Scientific Papers. Series E. Land Reclamation, Earth Observation&Surveying, Environmental Engineering. Vol. I, 2012
Print ISSN 2285 – 6064, CD-ROM ISSN 2285 – 6072, ISSN-L 2285 – 6064

EFFICIENCY STRATEGY FOR AN AGRICULTURAL FARM BASED ON THE AMOUNT OF WATER AVAILABLE FOR IRRIGATION

Nicoleta SARBU, Augustina TRONAC

University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd., 011464, Bucharest, Romania – Faculty of Land Reclamation and Environmental Engineering, phone number: +40 (21) 318 30 75, fax: +40 (21) 318 30 75

Corresponding author email: sarbu_nicoleta2001@yahoo.com

Abstract

Based on the soil-water-plant relationship and water balance in a river basin, this paper aims to propose a model for maximizing the use of farm resources, based on the amount of water available for irrigation in a reservoir, as established by the operating regulation. For this purpose, we have usde an information system that allows finding out the situation in real time and becomes a tool to support management decision in the agricultural association.

Key words: *Soil-water-plant relationship, irrigations, available water amount, information system, farm efficiency.*

INTRODUCTION

Globally, water is a hardly renewable, vulnerable and limited natural resource. Rivers play an important role in human evolution, providing the water demand for agriculture, industry, population, navigation, aquatic habitat, hydropower energy, etc.

The lack of water and the enhancing hydrological and agricultural drought of the recent decades has important implications for the social and economic potential of Romania.

The statistical analysis of the 2003 hydrological drought in Romania showed an increased frequency of dry and very dry years during 1982-2003, from 33.4% (before 1982) to 80%, which demonstrates a trend towards aridity in the Oltenia Plain, Romanian Plain and Barlad Plain. [1] In 2003, the Danube hydrological regime was reported as the most severe since 1840, being strongly influenced by low rainfall on the upper and middle river basins.

Under these circumstances, irrigation is the drought-control solution. Irrigation is a major factor in achieving high yields, relatively constant every year, with favorable implications for the food security of the population and surplus for the export of agricultural products. [5]

The history of irrigation development in Romania was presented by the founder of scientific research on land reclamation – Marcu Botzan, member of Romanian Academy. [2].

Romania has 14.7 million ha of agricultural land. Its irrigation systems are located almost exclusively in the South and Southeast of the country, where there is a warm climate area that can be divided into five areas: the Oltenia Plain, Olt-Arges area, Arges-Ialomita, Ialomita-Siret area and Dobrogea [3].

The irrigation facilities existent in Romania consist generally of large systems, with areas ranging from 50,000 to 100,000 ha, or even larger (Carasu, Giurgiu - Răsmireşti, Covurlui Plain). [4]

Due to the application of the land law, excessive plotting (expressed by an average of 2.5 ha/family) resulted in an almost impossible controlled and efficient exploitation of the irrigation systems. Consequently, the use of systems decreased dramatically after 1991.

Only a variable percentageis in use annually, that is, 2,998,255 ha - irrigation equipped areas managed by the Romanian National Agency for Land Reclamation (ANIF).

Table 1. Irrigated areas in Romania, 2005-2009

Year	Suitable area for irrigation	Area under contract	Irrigated area (1st watering)	Percentage of suitable area for irrigation on which watering was applied	Percentage of area under contract on which watering was applied
	(ha)	(ha)	(ha)	(%)	(%)
2005	1,500,000	352,890	45,719	3.05	12.96
2006	1,500,000	198,036	96,244	6.41	48.59
2007	1,500,000	433,747	301,450	20.10	69.50
2008	1,500,000	507,863	208,218	13.88	41.00
2009	1,500,000	562,952	294,138	19.61	52.25

For a good evolution assessment of the irrigated and non-irrigated area ratio in Romania, we should consider the 2009-2013 Land Reclamation strategy devised by the Ministry of Agriculture, Forestry and Rural Development (MAPRD). The strategy is based on the following concepts [7]:

- withdrawal from operation of thr economically unsustainable irrigation facilities;
- the existing funding opportunities to develop rural areas, rehabilitation, modernization, refurbishment and expansion of the land reclamation schemes correlated with environmental standards, water demand and the amount of water available for irrigation;
- the existence of the legal and institutional framework that relieves the state from certain expenses incurred for the management of the irrigation infrastructure;
- on the EU level special attention given to environmental protection, drought, aridisation, desertification control, wetland conservation and degraded area improvement.

