Criteria for Evaluation of Agricultural Land Suitability for Irrigation in Osijek County Croatia

Tadić, Lidija

16

Criteria for Evaluation of Agricultural Land Suitability for Irrigation in Osijek County Croatia

Lidija Tadić
Faculty of Civil Engineering
University of J. J. Strossmayer Osijek
Croatia

1. Introduction

Considering the basic purpose of agriculture – ensuring of sufficient quantities of food with appropriate quality and unquestionable health soundness, the management of land should not sideline environmental and social aspects. Today, modern agriculture and rural development besides food production, involves ecosystems sustainability and rising values of landscape and rural space in general. Irrigation also must be part of this approach to modern food production. Irrigation in Europe is developing continuously, especially in Mediterranean countries (France, Greece, Italy, Portugal and Spain) resulting in the increase of water quantities used for irrigation. Many countries which recently joined the EU also develop their irrigation systems and this trend will probably continue. So, the future development must be done according to local natural conditions, social and economic background. As an undertaking which ensures optimal water supply for demands of agricultural production, the irrigation might have significant impacts on environment, which should be foreseen and targeted by use of economically acceptable activities in order to eliminate or lower those potentially negative impacts to the acceptable levels. The aim of every project of the hydro-melioration system, including irrigation is to ensure positive long-term effects of the implemented system which is achieved by: anticipation of potential problems, defining the means of monitoring, finding the ways to avoid or reduce problems and promotion of positive effects (Tadić, Bašić, 2007).

It can be said that importance of irrigation grows every year, even in the countries which are not located in arid or semi-arid regions. General objectives of irrigation implementation in any given area are:

- **Increasing of agricultural production and stability of production during dry years,**
- **Introduction of new more profitable crops on the market,**
- **Reduction of food import and stimulation of domestic agricultural production,**
- **Reduction of climate change impacts, first of all frequent drought periods,**
- **Reduction of agricultural land,**
- **Negative water balance during the vegetation period,**
- **Increase the interest for farming and employment in the agriculture (Romić, Marušić, 2005)**

Irrigation systems should be based upon principles of integrated water resources management and sustainable management taking under consideration potentials and restrictions of specific river basin. Several levels of data evaluation are needed:

- **Physical plans give basic information of agricultural areas, present state and future development, possible increase or decrease of the area.**
- **Soil properties are one of the most important factors because soil categorization from very suitable to not suitable for irrigation has a great impact on the final decision.**
- **Agricultural potential, mechanisation and other resources of agricultural production, including tradition of growing crops and interest of local people for irrigation. Part of the agricultural potential is developed land drainage and flood protection system.**
- **Analysis of hydrological and meteorological data, particularly analysis of drought, defines the real necessity for implementation of irrigation. Frequency, intensity and duration of water deficit in the vegetation period indicate the crop water requirement which has to be assured.**
- **Availability of water resources is one of the most restrictive criteria, where two aspects have to be considered – water quantity and quality. In the area with evident water shortage, for example Mediterranean islands, some alternative sources of water have to be applied.**
- **All possible environmental impacts of irrigation implementation should be recognized in the area due to its vulnerability and sensitivity on changes by its structure or genesis (e.g. karst regions).**

Basically, above mentioned levels of evaluation are given according to the DPSIR (driving force- pressure-state-impact-response) relationship, which is dynamic in time. Sustainability of the irrigation system can be achieved only by its constant improvement and development. Figure 1 gives a scheme of sustainable use of water resources in irrigation.

If any of the components in the DPSIR relationship changes in time, the whole scheme changes as well. The aim of sustainable approach is to achieve positive movement of the whole process, which means the decrease of pressure and unwanted impacts together with improvement of the state with ensuring domination of positive impacts. This process will be possible with strong response development.

Starting point in irrigation development is the initiative of farmers, investors and final users of the irrigation system. All other phases will be elaborated in the following chapters.

2. Physical planning

The irrigation systems are very pricey and complex undertakings and their implementation needs clear economic analysis, and no omissions should be allowed during their planning.

The initial phase in planning of irrigation systems is identification of spatial limitations as defined in physical planning documentation of either Municipality or County. Physical planning documentation, apart from natural and social characteristics of the analysed area, define the scope of economic development, including transportation, electric power, water management and other activities within the space, as well as limitations to construction in regard to protected areas.

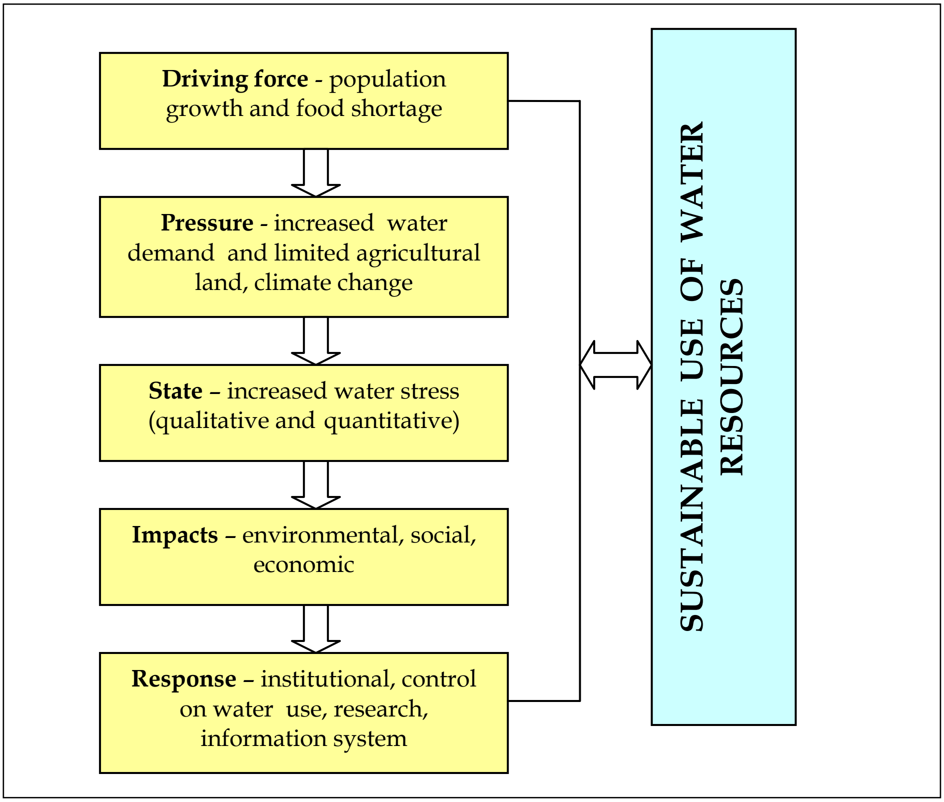


Fig. 1. Scheme of sustainable approach to irrigation (Boss, Burton 2005)

Anticipated change in landuse of a certain area, i.e. from agricultural to construction land or intersecting of the agricultural area with the large-scale infrastructure project such as road or railway, derivative channel, navigable channel or transmission line may impact a decision regarding withdrawal of construction of the irrigation system on certain agricultural land regardless of needs and natural potential.

Some of the proposed activities in space do not need to fully stop development of an irrigation system but may significantly influence the choice of irrigation methodology. These may also provoke additional costs towards implementation of environmental protection measures in the case if agricultural land is located within protected water well site or in the vicinity of areas protected for their natural values. Using physical planning documents it is possible to establish availability of water resources as well as planned activities on waterways.

For determination of agricultural land suitability for irrigation and economic feasibility of the system it is very important to consider the existing access road and electric power infrastructure, which are very important aspects for the investment project.

