of agricultural water management

Table 1 shows obtained results of this study.

Table 1. (a) Estimated values for the main indexes using the Equations related to the Figs. 3a, PC indicates permanent crops to cultivated area, RP indicates rural population to total population, LF (labor force) indicates total economically active population in agriculture to 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 the difference between NIR and irrigation water requirement, (b) Estimated values for area equipped for irrigation using the Equations related to the Figs. 3b, (c) Estimated values for area equipped for irrigation and pressure on renewable water resources by irrigation using the Eq. (1) and Fig. 4, respectively

a	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
PC (%)	20.3	21.3	20.0	20.7	19.8	20.3
RP (%)	31.9	22.3	34.6	27.9	36.5	31.7
LF (%)	15.5	4.7	18.6	11.0	20.6	15.2
HDI	0.763	0.893	0.726	0.817	0.701	0.766
GDP (%)	5.9	0.0	7.7	3.3	8.9	5.7
IWR (mm/yr)	457.8	531.1	436.7	488.0	422.6	459.3
NRI-IWR (mm/yr)	738.9	634.7	768.9	695.9	788.9	736.8
D (%)	14.7	18.7	13.6	16.4	12.8	14.8

b	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
PC	20.5	25.5	19.0	22.6	18.1	20.6
RP	20.5	25.7	19.0	22.6	18.0	20.6

LF	20.7	26.0	19.2	22.9	18.2	20.8
HDI	18.8	24.3	17.1	21.0	16.1	18.9
GDP	20.7	25.6	19.2	22.9	18.2	20.8
IWR	21.8	27.9	20.0	24.3	18.8	21.9
NRI-IWR	21.7	27.9	20.0	24.3	18.8	21.9
D	20.8	26.1	19.2	23.0	18.2	20.9

c	Area equipped for irrigation (%)							Pressure on renewable water resources (%)						
		Scenario (I)		Scenario (II)		Scenario (III)			Scenario (I)		Scenario (II)		Scenario (III)	
	2011	2035	2060	2035	2060	2035	2060	2011	2035	2060	2035	2060	2035	2060
	16	20.7	26.1	19.1	22.9	18.0	20.8	5.5	7.1	9.2	6.5	8.0	6.1	7.2

According to the Table 1a, if the current decreasing trend continues, we will meet the world without value added to GDP by agriculture in the future. In addition, decreasing slope for rural population to total population and labor force is warning. In the Table 1b, the minimum value for equipped area is related to HDI (16.1% in the third scenario by 2035) and the maximum value is related to irrigation water requirement and difference between NRI and irrigation water requirement (27.9% the first scenario by 2060). The similar values show that all selected indexes are important and their selection is reasonable to study of agricultural water management and estimation of area equipped for irrigation in the future. In the Table 1c, values of pressure on the renewable water resources by irrigation that estimated using Fig. 4 have been presented.

