Article

Variations of land use and agricultural water management under different scenarios

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Abstract: In this paper, area equipped for irrigation has been estimated in Europe using three different scenarios by 2035 and 2060. The 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 the nature of the indexes and conditions of the regions. The maximum value for area equipped for irrigation is related to Mediterranean Europe; 33.6% and 38.8% by 2035 and 2060, respectively.

Keywords: Europe; optimum decision; sustainable agriculture

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1. Introduction

The world population is growing day to day and need to provide the food according to meet sustainable development distinguishes necessity of accurate decision in the agricultural management. Due to limitation of water resources, role of macroeconomic policies in agricultural water management is vital and undeniable. Although more countries in Europe are developed countries, actual crop yield as percentage of potential yield is about 60% for Western and Central Europe and it is about 30% for Eastern Europe and Russian Federation [1]. In addition, simulated net irrigation requirements (for Europe) range from 53 mm/yr in Denmark to 1120 mm/yr in Spain [2]. Therefore, studying agricultural water management is still reasonable for Europe. The different aspects of irrigation in agricultural water management such as irrigation efficiency [44-49], soil salinity [3], water-saving [4], sustainable development [5], soil water management [6], and crop yield [7] have been investigated in previous works. Also, FAO [8-9] showed that pressure to water resources due to irrigation would be increased to 2050. Turral et al. [10] showed that investment is one of the most factors on area equipped for irrigation to 2050. Neuman et al. [11] cited that area equipped for irrigation to be expanded by 40 million ha, by 2030. Plusquellec [12] claimed that area equipped for irrigation would be increased by 15% to 22% for 2025. Schaldach et al. [13] 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 et al. [14] 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. [15] 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 [50-60] 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 et al. [16] 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. Khan et al. [17] 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 Europe.

2. Materials and Methods

Irrigation controls global yield variability heavily [19]. 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 to 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 [20], 10 main indexes were selected to assessment of agricultural water management in Europe and values of them were checked using WBG database [21]. Then, values of area equipped for irrigation were estimated in 2035 and 2060 using three different scenarios.

2.1. Main indexes

2.1.1. Permanent crops to cultivated area (%)

This index is determined as

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

2.1.2. Rural population to total population (%)

This index is determined as

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

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

This index is determined as

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

2.1.4. Human development index (HDI)

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

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

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

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

The NRI is defined as the national average of the total annual precipitation weighted by its long-term average. The calculation of the NRI is different in the northern and the southern hemisphere. In the northern hemisphere the indices were calculated based on the January-December rainfall; the rainfall indices coincide with the calendar year. 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.

2.1.7. Irrigation water requirement (mm/yr)

This index (I_7) corresponds to net irrigation water requirement.

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

This index shows water deficit and is determined as

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

2.1.9. Percent of total cultivated area drained (%)

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

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

2.1.10. Area equipped for irrigation to cultivated area (%)

This index is determined as

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

2.2. 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 R2 value then amount of each index was estimated in 2035 and 2060 by obtained equations and three different scenarios. In the first scenario, the author assumed that values of the main 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 R2 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 R2 have been showed in the Figs 1-9b.

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

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

Fig. 1

According to the Fig. 1a value of permanent crops to cultivated area has been decreased in Western and Eastern Europe and this index has been increased in the other regions. Thus, role of permanent crops to cultivated area is decreasing for area equipped for irrigation in Western and Eastern Europe 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 [22], tendency of farmers [23], and government's policy [24]. Fig. 2 shows variations of rural population to total population versus time and area equipped for irrigation.

Fig. 2

According to the Fig. 2a value of rural population to total population has been decreased in Europe. 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 [25]. Fig. 3 shows variations of total economically active population in agriculture to total economically active population versus time and area equipped for irrigation.

Fig. 3

According to the Fig. 3a value of economically active population in agriculture is has been decreased in Europe. 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 [26]. Fig. 4 shows variations of human development index (HDI) versus time and area equipped for irrigation.

Fig. 4

As expected, value of HDI has been increased in Europe (Fig. 4a). Thus, role of this index is increasing for area equipped for irrigation (Fig. 4b). In addition, a significant raise is observable in 1990s (Northern, Central, Western, and Mediterranean Europe). However, slope of reduction of rural population to total population and total economically active population in agriculture to total economically active population (Figs. 2 and 3) is more than increasing slope of HDI in Europe. It is a big warning [29] because although mechanization and use of new technologies have an important role in enhancement of agricultural knowledge and increasing productivity [30], labor force has a vital and irreplaceable role in agricultural scheduling and macroeconomic perspectives [31]. The HDI index as a weighted measure of the Falkenmark indicator [32] in order to account for the ability to adapt to water stress is termed the Social Water Stress Index. Fig. 5 shows variations of value added to GDP by agriculture versus time and area equipped for irrigation.

Fig. 5

According to the Fig. 5a, value of this index has been decreased in the all regions. Thus, role of permanent crops to cultivated area is decreasing for Europe (Fig. 5b). Neumann et al. [33] mentioned effect of GDF on irrigation. Fig. 6 shows variations of NRI versus time and area equipped for irrigation.

Fig. 6

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 [34], global warming [35], climate change [36] 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 [37], this index was known as a considerable factor in drought studies [39]. Fig. 7 shows variations of irrigation water requirement versus time and area equipped for irrigation.

Fig. 7

According to the Fig. 7a, value of irrigation water requirement has been increased in Europe. 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 [61], water allocation policy [62], and agricultural expansion [63]. Fig. 8 shows variations of difference between NIR and irrigation water requirement versus time and area equipped for irrigation.

Fig. 8

According to the Fig. 8a, value of this index has been increased in Western and Northern Europe and this index has been decreased in the other regions. Thus, role of difference between NIR and irrigation water requirement is increasing for area equipped for irrigation in Western and Northern Europe and it is decreasing for the other regions (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 [64-65]. Fig. 9 shows variations of percent of total cultivated area drained versus time and area equipped for irrigation.

Fig. 9

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

Fig. 10

In Northern Europe and Central the most trends is related to difference between NIR and irrigation water requirement, in Western Europe the most trends is related to percent of total cultivated area drained and in Mediterranean Europe and Eastern Europe the most trends is related to irrigation water requirement. According to the Fig. 10, the observed trend is changed from 8.7% (Eastern Europe) to 12.5% (Mediterranean Europe) for permanent crops to cultivated area. These changes are from 12.3% (Northern and Western Europe) to 12.5% (Central, Mediterranean, and Eastern Europe) for rural population to total population (minimum of changes), they are from 12.3% (Eastern Europe) to 13.6% (Mediterranean Europe) for total economically active population in agriculture to total economically active population, they are from 12.1% (Central Europe) to 14.3% (Central Europe) for HDI, they are from 9.8% (Mediterranean Europe) to 13.0% (Western Europe) for value added to GDP by agriculture, they are from 11.1% (Northern Europe) to 15.0% (Eastern Europe) for irrigation water requirement, they are from 10.7% (Western Europe) to 14.8% (Eastern Europe) for difference between NRI and irrigation water requirement (maximum of changes), and they are from 11.6% (Eastern Europe) to 13.5% (Northern and Western Europe) 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.