3. Soil suitability for irrigation

The following group of parameters which define the need for irrigation but also the its' methodology are characteristics of soil. The soil characteristics are the result of paedogenesis factors and processes, which have been influencing their mechanical, physical and chemical properties during the long period of time, and the most importantly its capability of movement and storage of water in the soil.

Along with these factors long periods of cultivation and use in intensive agriculture have contributed to significant anthropogenesis of initial natural characteristics.

Soil in this case is being analysed as a cultivation space in which during the vegetative period is lacking specific amount of water and which has to be introduced by artificial means, while getting the best possible effects:

- Maximum usage of added water which is firstly, economic but also environmental condition;
- Preservation of soil structure – during which it is necessary to assess the water regime in the soil during the entire year, especially if there is a risk of soil salinisation.

Therefore, for the assessment of soil potential for irrigation the following parameters are of key importance: soil depth, drainage and flood protection, land slope and erosion potential, water capacity, soil salinity, quantity of nutrients, etc. Based on analysis of these parameters, soli potential for irrigation is evaluated for the area of proposed activity, and also the most suitable methodology and measures required for improvement of existing soil potential are proposed.

Considering the potential for irrigation, soils are usually being classified as excellent (P-1), suitable (P-2) and restrictively suitable (P-3). In classes of potential P-2 and P-3 it is necessary to undertake hydro-technical and agro-technical interventions of different scope, which would increase the degree of their potential for irrigation (Tadić, Ožanić, et.al.2007).

This creates additional costs which investor has to bear in order to implement proposed irrigation system, but this system will then enable rational usage of water, preservation of soil characteristics and limiting of unwanted consequences to a minimum.

In specific cases, there is an occurrence of soil characteristics, which would categorise the soil as permanently inadequate for implementation of irrigation because the costs of soil characteristic's improvement would be immensely high and would impact the economic feasibility of the system, i.e. areas without surface and ground drainage, which is necessary due to retention of water in plant roots zone, or areas with a significant inclination which are prone to water erosion.

For example, Figure 2 presents total agricultural area of Osijek County, which is about 280.000 ha (100%). Part of it belongs to the Nature Park and well site for public water supply, and intensive agricultural production are not allowed (30%). Part of the area belongs to the roads, water bodies and settlements (33%), and about 1% is completely unsuitable for irrigation. The rest of the agricultural land, about 36%, can be considered as more or less suitable for irrigation according to physical and chemical properties, environmental characteristics and drainage conditions. This type of soil evaluation was made in order to avoid negative irrigation effects on the soil and to minimize the costs of land reclamation.

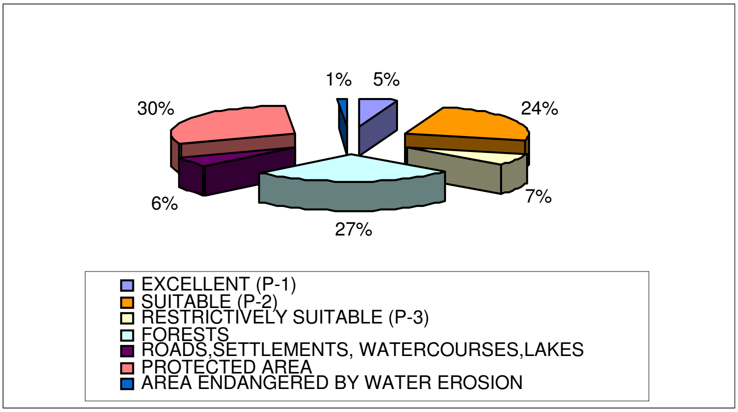


Fig. 2. Example of land suitability for irrigation in Osijek County , Croatia (Tadić, 2008)

4. Agricultural potentials

Introduction of the irrigation system implies the existence of interest of agricultural producers for improvement in production means of agricultural goods. The aim of irrigation is increase and stabilisation of yield and increase in market value of final product. Financial investments in irrigation are considerable, which means that the users should have on their disposal land, machinery, but also the knowledge which would enable them to reach the wanted goal. Existing land protection from outside waters (flood protection) and excessive surface and ground waters, and existence of the drainage system for surface and ground waters are important prerequisites for construction of an irrigation system. Agricultural potential also means readiness for introduction of new crops, which are more profitable on the market and which cultivation is impossible without irrigation.

In Croatia, majority of the continental part of the country is the traditionally agricultural area with relatively high level of agricultural production with regard to land organization, as well as production technology, mechanization and application of scientific and contemporary methods in agricultural production. Main characteristics of present crop production are as follows: orientation toward an extensive food production and small number of cultivated crops that are present on small acreage, low presence of fruit and vegetables and inadequate use of quality land resources suitable for production diversification (Tadić et al. 2007). Introduction of irrigation could enlarge the strength of present agricultural production with the introduction of more profitable, water dependent sensitive crops.

5. Irrigation necessity

The most common way of elaboration of irrigation necessity is an analysis of water deficit during the vegetation period. It causes reduced actual evapotranspiration compared to the potential evapotranspiration. Water deficit (drought) in different crop development stages causes stagnation in growth and finally reduces the yield. Drought damages depend on duration, strength and intensity of drought, which is basically characterized by geographical characteristics, soil type and sort of crop as well. In Croatia, the most severe damages are in vegetable yields, and the least in cereal yields.

During recent years many results were published, which prove damages caused by drought during the vegetation period. Table 1 presents yield reduction for crops, which are specific in Croatia.

The emphasis is given to the influence of soil type. Light soil with poor water retention capacity is more vulnerable to the water deficit.

CROP	Water deficit (mm)		Yield reduction (%)			
			Light soil		Heavy soil	
	Average year	Dry year	Average year	Dry year	Average year	Dry year
Corn	187	287	35,4	61,5	27,1	54,4
Sugar beat	246	349	36,7	58,7	29,1	52,6
Tomato	188	260	37,3	54,8	29,8	47,9
Apple without mulch	180	294	25,7	49,4	20,8	41,8

Table 1. Water deficit and yield reduction in average and dry years observed depending on soil conditions (Tadić,2008)

The fact that different crops have different sensitivity to water deficit affects the decision on irrigation implementation and cost-benefit analysis of a planned irrigation system. Intensity of crop diversification and implementation of irrigation are strongly influenced by trends on the market.

Decrease of the yields due to the water deficit can be expressed in several ways. One of them is the linear statistical relationship between total evapotranspiration and yield of cereal grains in some climate zone (Hoffman et al.2007). It can be given by equation:

$$Y_g = bET + a \tag{1}$$

where: Y_g= yield (t/ha)
ET= vegetation season evapotranspiration (mm)
b=slope of the yield-ET line (t/ha mm)
a=constant (t/ha).

The second one is very often used relation proposed by FAO (Doorenbos et al.1986):

$$\left(1-\frac{Y_a}{Y_m}\right)=k_y\left(1-\frac{ET_a}{ET_m}\right) \tag{2}$$

where: Y_a = actual harvested yield (t/ha)
Y_m= maximum harvested yield (t/ha)

k_y= yield response factor
ET_a= actual evapotanspiration (mm)
ET_m= maximum evapotranspiration (mm)

Increase in yield can be achieved by the sufficient amount of available water which will increase actual evapotranspiration in the vegetation period during crucial crop development stages.