MATERIALS AND METHODS

The soil-water-plant relationship needs to be customized for each culture according to the depth (H) of the active root layer which differs during the growing season.from one plant to another

In order to determine the water demand of the crops, we operate with the following concepts:

a) wilting coefficient (CO) - the water content of the soil on the depth (H) below which the plant withers irreversibly:

$$CO = (1/2,4\ldots\ 1/2) \times CC \qquad (1)$$

where:

CC = field capacity

b) useful water capacity (CU) (active humidity interval - IUA) - the amount of water that soil can hold and make available to plant growth:

$$CU = CC - CO \qquad (2)$$

c) minimum threshold of soil moisture (PM) - the limited water pool below which field capacity ensures the plant biomass close to the maximum:

$$PM = CO + \beta.CU \qquad (3)$$

where:

β = fraction of usable water capacity (CU) above the wilting coefficient (CO) whose value varies according to the soil type [8]

d) net irrigation norm (mo) - the amount of water to be applied on one watering in order to fill the soil reservoir on depth (H), from the minimum threshold of soil moisture to the field capacity.

The water balance equation in the open circuit (without groundwater contribution), used by research institutions in the experimental field network for a given crop during one month, is [9]:

$$ETRo = \Delta R + P + M \qquad (4)$$

where:

-ETRo is the real optimum consumption by evapotranspiration of a crop, obtained from the direct measurements of parameters ΔR, P and M;

- ΔR = Ri - Rf is the variation of soil water reserves during the balance period of time;
- Ri is the initial water reserve in the soil, determined by the gravimetric method at the beginning of the calculation month;

- Rf is the final water reserve in the soil water at the end of the calculation month;
- P is the gross monthly rainfall recorded at a weather station or experimental field;
- M is the gross monthly irrigation norm, measured by amount and applied in the experimental fields of ICITID - Băneasa Giurgiu [9]

Both monthly irrigation norm (M) and gross monthly rainfall (P) cannot be fully used by plants, leading to an overstatement of the monthly water consumption (Etro).

Therefore, it is necessary to correct the equation by accepting and using two parameters:
- net irrigation norm (Mo) - standard monthly net irrigation norm, fully consumed by evapotranspiration <M;
- serviceable rainfall (Pu) - monthly rainfall fully consumed by evapotranspiration <P.

On the account of the numerous relationships appealing to the climatic parameters, Romania has adjusted the Thornthwaite equation (using the mean monthly temperatures and weather station latitude). The relationship (ETp) adopted for (dc) coefficient calculation will be called "reference climate potential evapotranspiration".

The amount of water available for irrigation results from the water balance in a given river catchment area. The basic water management balance equation in a section is:

$$\Delta_{i,j} = Q_{ai,j} - [\sum_{k=1}^{nf} (Q_{pi,j})_k + Q_{di,j}] \quad (5)$$

where:
- $\Delta_{i,j}$ is the surplus (+)/deficit (-) per month;
- $Q_{ai,j}$ are monthly average natural flows tributary in the section;
- $\sum_{k=1}^{nf}(Q_{pi,j})_k$ are the monthly average flows taken upstream and unreturned in the section by the "nf" water uses;
- $Q_{di,j}$ are the average monthly flows effluent from the section.

The effluent flow outcoming from the operating upstream water management works is determined from the basic equation of hydrograph change:

$$Q_{di,j} = Q_{ai,j} - [\sum_{k=1}^{ng} (\Delta Q_{gi,j})_k + \sum_{k=1}^{nf} (Q_{pi,j})_k] \quad (6)$$

where:
- $\sum_{k=1}^{ng}(\Delta Q_{i,j})_k$ is the effect of "ng" upstream water management works on the flow;
- $\sum_{k=1}^{nf}(Q_{pi,j})_k$ is the sum of taken and unreturned flows by the "nf" water uses located upstream the calculation section [10].

We considered the case study of an agricultural association which was supplied with 1 m^3/s from a reservoir for irrigation purposes, on the probable use provision of about 80%. The total surface was 37,300 ha, cultivated with: winter wheat, barley for consumption, three row barley, maize, sunflower, soybean for consumption, beans, sugarbeet, winter potato. The choice was based on suitability and tradition; the owners made the choice and were supported by a specially designed information system. The information system had the advantage of fast simulation, performed with accuracy for the use of the water resulting as available for irrigation at the water intake point in the reservoir and in order to obtain the expected profit immediately.