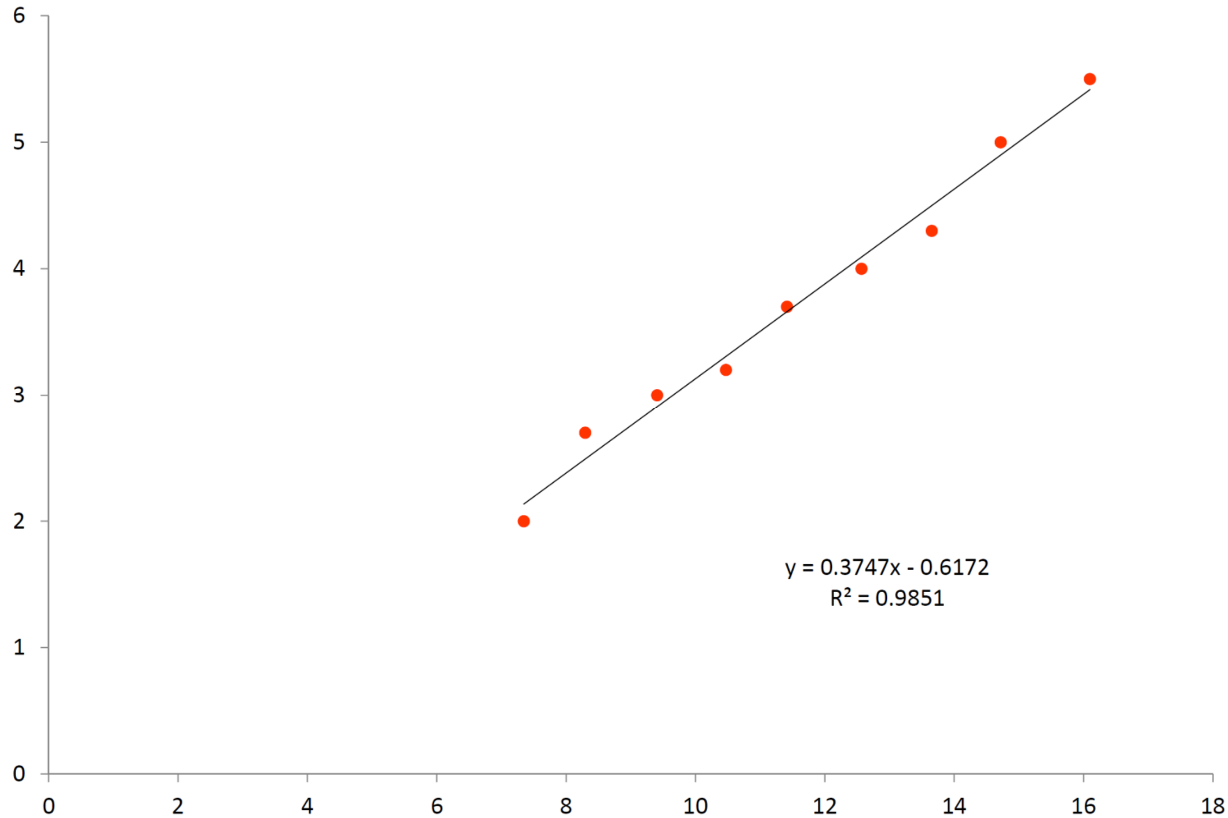

Fig.4 Trend between pressures on renewable water resources by irrigation (vertical axis) versus area equipped for irrigation to cultivated area (horizontal axis) in the previous half of century

As seen in the Table 1c, the minimum change related to the third scenario by 2035 (11.4%) and the maximum change related to the first scenario by 2060 (66.6%). Thus, pressure on renewable water resources will increase in the future and it can be considered in many different sections. As shown in the Fig. 5, percent of area equipped for irrigation by surface water has been increased and instead percents of area equipped for irrigation by groundwater and mixed surface water and groundwater have been increased.

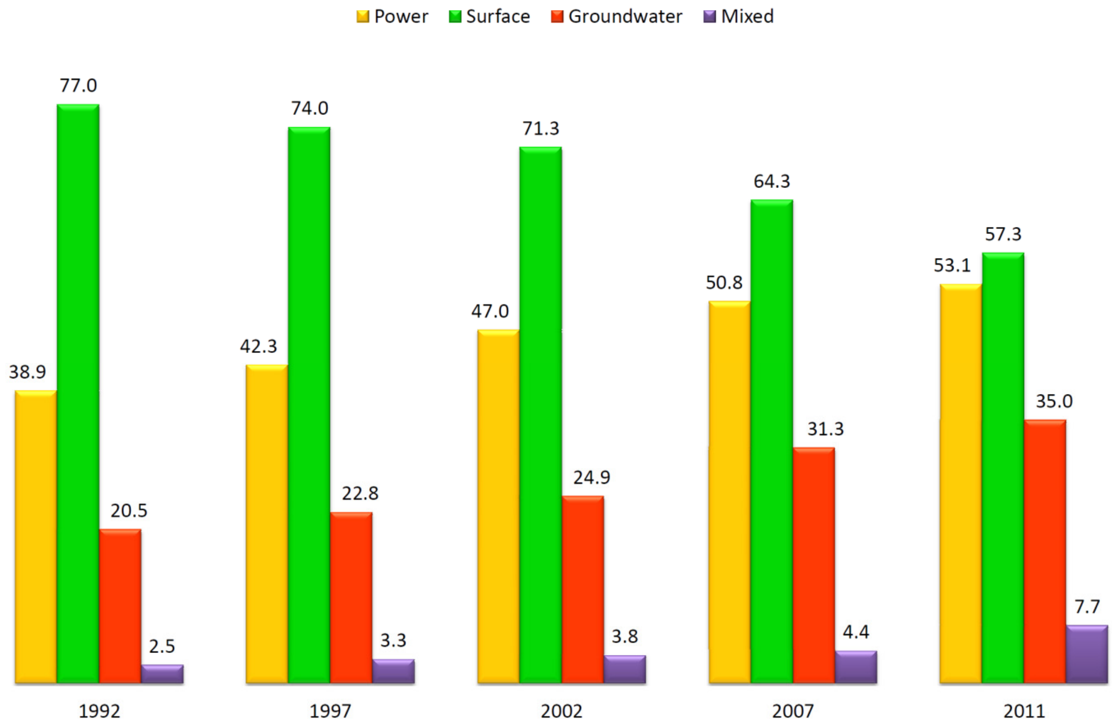

Fig.5 Pressure on water resources in the previous two decades, Surface indicates percent of area equipped for irrigation by surface water (%), Groundwater indicates percent of area equipped for irrigation by groundwater (%), Mixed indicates percent of area equipped for irrigation by mixed surface water and groundwater (%), Power indicates percent of area equipped for irrigation power irrigated (%)

These lead to increase of pump stations to extraction of groundwater. In other hand, the tendency to pressurized irrigation systems due to their advantages increases the need to electrical energy. Hence, percent of power irrigation has been increased (Fig. 5). So, estimation of area equipped for irrigation can be helped not only for estimation of its pressure on renewable water resources but also for the study of many different aspects of its impact on the science involved with irrigation and water resources. Although we can estimate area pressure on renewable water resources for after 2060, but it is advised that we update our information every year, every decade, or at least every half of the century

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

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