6. Drought analysis

Draught ¸may vary in time and space, depending on climate and hydrological conditions of some area. According to World Meteorological Organization, drought is a protracted period of deficient precipitation with high impacts on agriculture and water resources. There are three types of droughts: meteorological, agricultural and hydrological drought. Any of these types can make a serious harm on agricultural production and economy in general. Long and frequent drought periods can cause desertification characterized by water shortage, overexploitation of available water resources, change and depletion of natural vegetation, reduction of crop varieties, reduction of water infiltration, etc. (EEA, 2000). Proper analysis of drought as an extreme hydrological event is essential for identification of irrigation necessity as a successful measure against it. In another hand, the same level of drought severity can cause different impacts in different regions due to the underlying vulnerabilities. Basic meteorological and hydrological data, precipitation, air temperature, evapotranspiration, relative humidity, wind, insolation and discharges must be available to provide proper analysis of drought. Figure 3 presents total annual precipitation and precipitation in growing period observed in the period from 1951 to 2000 on meteorological station Osijek, Croatia. The both trend lines show decreasing of precipitation. There is no significant decreasing during the vegetation period, which is good, but it indicates smaller possibilities of groundwater recharge during winter time.

Figure 4 presents average annual air temperature, and average air temperature during growing season observed also in the period from 1951 to 2000 on meteorological station Osijek. Increase of air temperature is obvious in both figures, but it is still lesser during the vegetation period.

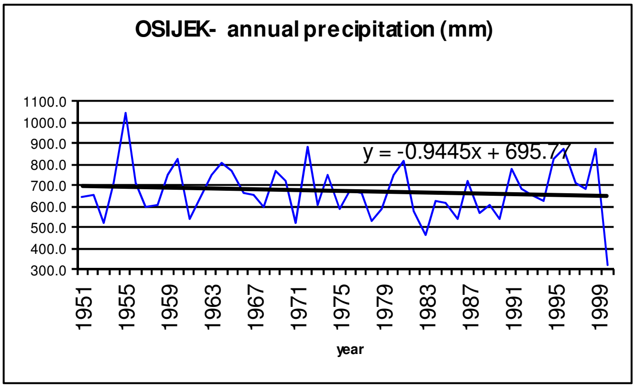
There are a lot of methods for drought estimation, developed for different climates and geographical features. Analysis of drought is very complex and the identification of a moment when drought starts and becomes extreme is very sensitive and variable.

There are two basic groups of methods: agro-climatic and hydrological. The methods in the first group are mostly based upon above mentioned two parameters, precipitation and air temperature. They give characteristics of the climate in some area with regards to the agriculture. The most common are:

- Lang's precipitation factor (KF)

$$KF = \frac{P}{T} \tag{3}$$

where: P= annual precipitation (mm) and T=average annual air temperature (°C)



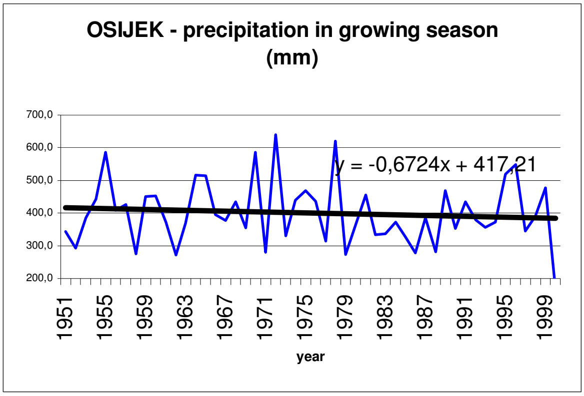


Fig. 3. Average annual precipitation and precipitation in growing season in the period 1951-2000, Osijek, Croatia

- Thronthwaite's humidity index (I_{pm})

$$Ipm = 1{,}65\left(\frac{P}{T+12{,}2}\right)^{10/9} \tag{4}$$

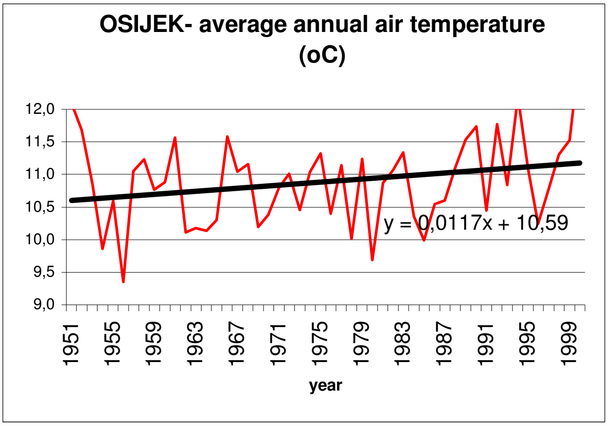
where: : P= annual precipitation (mm) and T=average annual air temperature (°C)

- de Martone's draught index (I_s)

$$Is = \frac{P}{T+10} \tag{5}$$

where: P= annual precipitation (mm) and T=average annual air temperature (°C)

- Walter's climate diagram gives relationship between precipitation and air temperature or evapotranspiration and in that way indicates the necessity of irrigation and the length of irrigation period . According to Walter's climate diagram, irrigation is necessary only in July and August .



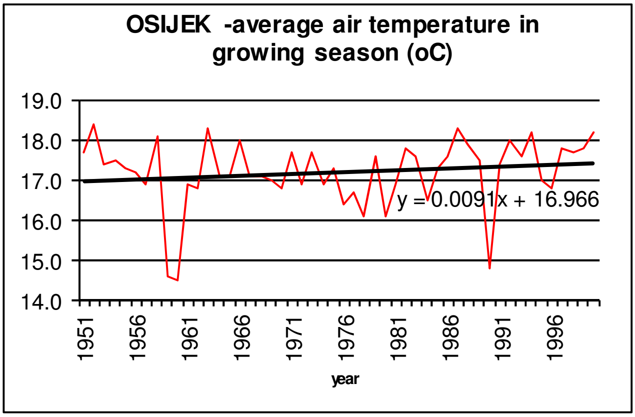


Fig. 4. Average annual air temperature and air temperature in growing season in the period 1951-2000, Osijek, Croatia

Table 2 presents climate description obtained by three of these methods applied on data of precipitation and air temperature for Osijek (1951-2000).

Lang's precipitation factor (KF)		Thronthwaite's humidity index (I_{pm})		de Martone's draught index (I_s)	
Extremes and average values	Climate description	Extremes and average values	Climate description	Extremes and average values	Climate description
KF_{min} =24,6	Arid	$I_{pm\ min}$=20,8	Semi-arid	$I_{s\ min}$=13,9	Dry sub-humid
KF_{aver}=62,2	Sub-humid	$I_{pm\ aver}$=8,1	Sub-humid	$I_{s\ aver}$=32,3	Humid
KF_{max}=98,4	Humid	$I_{pm\ max}$=75,4	Humid	$I_{s\ max}$=50,6	Per-humid

Table 2. Drought estimation obtained by Lang's precipitation factor, Thronthwaite's humidity index and de Martone's drought index

Results in Table 2 indicate climate characteristics of the region, considering annual data. They vary in the range from arid to per-humid. The average values show sub-humid to humid climate characteristics. Besides, Walter's climate diagram shows the need of irrigation in June and July what corresponds with other approaches.

The methods in the second group also use meteorological and hydrological parameters for drought identification, but they can be considered as more comprehensive and reliable.

Because of the great variety of approaches and methods, it is recommended to use more than one method to estimate an intensity of drought periods and necessity of irrigation. In that way, it is possible to give more accurate estimation of water deficit in some region. Some of the most frequently used methods will be briefly explained.