4. Estimation of area equipped for irrigation to 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 the Figs. 1-9a.

Table 1

Permanent crops to cultivated area: the minimum value is 0.0% (in the first scenario by 2060) for Eastern Europe and the maximum value is 23.8% (in the first scenario by 2060) for Mediterranean Europe. A significant decreasing is considerable for Europe in the future. Rural population to total population: the minimum value is 4.4% (in the first scenario by 2060) for Northern Europe and the maximum value is 35.1% (in the third scenario by 2035) for Central Europe. Total economically active population in agriculture to total economically active population: the maximum value is 4.0% (in the third scenario by 2035) for Eastern Europe. If current decreasing trend is followed, we will meet Europe without labour force in the future. HDI: the minimum value in the future is related to Northern Europe (0.880 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 5.5% (in the third scenario by 2035) for Eastern Europe. If current decreasing trend is followed, we will meet Europe without value added to GDP by agriculture. Irrigation water requirement: the minimum value is 51.4 mm/yr (in the third scenario by 2035) for Northern Europe and the maximum value is 528.1 mm/yr (in the first scenario by 2060) for Mediterranean Europe. Difference between NIR and irrigation water requirement: the minimum value is -291.1 mm/yr (in the first scenario by 2060) for Mediterranean Europe and the maximum value is 1113.7 mm/yr (in the first scenario by 2060) for Northern Europe. Percent of total cultivated area drained: the minimum value is 6.4% (in the third scenario by 2035) for Mediterranean Europe and the maximum value is 63.7% (in the first scenario by 2060) for Northern Europe. Table 2 shows estimated values for area equipped for irrigation using the Equations related to the Figs. 1-9b.

Table 2

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 3 shows estimated values for area equipped for irrigation using the Eq. (7).

Table 3

According to the Table 3, in the first scenario, the most changes is related to Eastern Europe (40.9% by 2035 and 83.5% by 2060), in the second scenario, the most changes is related to Eastern Europe (23.5% by 2035 and 59.2% by 2060), and in the third scenario, the most changes is related to Mediterranean Europe (17.7% by 2035) and Eastern Europe (41.8% by 2060). Therefore, Eastern Europe has a better potential to increasing area equipped for irrigation in the future. 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.

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

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Fig. caption

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

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

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

Fig.4 Variations of HDI versus time and area equipped for irrigation, (a) horizontal axes is time (year) and vertical axes is HDI and (b) horizontal axes is HDI and vertical axes 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

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

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

Fig.7 Variations of irrigation water requirement versus time and area equipped for irrigation, (a) horizontal axes is time (year) and vertical axes is irrigation water requirement (mm/year) and (b) horizontal axes is irrigation water requirement (mm/year) and vertical axes 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

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

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

Fig. 10 Percent of observed trend between changes of the main indexes and area equipped for irrigation in the different regions of Europe (this is equivalent to role of each index to estimate area equipped for irrigation based on R2 values in the Figs. 1-9b), role of NRI has not been considered due to very poor trend, PC indicates permanent crops to cultivated area, RP indicates rural population to total population, LF (labour 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 difference between NIR and irrigation water requirement

Table caption

Table 1 Estimated values for the main indexes using the Equations related to the Figs. 1-9a, PC indicates permanent crops to cultivated area, RP indicates rural population to total population, LF (labour 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 difference between NIR and irrigation water requirement

Table 2 Estimated values for area equipped for irrigation using the Equations related to the Figs. 1-9b, PC indicates permanent crops to cultivated area, RP indicates rural population to total population, LF (labour 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 difference between NIR and irrigation water requirement

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

Table 1

Table 1. *Estimated values for the main indices using the Equations related to the Figs. 1-9a, PC indicates permanent crops to cultivated area, RP indicates rural population to total population, LF (labour 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 difference between NIR and irrigation water requirement*

PC	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	4.2	7.1	3.4	5.4	2.8	4.2
Western Europe	10.6	13.9	9.7	12	9.1	10.7
Central Europe	3.9	4.9	3.6	4.3	3.4	3.9
Mediterranean Europe	34	42.7	31.5	37.6	29.8	34.2
Eastern Europe	3.2	4.2	2.9	3.7	2.6	3.2

RP	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	11	14.4	10	12.4	9.3	11.1
Western Europe	11.6	15.3	10.6	13.1	9.9	11.7
Central Europe	3.9	5	3.6	4.4	3.4	3.9
Mediterranean Europe	34.1	42.6	31.7	37.6	30	34.3
Eastern Europe	3.7	5.1	3.3	4.2	3	3.7

LF	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	11	11	10.4	11	9.7	11
Western Europe	10.5	10.5	10.5	10.5	10.2	10.5
Central Europe	3.4	3.4	3.4	3.4	3.4	3.4
Mediterranean Europe	33.9	33.9	33.5	33.9	31.7	33.9
Eastern Europe	3.7	3.7	3.4	3.7	3.1	3.7

HDI	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	8.5	10.7	7.4	10.2	6.6	8.6
Western Europe	11.9	11.9	11.9	11.9	11.2	11.9
Central Europe	4.8	4.8	4.5	4.8	4.3	4.8
Mediterranean Europe	38.3	38.3	38.3	38.3	37	38.3
Eastern Europe	6	6	5.2	6	4.8	6

GDP	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	9.9	9.9	9.9	9.9	9.5	9.9
Western Europe	9	9	9	9	9	9
Central Europe	3.7	3.7	3.6	3.7	3.3	3.7
Mediterranean Europe	32.1	38.2	29.9	35.1	28.5	32.2
Eastern Europe	3.4	3.8	3	3.8	2.8	3.4

IWR	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	12.7	17.4	11.4	14.7	10.5	12.8
Western Europe	12.3	16.3	11.2	14	10.5	12.4
Central Europe	5.2	7.4	4.6	6.1	4.2	5.3
Mediterranean Europe	30	34.7	28.7	31.9	27.8	30.1
Eastern Europe	6.1	9.2	5.2	7.4	4.5	6.1

NRI-IWR	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	13.5	18.9	12	15.7	11	13.7
Western Europe	11.6	15	10.7	13	10	11.7
Central Europe	5.2	7.4	4.6	6.1	4.2	5.3
Mediterranean Europe	29.7	34.1	28.4	31.5	27.6	29.8
Eastern Europe	6.1	9.3	5.2	7.4	4.6	6.2

D	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	11.6	15.3	10.5	13.1	9.8	11.6
Western Europe	12.1	16	11	13.7	10.2	12.2
Central Europe	3.9	5	3.6	4.4	3.4	3.9
Mediterranean Europe	36.1	45.4	33.4	39.9	31.6	36.2
Eastern Europe	3.7	5.2	3.3	4.3	3.1	3.8

Table 2

Table 2. *Estimated values for area equipped for irrigation using the Equations related to the Figs. 1-9b, PC indicates permanent crops to cultivated area, RP indicates rural population to total population, LF (labour 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 difference between NIR and irrigation water requirement*