We proposed work technologies for each crop, estimating the crop budget (valuescoresponding to the 2008-2009 agricultural year) in an irrigated and non-irrigated system.

In order to make an informed selection regarding the water use optimization for irrigation and profit maximization within an agricultural association, we perofrmed a preliminary analysis of the budgets and we found that the highest profit per ton resulted from the irrigated beans crop while the highest profit per hectare resulted from the irrigated winter potato crop.

We conceived scenarios regarding the allocated areas according to crop and production system, following the variation trend of the two basic elements composing agricultural production: the amount of irrigation water and agricultural profit.

We proposed five scenarios, the differences between consisting of the crops selected based on the landowners' demand and water provision method, i.e. irrigated or non-irrigated system. For any of the five scenarios, we considered:

- the land areas occupied by each crop, divided into irrigation-receiving areas and non-irrigated areas; the area was fully grown;
- we evaluated the amount of water in September, May, June, July, August and we simulated the maximum use of available water given by a reservoir outlet at a rate of 1 m^3/s, according to the agreement with the Romanian Water Authority ("Apele Romane") and specifications of the reservoir operating regulation;
- the share of each crop out of the total area;
- the share of irrigated area out of the total area;
- for every crop and watering method, we calculated the profit per hectare, total profit, share of each crop out of the total profit.

RESULTS AND DISCUSSIONS

Comparing the results of the proposed scenarios, the following could be observed:

- The maximum irrigated surface area was about 4782 ha (scenario 4), i.e. 12.82% of the surface; it appears that the available irirgation water was fully consumed in May and July, basically limiting irrigation of the larger areas; the use of an information system could solve punctual, real-time problems, being able to display the water availability in the reservoir as a result of lack or reduced consumption for other uses. In the current system of water resource allocation, it was chosen to provide the required flow at the design value; there was an excess of irrigation water in April, June, August and September, due to the fact that irrigation could not be assured throughout the entire growing season, as crops required;
- The maximum use level of water was about 62.59% (scenario 2) and demonstrated that the lack of water availability in the peak months (May and July) limited the posibility to increase the irrigation area, leading to the impossible use of significant water amounts; these amounts were not carried forward for irrigation use in the current allocation but were chosen for a constant monthly flow; the under these circumstances, the proposed information system would be able to manage the irrigation water balance in the reservoir as if this amount were independent, operating as a bank account;
- The minimum of total expenditure was about 32,5 mil lei (scenario 5), with an average of 872 lei/ha for the entire association and a weighted average of 873 lei / ha for the irrigated crops.
- The maximum profit was about 82,0 mil lei (scenario 3), with the irrigated crop recording a share of 8.5% in profit for a share of 12.6% in the area; the selected crops had different productivity per hectare and selling price on the market; consequently, there was no proportionality between the irrigated area and the entire organization profit; depending on the amount of available water predicted at the time of production forecast for the agricultural association, decision-making could maximize profits under the given conditions, regarding the use of irrigation water;
- The best benefit/cost ratio recorded is about 2.4 (scenario 3 - 240% of investment), which represented an excellent use of resources in terms of any management system.

Based on the reservoir water balance computation, we drew maps that showed how to use water in the agricultural association. Thus, we justified the use of the information systems in the calculation of water balance for irrigation use, and proved that the mode of representation wass very fast and correlated in time with the events that affected water balance.

Table 2. Summary of scenario results [11]