- Standard Precipitation Index (SPI) is one of the most popular methods, proposed as a most appropriate method for any time scale and any region in the world. The SPI is an index based on the probability of precipitation using the long-term precipitation record. A drought event begins when the SPI is continuously negative and ends when SPI becomes positive (WMO).

$$SPI_n = \frac{1}{\sigma_n}\left(\sum_{i=1}^{n} P_i - P_n\right) \tag{6}$$

where: n= number of monthly precipitation data,
P_i = precipitation in each month (mm),
Pn= average precipitation of the observed period (mm),
σ_n =standard deviation.

- Deciles is a method in which monthly precipitation sums from a long term record are first ranked from highest to lowest to construct a cumulative frequency distribution. The distribution is then divided into 10 parts (deciles). A longer precipitation record (30-50 years) is required for this approach.
- The Rainfall Anomaly Index (RAI) also ranks the precipitation data of the long-term period in the descending order. The average of the 10 highest values as well as that of the 10 lowest precipitation values were calculated (Figure 7).

$$RAI = \pm 3\frac{P - \overline{P}}{\overline{E} - \overline{P}} \tag{7}$$

where $\overline{P}$ is average of the annual precipitation for each year (mm) and $\overline{E}$ is average of 10-extrema for both positive and negative anomalies (mm).

- The Stochastic Component Time Series (SCTS) is given by the equation

$$Z\varepsilon = \frac{\varepsilon t - \overline{\varepsilon}}{\sigma\varepsilon} \tag{8}$$

where εt is total annual rainfall for each year (mm), $\overline{\varepsilon}$ is average annual rainfall for each year (mm) and $\sigma\varepsilon$ is standard deviation of rainfall for each year (Figure 5).

These methods applied on precipitation data observed on Osijek meteorological station (1951-2000) give results in Figure 5 and Table 3.

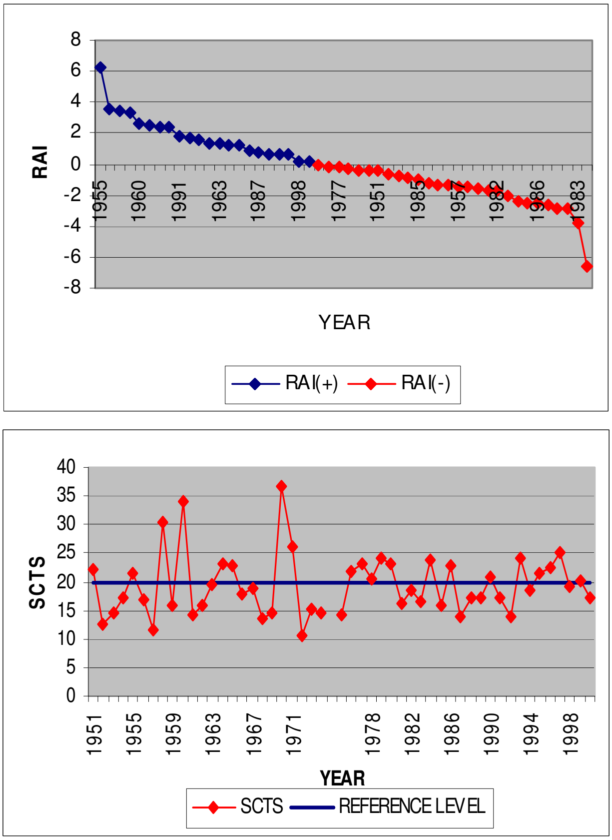


Fig. 5. Application of RAI method and SCTS method on precipitation data of Osijek, Croatia (1951-2000)

Rainfall Anomaly Index (RAI) shows that 28 years in the observed period were dry and 22 were less dry. According to Stochastic Component Time Series (SCTS) 29 years were dry and 21 years less dry.

Standard Precipitation Index (SPI)		Deciles	
Value	Classification of dryness	Months (%)	Classification dryness
-4,4	Extremely dry	23	Average
		56,5	Below the average
		20,5	Very much below the average

Table 3. Application of SPI Method on precipitation data of Osijek, Croatia (1951-2000)

Standard Precipitation Index (SPI) indicates the considered period extremely dry and Deciles classified 77% of the total number of months in the 50 years long period as below and very much below the average.

In the hydrological analysis, it is very often stressed that data series of precipitation, discharge, water level, etc., should be as long as it is possible. The length of the data series should guarantee reliability of final results and conclusions. This can be questioned due to the process present in recent decades, often referred to as a climate change. Hydrological analysis based upon a long-term data series (50, 70 or 100 years) sometimes can lead to the false conclusions. In that case, it is recommended to apply the RAPS (Rescaled Adjusted Partial Sums) method. This analysis helps us to recognize any change in time series, like periodicity, sudden leaps or smaller errors in the data series. Figure 8 and 9 present two examples of RAPS implementation. The example on Figure 6 shows annual precipitation data (1948-2008) of Vela Luka and Korčula, small places in Korčula Island in Adriatic Sea. The complete data series show the negative trend line of the same magnitude. Application of RAPS resulted by obvious break in the both data series, which occurs in 1982 and the both sub-series have the positive trend line (Ljubenkov, 2010).

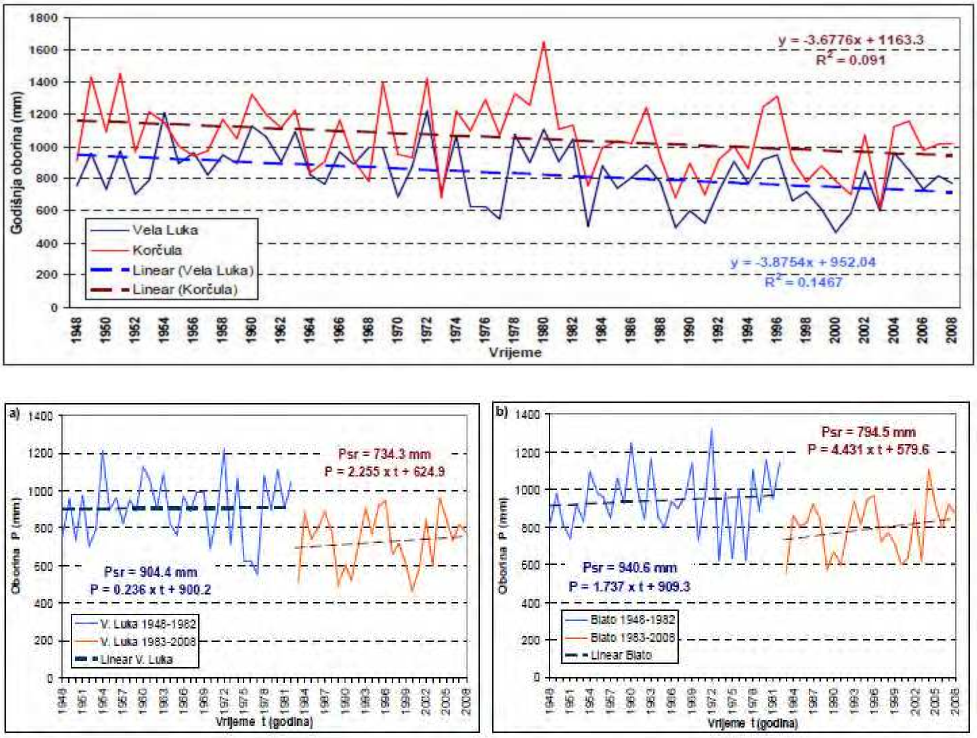


Fig. 6. Application of RAPS method on precipitation data of Korčula, Croatia (1948-2008) (Ljubenkov, 2011)

Figure 7 presents application of RAPS method on annual precipitation data of Osijek (1951-2000) and it shows two breaks, in 1974 and 1990. The first data sub-series 1951-1974 have a mild positive trend line, and next two sub-series have emphasised negative trend lines. Comparing to the complete annual data serine presented in Figure 3 with the continuous negative trend line the difference is significant.