PC	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	4.2	7.1	3.4	5.4	2.8	4.2
Western Europe	10.6	13.9	9.7	12	9.1	10.7
Central Europe	3.9	4.9	3.6	4.3	3.4	3.9
Mediterranean Europe	34	42.7	31.5	37.6	29.8	34.2
Eastern Europe	3.2	4.2	2.9	3.7	2.6	3.2

RP	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	11	14.4	10	12.4	9.3	11.1
Western Europe	11.6	15.3	10.6	13.1	9.9	11.7
Central Europe	3.9	5	3.6	4.4	3.4	3.9
Mediterranean Europe	34.1	42.6	31.7	37.6	30	34.3
Eastern Europe	3.7	5.1	3.3	4.2	3	3.7

LF	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	11	11	10.4	11	9.7	11
Western Europe	10.5	10.5	10.5	10.5	10.2	10.5
Central Europe	3.4	3.4	3.4	3.4	3.4	3.4
Mediterranean Europe	33.9	33.9	33.5	33.9	31.7	33.9
Eastern Europe	3.7	3.7	3.4	3.7	3.1	3.7

HDI	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	8.5	10.7	7.4	10.2	6.6	8.6
Western Europe	11.9	11.9	11.9	11.9	11.2	11.9
Central Europe	4.8	4.8	4.5	4.8	4.3	4.8
Mediterranean Europe	38.3	38.3	38.3	38.3	37	38.3
Eastern Europe	6	6	5.2	6	4.8	6

GDP	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	9.9	9.9	9.9	9.9	9.5	9.9
Western Europe	9	9	9	9	9	9
Central Europe	3.7	3.7	3.6	3.7	3.3	3.7
Mediterranean Europe	32.1	38.2	29.9	35.1	28.5	32.2
Eastern Europe	3.4	3.8	3	3.8	2.8	3.4

IWR	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	12.7	17.4	11.4	14.7	10.5	12.8
Western Europe	12.3	16.3	11.2	14	10.5	12.4
Central Europe	5.2	7.4	4.6	6.1	4.2	5.3
Mediterranean Europe	30	34.7	28.7	31.9	27.8	30.1
Eastern Europe	6.1	9.2	5.2	7.4	4.5	6.1

NRI-IWR	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	13.5	18.9	12	15.7	11	13.7
Western Europe	11.6	15	10.7	13	10	11.7
Central Europe	5.2	7.4	4.6	6.1	4.2	5.3
Mediterranean Europe	29.7	34.1	28.4	31.5	27.6	29.8
Eastern Europe	6.1	9.3	5.2	7.4	4.6	6.2

D	Scenario (I)		Scenario (II)		Scenario (III)	
	2035	2060	2035	2060	2035	2060
Northern Europe	11.6	15.3	10.5	13.1	9.8	11.6
Western Europe	12.1	16	11	13.7	10.2	12.2
Central Europe	3.9	5	3.6	4.4	3.4	3.9
Mediterranean Europe	36.1	45.4	33.4	39.9	31.6	36.2
Eastern Europe	3.7	5.2	3.3	4.3	3.1	3.8

Table 3

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

	Area equipped for irrigation (%)							Changes (%)					
		Scenario (I)		Scenario (II)		Scenario (III)		Scenario (I)		Scenario (II)		Scenario (III)	
Region	2011	2035	2060	2035	2060	2035	2060	2035	2060	2035	2060	2035	2060
Northern Europe	8.3	10.5	13.2	9.5	11.7	8.8	10.5	26.5	59.8	15.2	41.4	6.4	27.2
Western Europe	8.7	11.2	13.4	10.6	12.1	10.0	11.3	28.9	54.4	21.6	39.4	15.3	29.4
Central Europe	3.2	4.3	5.3	3.9	4.7	3.7	4.3	32.6	62.9	22.0	45.1	14.6	33.2
Mediterranean Europe	26.0	33.6	38.8	32.1	35.8	30.6	33.7	29.2	48.9	23.2	37.5	17.7	29.6
Eastern Europe	3.3	4.7	6.1	4.1	5.3	3.7	4.7	40.9	83.5	23.5	59.2	11.5	41.8

Fig 1

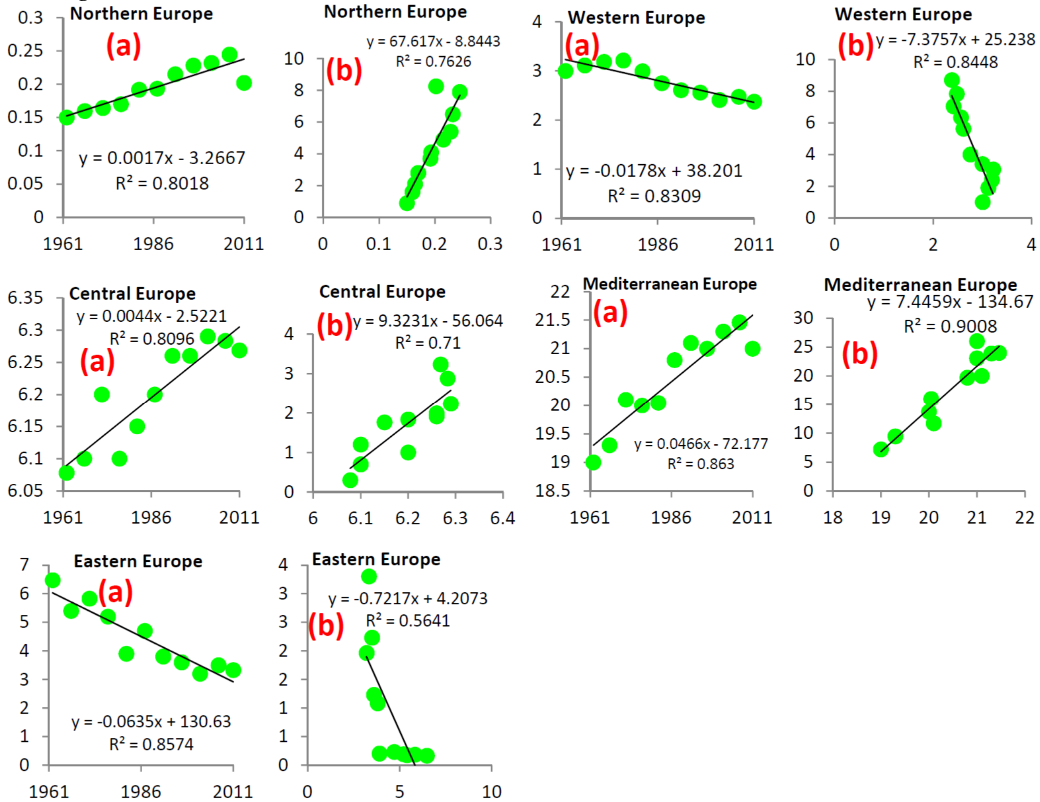

Northern Europe
(a)
y = 0.0017x - 3.2667
R² = 0.8018
Northern Europe
(b)
y = 67.617x - 8.8443
R² = 0.7626
Western Europe
(a)
y = -0.0178x + 38.201
R² = 0.8309
Western Europe
(b)
y = -7.3757x + 25.238
R² = 0.8448
Central Europe
(a)
y = 0.0044x - 2.5221
R² = 0.8096
Central Europe
(b)
y = 9.3231x - 56.064
R² = 0.71
Mediterranean Europe
(a)
y = 0.0466x - 72.177
R² = 0.863
Mediterranean Europe
(b)
y = 7.4459x - 134.67
R² = 0.9008
Eastern Europe
(a)
y = -0.0635x + 130.63
R² = 0.8574
Eastern Europe
(b)
y = -0.7217x + 4.2073
R² = 0.5641