Crop	Scenario no.1					Scenario no.2					Scenario no.3					Scenario no.4					Scenario no.5				
	Irrigated are (ha)	Non-irrigated area (ha)	Share of system (%)	Share of expenditure (%)	Share of profit (%)	Irrigated area (ha)	Non-irrigated area (ha)	Share of system (%)	Share of expenditure (%)	Share of profit (%)	Irrigated area (ha)	Non-irrigated area (ha)	Share of system (%)	Share of expenditure (%)	Share of profit (%)	Irrigated area (ha)	Non-irrigated area (ha)	Share of system (%)	Share of expenditure (%)	Share of profit (%)	Irrigated area (ha)	Non-irrigated area (ha)	Share of system (%)	Share of expenditure (%)	Share of profit (%)
Winter wheat	-	-	-	-	-	-	-	-	-	-	190	-	0.51	0.39	0.14	-	-	-	-	-	-	-	-	-	-
Barley for consumption	-	-	-	-	-	140	1,360	4.02	2.57	0.97	-	1,190	3.19	2.16	0.61	-	-	-	-	-	-	-	-	-	-
Three row barley	90	1,910	5.36	3.46	1.29	-	-	-	-	-	-	-	-	-	-	-	700	1.88	1.10	0.43	-	1,000	2.68	1.83	0.68
Maize	-	500	1.34	0.93	0.30	-	-	-	-	-	-	-	-	-	-	180	-	0.48	0.30	0.21	-	-	-	-	-
Sunflower	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	155	-	0.42	0.55	0.07
Soybean for consumption	-	-	-	-	-	-	6,000	16.09	26.68	2.07	-	-	-	-	-	12	4,818	12.95	20.29	1.67	-	7,000	18.77	34.36	2.36
Beans	4,200	-	11.26	27.06	4.66	4,100	-	10.99	25.24	5.08	4.000		10.73	26.16	4.29	4,380	-	11.74	25.48	5.40	3,901	-	10.46	26.51	4.71
Sugar beet	-	12,500	33.51	7.26	43.64	-	14,000	37.53	7.78	54.49	103	13,397	36.19	7.96	45.86	-	12,000	32.17	6.30	46.54	-	18,000	48.26	11.04	68.29
Winter potatoes	440	17,660	48.53	61.26	50.09	480	11,220	31.37	37.74	37.40	420	18,000	49.38	63.30	49.09	210	15,000	40.78	46.54	45.74	500	6,744	19.42	25.70	23.89
Total costs	34,294,420					35,899,712					33,782,102					37,992,862.6					32,517,927.5				
Total profit	79,200,144					71,046,932					81,974,477					71,300,141.72					72,876,164.8				
Share of irrigated crops in system	12,68					12,60					12,60					12,82					12,20				
Share of irrigated crops in total profit	8,73					9,84					8,50					7,62					9,45				
Water use percentage	62,28					62,59					62,35					61,00					60,00				
Profit-Cost ratio	2,309					1,979					2,426					1,876					2,241				

CONCLUSIONS

When water resource is limited to 1 m^3/s the best option is Scenario no.3.

However, it is wiser is to recalculate the amount of available water according to the recorded reservoir water level, taking into account both the forecasts and demands of other uses. This way may result not only in a higher delivered irrigation water than the values forecasted at a certain moment (generally, in May and July) but also in a higher percentage of irrigation water use and, consequently, a larger irrigated area.

Such calculations can be performed quickly and accurately with the programs associated to the information systems, and can measure the corresponding areas gained; this approach enables real-time analysis of the situation and the establishment of an optimal variant of water and crop management, as it is a highly suggestive method that may be an important factor not necessarily addressing a water-management specialist but rather a water user.

Thus, the information system will become a tool for farm management decision-making as it fully respects the main desire of any owner: "the full use of resources, accompanied by minimizing costs and maximizing profits".

REFERENCES

[1] P. Stanciu, Drought in 2003 on the Danube and the inside rivers of Romania, http://www.agwater.ro/Seceta.html

[2] Botzan M., Waters in the life of the Romanian people, Ceres Publishing House, Bucharest, 1984

[3] Grumeza N. et al., Evolution of groundwater level and chemistry within irrigation facilities in interrelationship with the environment, Technical and agricultural propaganda editorial, Bucharest, 1990

[4] Nicolaescu I., Manole E., Evaluating effects of irrigation system rehabilitation and modernization by establishing the water demand minimum level for profitable operation, Proceeding of International Conference on the Challenges Facing Irrigation and Drainage in the New Millennium, Fort Collins, Colorado - USA, 2000

[5] Moisa M., Nicolaescu I., Irrigation systems efficient utilization limits model, ICID Special Technical Session, Rome, 1995

[6] www.anif.ro/anifmonitor/2009

[7] www.anpm.ro

[8] Canarache A., Agricultural soils physics, Ceres Publishing House, Bucharest, 1990

[9] ICITID Băneasa Giurgiu Annals

[10] Teodorescu, I., Filotti, A., Chiriac, V, Ceausescu, V., Buchanan, A. Water management, Ceres Publishing House, Bucharest, 1973

[11] Sârbu Nicoleta Contributions to the evaluation of water resources for crop irrigation by using information systems, USAMV Bucharest, 2010