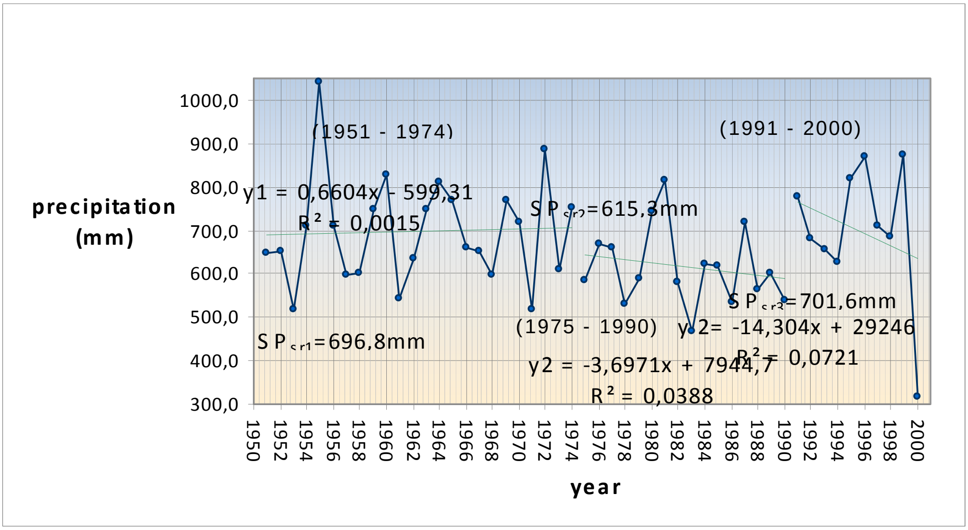


Fig. 7. Application of RAPS method on precipitation data of Osijek, Croatia (1951-2000)

7. Water availability

The next important precondition for implementation of irrigation systems is availability of water and is one of the most limiting factors. Water resources are estimated in accordance to three criteria: quantity, quality and location. Together they form water potential (Đorđević, 1990). Quantities of water required for irrigation are considerable and depend on water deficit, crops and size of the area. All three characteristics have to be met in order for water capture to satisfy long-term needs and if only one of them is not met, quantity, quality or accessibility of location such source of water becomes questionable. Usual sources of water for irrigation are rivers, ground water tables and reservoirs, and in the more recent times various non-conventional sources. In the majority of Europe and world, the shortage of water is becoming more emphasised, especially in some regions, and every new consumer of water significantly affects the water balance. Large rivers often have multiple uses: navigable waterway, electric power generation, capturing of water for different purposes, the recipient of waste waters and provision of quality water environment for a number of species, and all these requirements have to be met without conflicts in interest. About 30% of abstracted water in Europe is used for irrigation, but in some Mediterranean countries (Italy, Spain, Greece) this percentage exceeds 55-80% (Nixon et al, 2000).

7.1 Open watercourses

Favourable conditions found in open water bodies for capturing of water for irrigation depend on their hydrological regime. Waterways with the glacial hydrologic regime are more suitable, since they have maximum flows during beginning of summer (June), while waterways with the pluvial regime have minimal flows during summer months in vegetation periods. It is important not to forget the global trends in the decrease of water quantities, increase of frequency and duration of low water regimes, which also cause droughts (Bonacci, 2003). Therefore, capturing possibilities are significantly reduced at low and average water flows for purposes of irrigation during vegetation periods. The limiting factor for such waterways is maintenance of biological minimum required for sustaining of life in water. Quality of water in open waterways generally meets requirements for irrigation.

7.2 Ground water

Ground water usage in irrigation is a very sensitive, but also easily available and cheap solution. Its quality is excellent and there are no qualitative restrictions for irrigation or any other usage. In the most of the countries it is the major public water supply resource. Groundwater overexploitation can endanger capacities of public water supply systems. That is the basic reason of its protection by heavy regulations in many European countries, and in Croatia as well.

Ground water exploitation is especially sensitive in the coastal region due to the possibility of salt water intrusion in aquifers.

In some countries, like Germany, Portugal, Lithuania special permission for groundwater usage in irrigation is required, and the exploited quantities are supervised by official persons (Tadić, Marušić, 2008). In Croatia, possibilities of groundwater usage in irrigation are limited to the resources which can be renewed in the one year.

7.3 Reservoirs

The construction of reservoirs represents a very acceptable but expensive solution applicable in cases where no other sources of water are present. Since reservoirs are very expensive structures they are often constructed as multipurpose structures having to meet requirements of all users, which may lead to conflict of interest, for example, generation of electric power and usage of water for irrigation. Quality of water in the reservoir depends on its geographic location and surrounding area, but in most cases meets the required quality for irrigation.

Natural lakes can have a great potential for usage in irrigation in the quantitative and qualitative sense. However, they are very often protected due to their biological values and landscape features.

7.4 Non-conventional water resources

Use of non-conventional water resources imply the use of treated waste water, rainwater, saline water and melted snow in regions where there are no sufficient amounts of the water present. Use of these sources of water for irrigation in a safe way for agricultural land and environment altogether, is very expensive, and is made possible by intensive development of technology for water treatment. Waste water re-use and seawater desalination are increasing in Europe (e.g. Southern Europe). Application of re-used water should be subject to more research on health aspects.

In Croatia due to wealth of water resources, these forms of water capture are rare, but it is recommended to use captured rainwater on Croatian Islands (Bonacci, 2003).

8. Environmental issues

In the case where there are protected areas in the vicinity of agricultural land, implementation of irrigation should not make any negative impacts on them. All environmental impacts of irrigation should be recognized and evaluated. According to the categorisation of environmental impacts, the expected impacts, which arise due to application of irrigation are:

- According to the *type of impact* – impacts on natural assets, predominantly on water and soil (physical environment), but also on quality of life (social-economic impacts),
- According to the *duration of impact* – long term,
- According to *the occurrence in time and space* - direct, since they occur on exact area, which is being irrigated and during the period of irrigation, but also *indirect*, which means that they also impact the downstream and upstream soils, and frequently appear only after significant periods of time,
- According to the *number of impacts* - individual and cumulative (Tadić, 2009).

All those elements make the impacts very complex and hardly predictable, while the intensity of their occurrence depends on properties of the watershed, water abundance, properties of soils, quality of water being used for irrigation, as well as depending on the applied methodology and means of irrigation.

This implies that the application of irrigation may leave permanent (irreversible) consequences on the environment if the impacts are not recognised, foreseen and possibly mitigated or completely prevented. Some of the changes are easily noticed and quantified, but there is a vast number of indirect impacts that are delayed in time after the prolonged application of irrigation and often appearing outside of the irrigated area. The solutions are found in systematic planning, designing, construction and operation of undertaking. For this reason, large-scale irrigation projects should include environmental impact assessment prior to the construction which will establish the possible alteration to the environment and assess the sustainability of the system.

8.1 Impacts on water

The irrigation has quantitative and qualitative impacts on surface and ground waters.