Fig 2

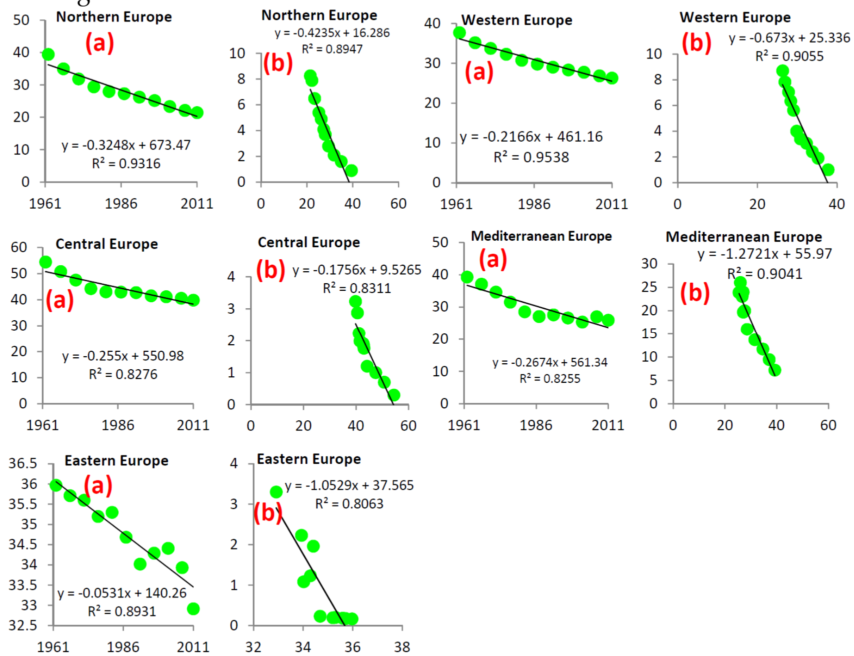

Northern Europe
(a)
y = -0.3248x + 673.47
R² = 0.9316
Northern Europe
y = -0.4235x + 16.286
R² = 0.8947
(b)
Western Europe
(a)
y = -0.2166x + 461.16
R² = 0.9538
Western Europe
(b)
y = -0.673x + 25.336
R² = 0.9055
Central Europe
(a)
y = -0.255x + 550.98
R² = 0.8276
Central Europe
(b)
y = -0.1756x + 9.5265
R² = 0.8311
Mediterranean Europe
(a)
y = -0.2674x + 561.34
R² = 0.8255
Mediterranean Europe
y = -1.2721x + 55.97
R² = 0.9041
(b)
Eastern Europe
(a)
y = -0.0531x + 140.26
R² = 0.8931
Eastern Europe
y = -1.0529x + 37.565
R² = 0.8063
(b)
1961
1986
2011

Fig 3

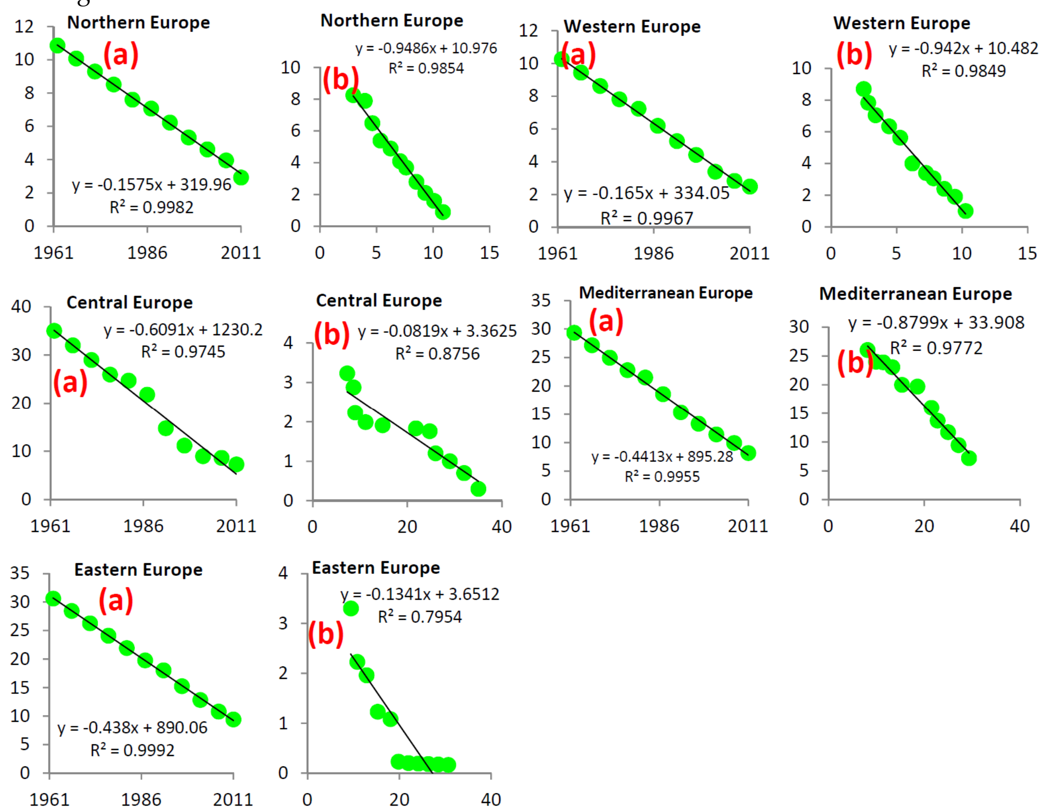

Northern Europe
(a)
y = -0.1575x + 319.96
R² = 0.9982
Northern Europe
(b)
y = -0.9486x + 10.976
R² = 0.9854
Western Europe
(a)
y = -0.165x + 334.05
R² = 0.9967
Western Europe
(b)
y = -0.942x + 10.482
R² = 0.9849
Central Europe
(a)
y = -0.6091x + 1230.2
R² = 0.9745
Central Europe
(b)
y = -0.0819x + 3.3625
R² = 0.8756
Mediterranean Europe
(a)
y = -0.4413x + 895.28
R² = 0.9955
Mediterranean Europe
(b)
y = -0.8799x + 33.908
R² = 0.9772
Eastern Europe
(a)
y = -0.438x + 890.06
R² = 0.9992
Eastern Europe
(b)
y = -0.1341x + 3.6512
R² = 0.7954