8.1.1 Impacts on water balance

Any capture of water will impact the existing water balance. Considering the occurrence of water resources in time, every uncontrolled capture, especially in dry periods, may result in undermining of minimum biological requirements of waterways. Some watercourses have minimum flows at the time of vegetation growth when there is a need for irrigation. In smaller waterways and streams this issue is even more pronounced. Hydrologic regime of surface waters is directly related to the levels of ground waters (Romić, Marušić, 2005). During the dry periods, ground waters feed the waterways while in the period of high-water levels, surface waters feed the ground waters. Intensive capturing of surface waters combined with usually water level slope result in increased hydraulic gradient in relation to ground waters. Impacts of capturing of water above renewable limits may appear after prolonged periods of utilisation and may result in lowering of ground water levels on wider area. In coastal areas lowered levels of ground waters may cause intrusion of salt water. Continuous lowering of ground waters, along with changes in water balance, may have effect on other economic activities and water customers. Such changes have the significant impact on sensitive ecosystems, firstly, on low-lying forests and wetlands.

As it was mentioned before, one of the solutions for ensuring supply of sufficient quantities of water for irrigation is construction of water reservoirs. Such structures are considered to be very sensitive hydro-technical undertakings, especially if they are reservoirs with large volume and area, which may have significant impacts on the environment, including both positive and negative effects. With construction of reservoirs, there is a change in land-use of the area (Tadić, Marušić, 2001). The reservoirs are considered as the most controversial hydrothechnical structures which on the one side enable rational use of water collected during wet periods of the year (flood protection), and from the other side have number of environmental consequences – change of landuse, impacts on landscape and wider environment, change of hydrological and biological characteristics of a waterway. Land area is being turned over into a water surface, which changes the fundamental biological structure. Furthermore, the transition from natural to the controlled regime of a waterway after construction of the reservoir causes the number of changes. One of them is a reduction of sediment transport, which is being accumulated and deposited within the reservoir along with increased kinetic energy of water, which affects river bed and banks downstream. Reservoirs have positive effects on the regime of low and high water level periods and consequently, on replenishing of ground water resources in the downstream area.

Changes in the hydrologic regime related to capturing of water may increase concentration of water pollution and generally affect the good status of water quality. Areas exceptionally sensitive to changes in water balance are protected ecosystems whose subsistence is dependent on sufficient water quantities, water capture areas, waterways with decreasing characteristic of water flow trends and coastal areas. One of the sensitive water resources are narural lakes and use of water from natural lakes is not recommended. Some of the lakes in Croatia are already under protection, and there is an incentive to protect all natural lakes in order to preserve values of their ecosystems (Romić, Marušić, 2005).

8.1.2 Impacts on water quality

Water pollution is broad term, but it is generally defined as the reduction of quality due to introduction of impurities and potentially harmful substances. Agriculture is one of the largest non-point sources of water pollution, which is generally hard to identify, measure and monitor. The irrigation is undertaking, which impacts the changes in the water regime of soil, and consequently, on transport of potentially harmful substances to the surface and ground waters (nitrates, phosphorus) causing the eutrophication. Plant manure, residuals of pesticides and other components of agricultural chemicals in natural and irrigated conditions with changed water balance are subject to flushing from soil, and as such they represent a pollution threat to water resources. The speed and intensity of pollution transport from soil depend on a number of factors related to hydrogeological and soil characteristics of the area. In this regard, the especially sensitive are karst and alluvial areas with the relatively thin topsoil layers. Possible protection measures include:

- Adjustment of existing regulations to international standards, or regulation of issues, which are not so far covered by the laws (Ayers, Westcot, 1985)
- Setting up of monitoring system, especially in case where irrigation is present;
- Setting up of an efficient supervision system.

8.1.3 Protected areas

Significant limitations to intensification of agriculture also referring to irrigation are areas under protection. For example, protected drinking water areas in Republic of Croatia amount to 19 % of land areas, while regulations are limiting agricultural production within zones I and II of sanitary protection, with zones III and IV of sanitary protection having no limitations. Meanwhile on water protection areas there should be no priority development of irrigation projects, because of protection applied to water resources aimed at drinking water supply. However, currently there are 2200 km^2 of protected areas used for agricultural production, with different types and intensity of utilisation (Romić, Marušić, 2005). In the case that within protected areas, and in compliance with valid regulations, there is a justified plan for intensive use of land for agriculture and construction of the irrigation system, it is required to complete the environmental impact assessment which will provide answers if the proposed technology of agriculture may have significant negative impacts on protected component of environment or on any other component of ecosystem. Possible protection measures may include:

- Controlled capture of surface water along with preservation of biological minimum and other requirements (water supply, hydro-energy, inland navigation),
- Controlled capture of ground waters within renewable limits,
- Ensuring of biological minimum in waterways on which reservoirs are built,
- The preference is given to smaller reservoirs over bigger ones,
- Discharge of sediment from reservoirs for safeguarding equilibrium within the waterway,
- Monitoring of ground water levels on wider area of undertaking,
- Monitoring of low water flow trends.

8.1.4 Impacts on biosphere

Changes in land-use of area and changes within ecosystems for purposes of agricultural production, along with application of irrigation, have direct impacts on biosphere. Transition of non-fertile land with specific ecosystems developed (wetland, forest and meadow ecosystems with great biological diversity), which was the common practice not so long ago is now forbidden and not practised any more.

Secondary or indirect impacts on biosphere as a consequence of irrigation may appear with significant reduction of ground water levels, which impairs biological conditions within an ecosystem. According to the Croatian Law (*Law on environmental protection*, OG 82/94) the main aims of environmental protection are permanent preservation of biological diversity of natural communities and preservation of ecological stability, followed by preservation of quality of living and non-living environment and rational use of natural resources, preservation and regeneration of cultural and aesthetic values of landscape and improvement of environmental state and safeguarding better living conditions (Tadić, 2001).

9. Sustainable irrigation

Previously elaborated matter deals with the main characteristics of agricultural land, which should be analysed and evaluated in order to define land suitability for irrigation. The main objective of land evaluation for irrigated agriculture is to define actual physical needs for irrigation and to predict future conditions after development has taken place. Therefore, all relevant land characteristics, including soil, climate, topography, water resources, existing and planned agricultural production, etc. and also socio-economic conditions and infrastructure need to be considered. Some factors that affect land suitability are permanent, and others are changeable at a cost. Typical examples of almost permanent features are meteorological characteristics, basic soil characteristics, topography and landscape. Features changeable with costs are water resources, agricultural potential and soil suitability for irrigation. The costs of necessary improvements can be determined (e.g. construction of a drainage system), so the economic and environmental consequences of development can be predicted. Figure 8 gives a scheme of evaluation criteria (A) and their influence on irrigation suitability (B) in large-scale projects. The third part of the relation (C) is more related to the projects of smaller scale. Parameters of irrigation methods and performance (C) must have separated economic analysis, more detailed and adjusted to the specific project. Five groups of criteria (A) can significantly reduce total agricultural area.