Fig 4

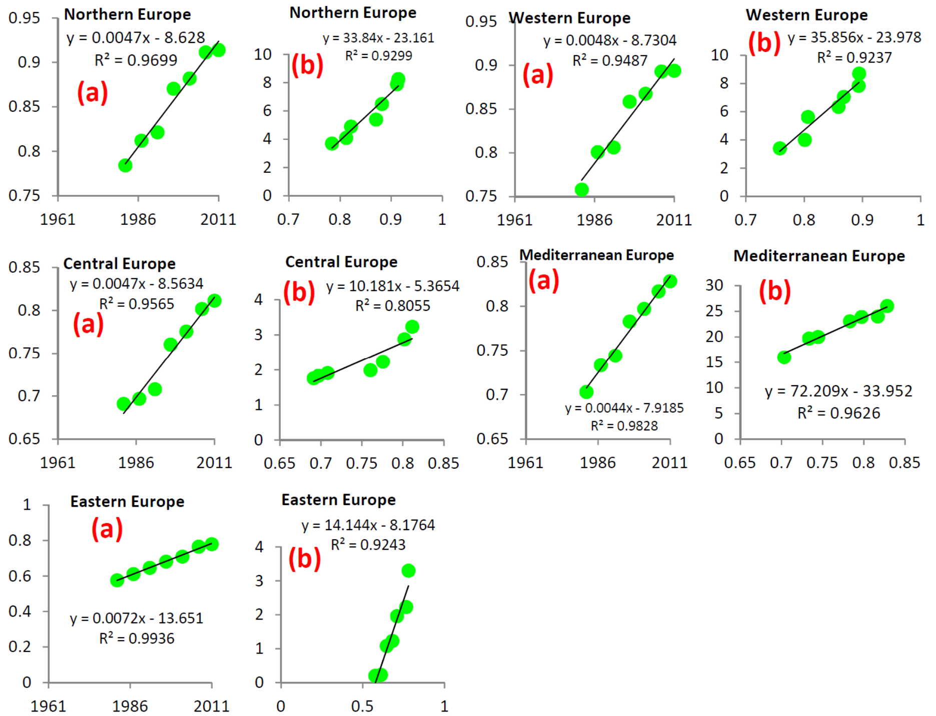

Northern Europe
y = 0.0047x - 8.628
R² = 0.9699
(a)
Northern Europe
y = 33.84x - 23.161
R² = 0.9299
(b)
Western Europe
y = 0.0048x - 8.7304
R² = 0.9487
(a)
Western Europe
(b)
y = 35.856x - 23.978
R² = 0.9237
Central Europe
y = 0.0047x - 8.5634
R² = 0.9565
(a)
Central Europe
(b)
y = 10.181x - 5.3654
R² = 0.8055
Mediterranean Europe
(a)
y = 0.0044x - 7.9185
R² = 0.9828
Mediterranean Europe
(b)
y = 72.209x - 33.952
R² = 0.9626
Eastern Europe
(a)
y = 0.0072x - 13.651
R² = 0.9936
Eastern Europe
y = 14.144x - 8.1764
R² = 0.9243
(b)

Fig 5

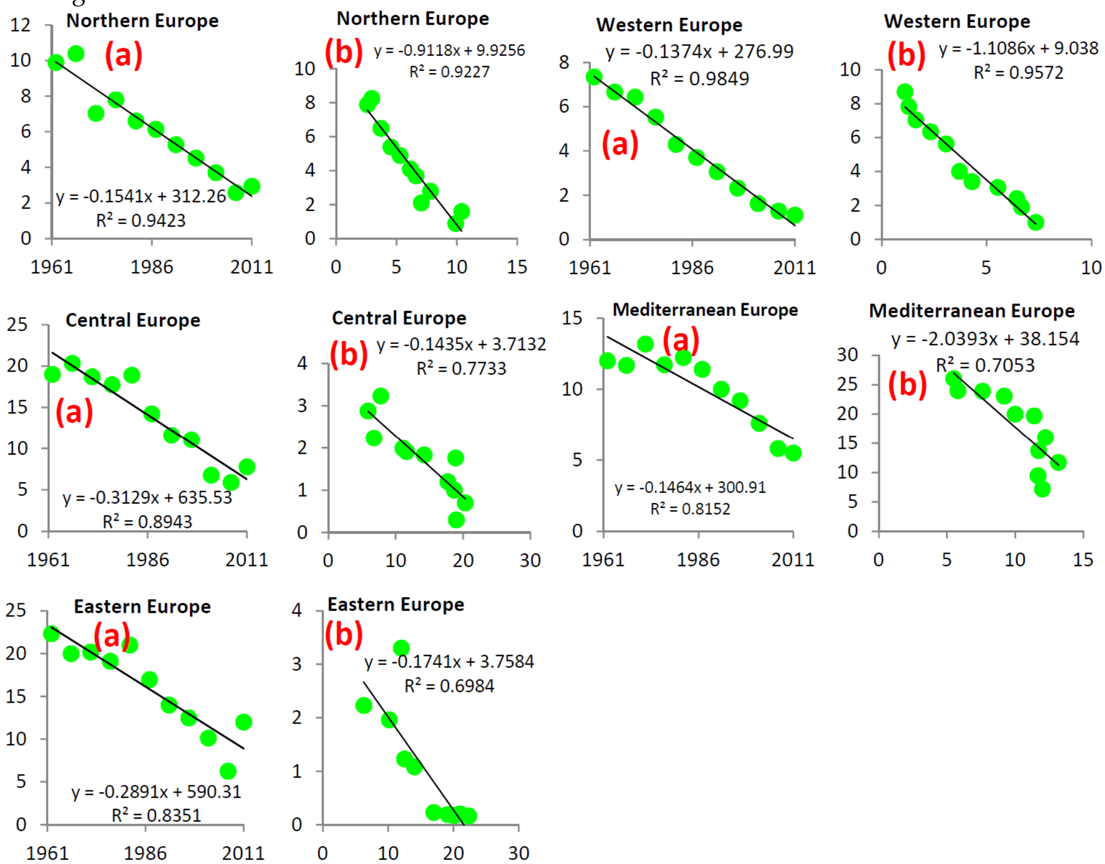

Northern Europe (a)
y = -0.1541x + 312.26
R² = 0.9423
Northern Europe (b)
y = -0.9118x + 9.9256
R² = 0.9227
Western Europe (a)
y = -0.1374x + 276.99
R² = 0.9849
Western Europe (b)
y = -1.1086x + 9.038
R² = 0.9572
Central Europe (a)
y = -0.3129x + 635.53
R² = 0.8943
Central Europe (b)
y = -0.1435x + 3.7132
R² = 0.7733
Mediterranean Europe (a)
y = -0.1464x + 300.91
R² = 0.8152
Mediterranean Europe (b)
y = -2.0393x + 38.154
R² = 0.7053
Eastern Europe (a)
y = -0.2891x + 590.31
R² = 0.8351
Eastern Europe (b)
y = -0.1741x + 3.7584
R² = 0.6984