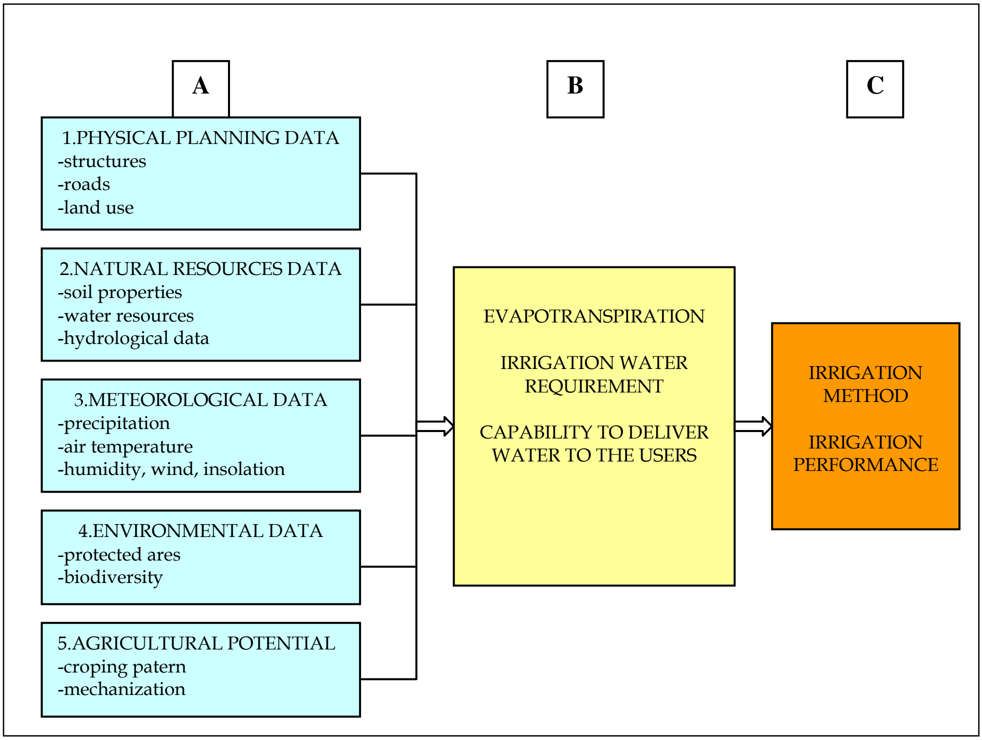


Fig. 8. Scheme of evaluation criteria and their influence on irrigation project development

According to the scheme, priorities in sustainable irrigation implementation would have already existing agricultural areas with types of soils suitable for irrigation considering their infiltration properties, areas where irrigation would not impact the overall environment. Besides, capturing of water from accessible water resources with a favourable hydrological regime must ensure sufficient amounts of water.

By meeting the required criteria, favourable conditions are accomplished for further development of a project on a lower level. Every case of neglecting of specific criteria or absence of systematic analysis leads to increase of investment value, and in long-term to overuse of natural resources and threats to the environment. On Figure 9 there is a scheme of reduction of total of agricultural land in regard to set criteria. Overall reduction may amount to over 50 %. Agricultural land found to be suitable for development of an irrigation project is subject to further economic analysis regarding application of specific irrigation methodology or choice of water sources for irrigation.

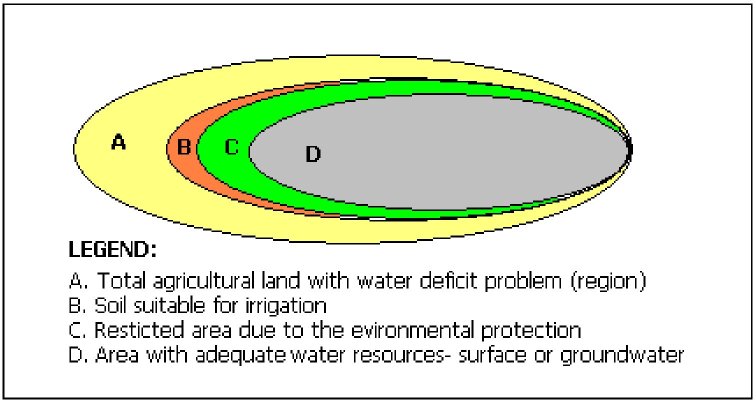


Fig. 9. Scheme possible reduction of total agricultural land in regard to irrigation suitability

Finally, the proposed procedure of data management contributes to the proper decision making. As an illustration, Figure 10 presents two maps of an agricultural land in Osijek County in Croatia (Master Irrigation Plan of Osijek County,2005). Previous analysis indicated a water deficit in vegetation period and frequent drought periods in the area.. The Figure 12a) shows the present state of irrigation, which is not very developed, basically only few separate fields have irrigated agriculture using water from open watercourses. After the process of evaluation of land suitability for irrigation, the second map (Fig. 10 b) shows agricultural areas with available water resources (open watercourses, ground water, reservoirs) on soil suitable for irrigation (excellent, suitable and restrictively suitable). All areas under any level of protection are considered to be unsuitable for irrigation development.

After this evaluation of land suitability for irrigation follows the procedure on a smaller scale by applying some of the multi-criteria methods. The most commonly used is linear programming, which is very suitable for this kind of problems. Optimal water management considers evaluation of available water resources in order to reach minimum expenses and satisfying needs of all other water users. Linear programming gives an optimum solution which can with minimum expenses of the system (structures, equipment, operation and

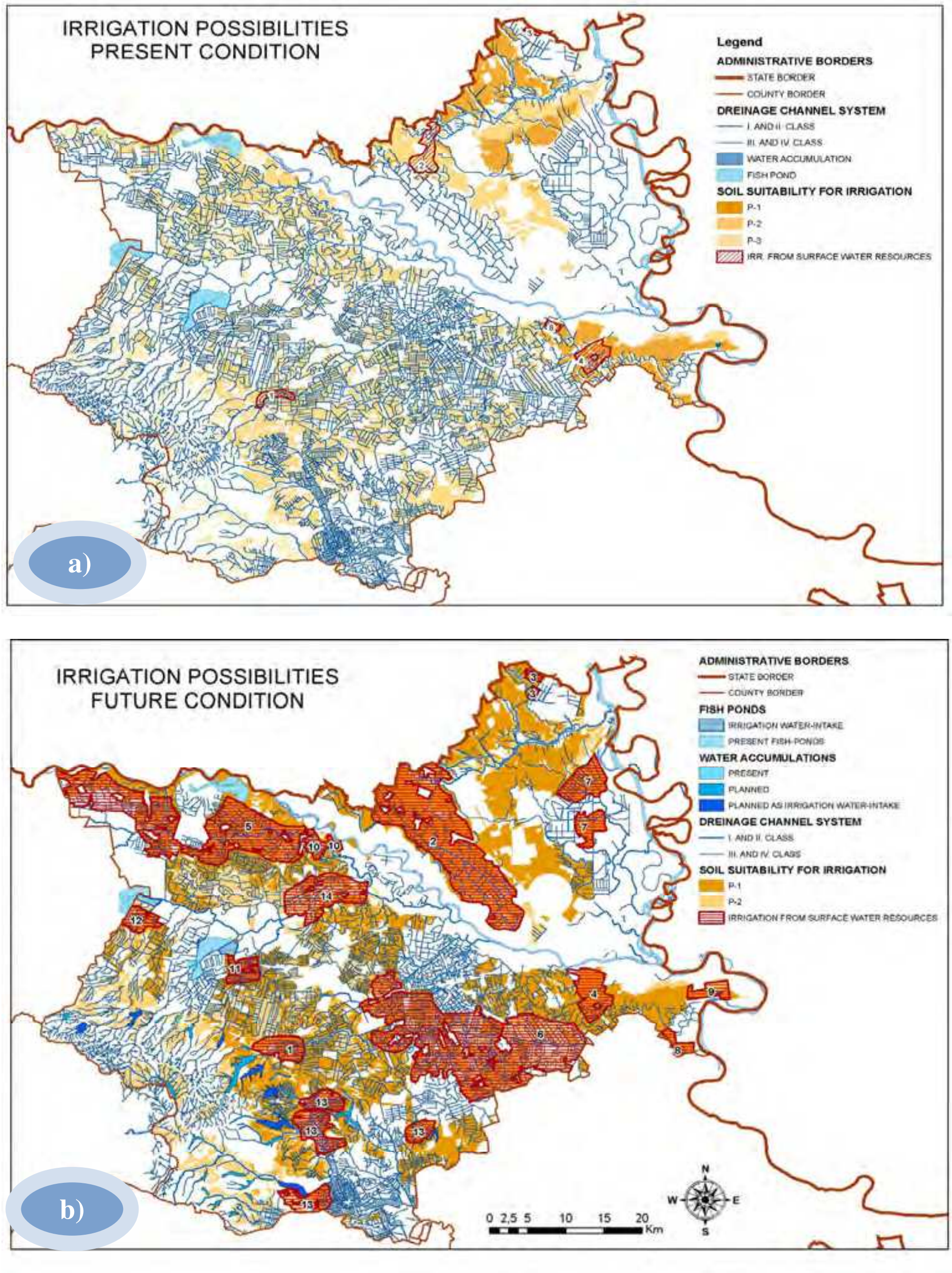


Fig. 10. Irrigation possibilities of Osijek County area, Croatia (Master Irrigation Plan of Osijek County, 2005)

maintenance) realize the maximum socio-economic benefits. Socio-economic benefits include, besides the least water price, increasing of employment possibilities, development of new economic fields, improvement of cropping pattern, etc.