Fig 6

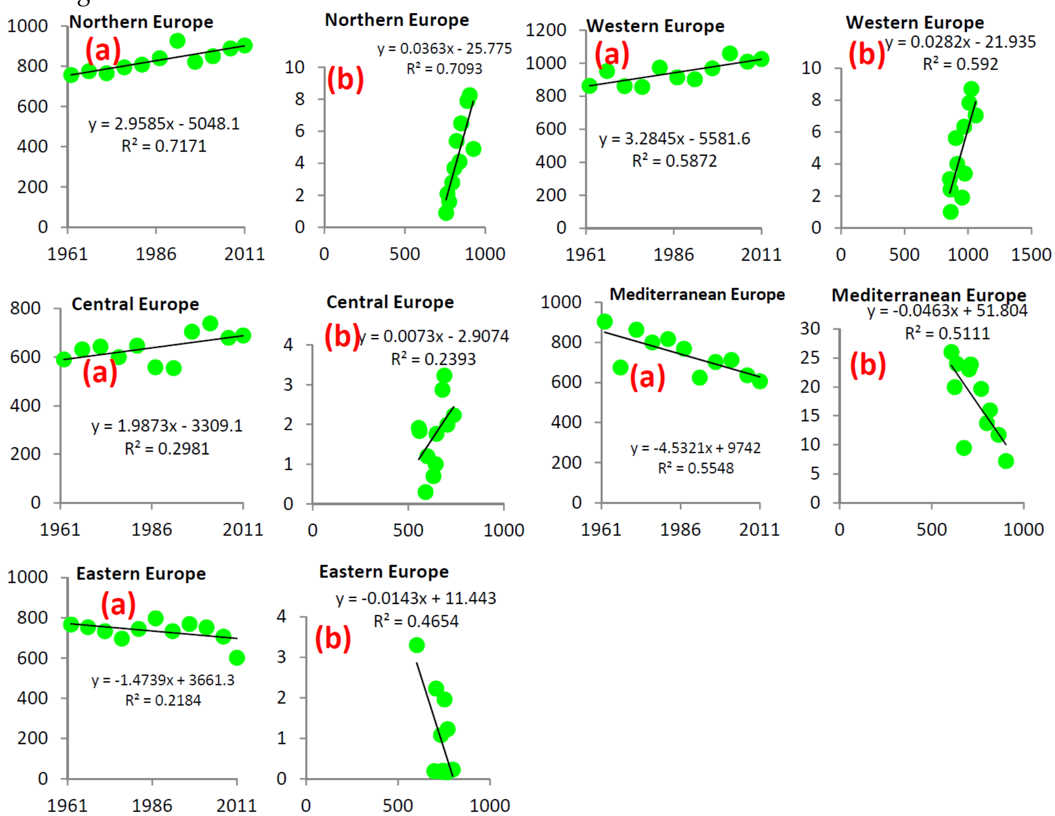

Northern Europe
(a)
y = 2.9585x - 5048.1
R² = 0.7171
Northern Europe
(b)
y = 0.0363x - 25.775
R² = 0.7093
Western Europe
(a)
y = 3.2845x - 5581.6
R² = 0.5872
Western Europe
(b)
y = 0.0282x - 21.935
R² = 0.592
Central Europe
(a)
y = 1.9873x - 3309.1
R² = 0.2981
Central Europe
(b)
y = 0.0073x - 2.9074
R² = 0.2393
Mediterranean Europe
(a)
y = -4.5321x + 9742
R² = 0.5548
Mediterranean Europe
(b)
y = -0.0463x + 51.804
R² = 0.5111
Eastern Europe
(a)
y = -1.4739x + 3661.3
R² = 0.2184
Eastern Europe
(b)
y = -0.0143x + 11.443
R² = 0.4654
1961
1986
2011

Fig 7

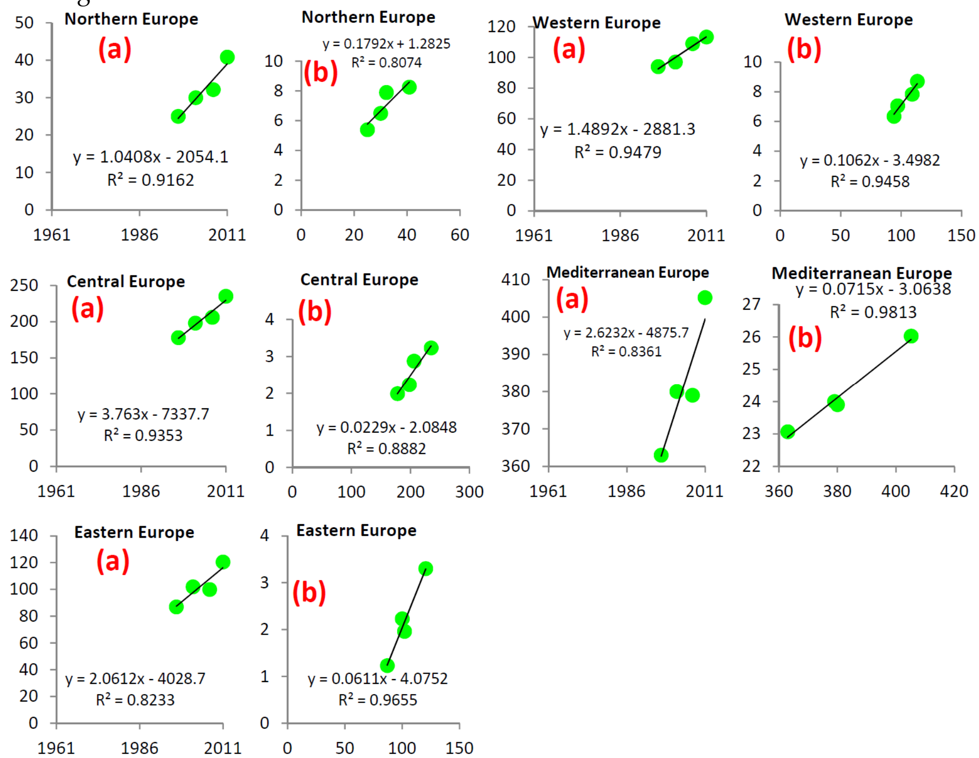

Northern Europe
(a)
y = 1.0408x - 2054.1
R² = 0.9162
Northern Europe
(b)
y = 0.1792x + 1.2825
R² = 0.8074
Western Europe
(a)
y = 1.4892x - 2881.3
R² = 0.9479
Western Europe
(b)
y = 0.1062x - 3.4982
R² = 0.9458
Central Europe
(a)
y = 3.763x - 7337.7
R² = 0.9353
Central Europe
(b)
y = 0.0229x - 2.0848
R² = 0.8882
Mediterranean Europe
(a)
y = 2.6232x - 4875.7
R² = 0.8361
Mediterranean Europe
(b)
y = 0.0715x - 3.0638
R² = 0.9813
Eastern Europe
(a)
y = 2.0612x - 4028.7
R² = 0.8233
Eastern Europe
(b)
y = 0.0611x - 4.0752
R² = 0.9655
1961
1986
2011

Fig 8

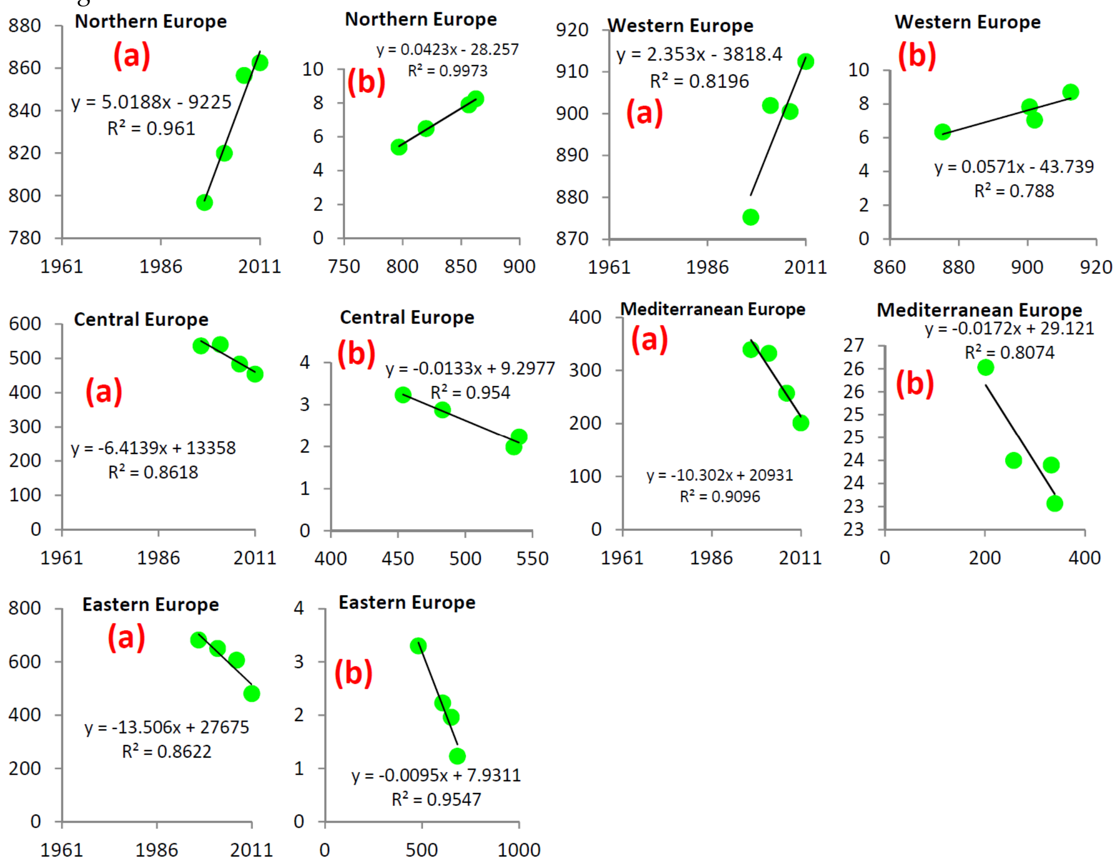

Northern Europe
(a)
y = 5.0188x - 9225
R² = 0.961
880
860
840
820
800
780
1961
1986
2011
Northern Europe
(b)
y = 0.0423x - 28.257
R² = 0.9973
10
8
6
4
2
0
750
800
850
900
Western Europe
(a)
y = 2.353x - 3818.4
R² = 0.8196
920
910
900
890
880
870
1961
1986
2011
Western Europe
(b)
y = 0.0571x - 43.739
R² = 0.788
10
8
6
4
2
0
860
880
900
920
Central Europe
(a)
y = -6.4139x + 13358
R² = 0.8618
600
500
400
300
200
100
0
1961
1986
2011
Central Europe
(b)
y = -0.0133x + 9.2977
R² = 0.954
4
3
2
1
0
400
450
500
550
Mediterranean Europe
(a)
y = -10.302x + 20931
R² = 0.9096
400
300
200
100
0
1961
1986
2011
Mediterranean Europe
(b)
y = -0.0172x + 29.121
R² = 0.8074
27
26
26
25
25
24
24
23
23
0
200
400
Eastern Europe
(a)
y = -13.506x + 27675
R² = 0.8622
800
600
400
200
0
1961
1986
2011
Eastern Europe
(b)
y = -0.0095x + 7.9311
R² = 0.9547
4
3
2
1
0
0
500
1000