10. Conclusion

To avoid subjectivity and unilaterally approach the very complex problem of irrigation implementation, methods of multi-criteria or multi-objective analysis have to be applied. This chapter tried to explain the procedure of this procedure on large-scale projects. Following of this procedure helps decision-makers to develop the project of irrigation based on sustainability and integrated water management. Considering regional physical plans, soil suitability, climatic characteristics and other geographical features, availability of water resources and their environmental vulnerability and environmental protection in general, it is possible to evaluate agricultural land suitable for irrigation. In that way, the total agricultural land will be reduced to the much smaller area, which has the good basis for irrigation implementation with reduced side effects. On a field scale, further system optimization is needed for specific cost-benefit analysis, which was not part of this elaboration.

Besides a relatively large number of potential negative side effects of irrigation described in literature and tested on the irrigated fields, without any doubts it can be said that implementation of irrigation is the necessary measure in agricultural production. The success in achieving irrigation sustainability depends on available data, reliability of the proposed procedure and reasonable data interpretation.

According to present negative trends in water and soil availability and large efforts made in environmental protection, future irrigation projects will even more depend on this kind of procedure. So we may expect development of more sophisticated and complex methods for evaluation of irrigation projects.

11. References

Ayers, R.S.,Westcot, D.W(1985). *Water Quality for Agriculture* (EDition) , FAO Irrigation and Drainage Paper 29, Rome

Bonacci, O.(2003). *Korištenje nekonvencionalnih vodnih resursa u sušnim područjima*, In: *Priručnik za hidrotehničke melioracije,* III/1, Nevenka Ožanić, 337-347, HDON, Rijeka.

Bonacci, O.(2003). *Ekohidrologija vodnih resursa i otvorenih vodotoka*, AGG Split & IGH Zagreb

Boss, M.G., Burton, M.A., Molden, D.J.(2005). *Irrigation and Drainage Performance Assessment-Practical Guidelines*, CABI Publishing, UK

Doorenbos, J.,Kassam,A.H.et.al.(1988). *Yield Response to Water* (4th E,dition) , FAO Irrigation and Drainage Paper 33, Rome

Đorđević, B.(1990). *Vodoprivredni sistemi*, Građevinski fakultet Beograd, Tehnička knjiga Beograd

Hoffman, G.J., Evans, R.G.,Jensen, M.E. et al (2007): *Design and Operation of Farm Irrigation Systems*, ASABE,

Ljubenkov, I.(2011*). Održivo gospodarenje vodnim resursima Korčule s naglaskom na njihovo korištenje za poljoprivredu*, Disertation, AGG Split, 2011.

Nixon,S.C.,Lack, T.J., HUnt,D.T.E.,Lallana,C et.al.(2000). *Sustainable use of Europe's water*. Environmetal assessment series No.7,EEA, Luxembourg

Romić, D.,Marušić,J.(2005). *Nacionalni projekt navodnjavanja i gospodarenja poljoprivrednim zemljištem i vodama u Republici Hrvatskoj (NAPNAV)*, Agronomski fakultet Zagreb.

Tadić, L., Marušić, J., Tadić, Z.(2001). *Sustainable Development of Land Management in Croatia*, 19th Regional Conference of International Commision on Irrigation and Drainage,Brno-Prag

Tadić, L (2001). *Analysis of Indicators Relevant for the Sustainable Water Management on the Karašica-Vučica Catchment Area*, Građevinski fakultet Osijek

Tadić, Z. (2005). Master Irrigation Plan of Osijek County ,hidroing Osijek

Tadić, L., Tadić, Z.,Marušić, J. (2007). *Integrated use of surface and groundwater resources in irrigation*, Proceedings of 22nd European Regional Conference ITAL-ICID, Pavia, Italy

Tadić L., Bašić F.(2007). *Utjecaj hidromelioracijskog sustava navodnjavanja na okoliš (Environmental impacts of irrigation).* Proceedings of the symposium Ameliorative measures aimed at rural space development, Croatian Academy of Sciences and Arts;173-190. Zagreb

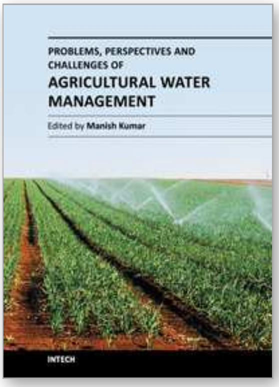
Tadić,L.,Ožanić, N., Tadić,Z., Karleuša, B.,Đuroković, Z.,(2007). Razlike *u pristupima izradi planova navodnjavanja na području kontinentalnog i priobalnog dijela Hrvatske Hrvatske vode*, Vol.15, No. 60, 201-212, Zagreb

Tadić,L.(2008). *Example of integrated use of surface and groundwater resources in irrigation in Croatia.* Journal of Water and Land Development, No. 12, 95-112

Tadić, L., Marušić, J.(2008*). Osnovni pokazatelji o načinu uređenja, korištenja i upravljanja sustavima za navodnjavanje u dijelu država Europske unije – s razvijenim navodnjavanjem*. Unpublished study.

Tadić,L.,Tadić Z.(2009). *Impacts of Irrigation on the Environment* //18th International Symposium on Water Management and Hydraulic Engineering / Editors: Cvetanka Popovska, Milorad Jovanovski. Skopje.University St Cyril and Methodius,Faculty of Civile Engineering Skopje. 2009. 659-667

Law on environmental protection (OG 82/94)



Problems, Perspectives and Challenges of Agricultural Water Management

Edited by Dr. Manish Kumar

ISBN 978-953-51-0117-8
Hard cover, 456 pages
Publisher InTech
Published online 09, March, 2012
Published in print edition March, 2012

Food security emerged as an issue in the first decade of the 21st Century, questioning the sustainability of the human race, which is inevitably related directly to the agricultural water management that has multifaceted dimensions and requires interdisciplinary expertise in order to be dealt with. The purpose of this book is to bring together and integrate the subject matter that deals with the equity, profitability and irrigation water pricing; modelling, monitoring and assessment techniques; sustainable irrigation development and management, and strategies for irrigation water supply and conservation in a single text. The book is divided into four sections and is intended to be a comprehensive reference for students, professionals and researchers working on various aspects of agricultural water management. The book seeks its impact from the diverse nature of content revealing situations from different continents (Australia, USA, Asia, Europe and Africa). Various case studies have been discussed in the chapters to present a general scenario of the problem, perspective and challenges of irrigation water use.

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821