Fig 9

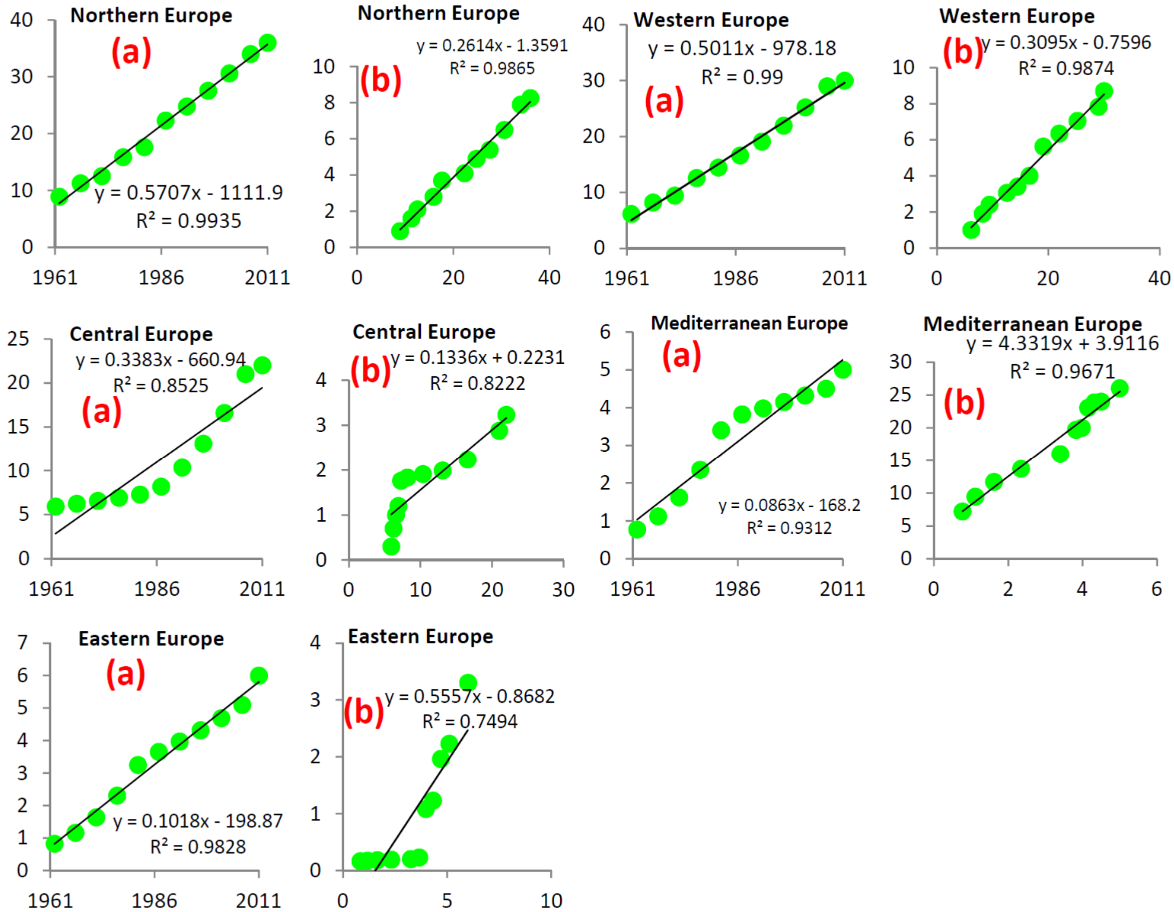
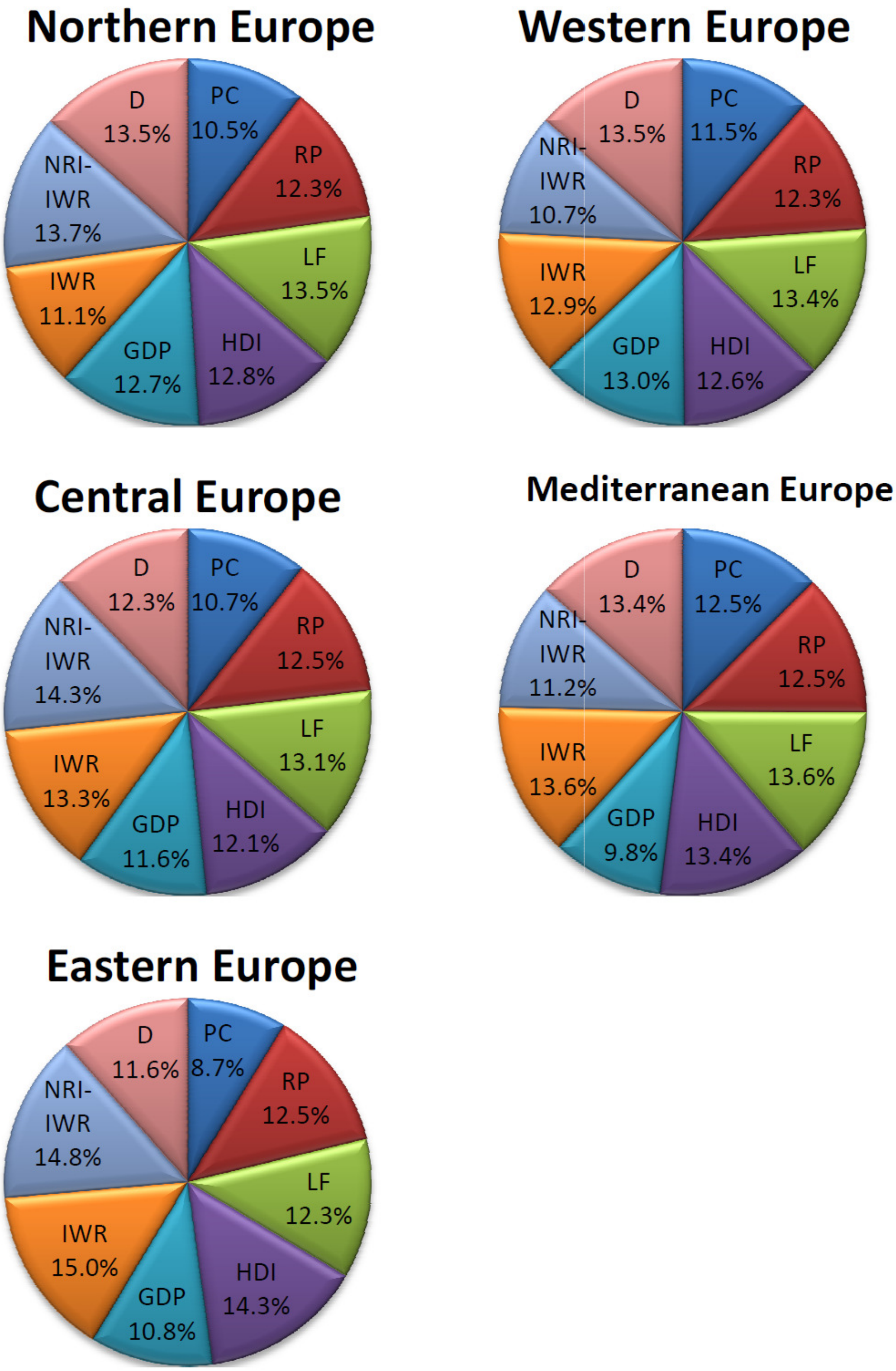

Northern Europe
(a)
y = 0.5707x - 1111.9
R² = 0.9935
Northern Europe
(b)
y = 0.2614x - 1.3591
R² = 0.9865
Western Europe
(a)
y = 0.5011x - 978.18
R² = 0.99
Western Europe
(b)
y = 0.3095x - 0.7596
R² = 0.9874
Central Europe
(a)
y = 0.3383x - 660.94
R² = 0.8525
Central Europe
(b)
y = 0.1336x + 0.2231
R² = 0.8222
Mediterranean Europe
(a)
y = 0.0863x - 168.2
R² = 0.9312
Mediterranean Europe
(b)
y = 4.3319x + 3.9116
R² = 0.9671
Eastern Europe
(a)
y = 0.1018x - 198.87
R² = 0.9828
Eastern Europe
(b)
y = 0.5557x - 0.8682
R² = 0.7494
1961
1986
2011

Fig 10


Northern Europe
PC 10.5%
RP 12.3%
LF 13.5%
HDI 12.8%
GDP 12.7%
IWR 11.1%
NRI-IWR 13.7%
D 13.5%
Western Europe
PC 11.5%
RP 12.3%
LF 13.4%
HDI 12.6%
GDP 13.0%
IWR 12.9%
NRI-IWR 10.7%
D 13.5%
Central Europe
PC 10.7%
RP 12.5%
LF 13.1%
HDI 12.1%
GDP 11.6%
IWR 13.3%
NRI-IWR 14.3%
D 12.3%
Mediterranean Europe
PC 12.5%
RP 12.5%
LF 13.6%
HDI 13.4%
GDP 9.8%
IWR 13.6%
NRI-IWR 11.2%
D 13.4%
Eastern Europe
PC 8.7%
RP 12.5%
LF 12.3%
HDI 14.3%
GDP 10.8%
IWR 15.0%
NRI-IWR 14.8%
D 11.6%