MORPHOLOGICAL CHANGES INDUCED BY THE IRRIGATION SYSTEMS AND SUSTAINABLE LAND USE IN BĂILEȘTI PLAIN

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Abstract: Current climate and practicing a modern and sustainable agriculture imply the need to rehabilitate the entire network of irrigation systems found in Băilești Plain. There are 9 irrigation systems with 1.015 km of canals, spread over an area of 194.648 ha. These large constructions, which cross the Danube meadow and terraces, induced morphological changes due to the canals built and the slopes resulted. By investigating the types of canals built and their morphometric values, we were able to estimate the quantity of relocated materials, 53.918.820 m³.

Failure to fully utilize the irrigation systems, deforestation and defective use of agricultural land have led to their degradation and amplification of geomorphological processes, especially on sandy surfaces. A complete analysis of the irrigation systems regarding their functionality, the existence of the Organizations for Water Users and the stage of rehabilitation contracts was carried out. The National Plan for the Rehabilitation of the Main Irrigation Infrastructure in Romania, aims at restoring the initial parameters for the functioning of the stations and canals by 2020. The purpose is to increase the irrigated areas, which nowadays are kept at a low value (50.000 ha) which fluctuates year by year.

1. Introduction

Current pedoclimatic conditions of Băilești Plain, an area vulnerable to aridity and drought, require irrigation. Besides rainfall, irrigation plays an important part in obtaining rich and stable crops each year, in ensuring food security for the population, in achieving export surplus and protecting the environment.

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The large irrigation systems in Romania were built around 1970, in 1989 the total area covered with irrigation infrastructure was 3.1 million ha, with a number of 375 irrigation systems. Since 1991, the fragmentation of agricultural land, which did not take into account the configuration of the irrigation infrastructure at that time, has made irrigation arrangements inoperable. (Audit Report of the Court of Accounts, 2014)

Since 2004, at the request of Water Users Organizations and Federations (WUO/FWUO) the National Agency for Land Improvement (NALI) has delivered, without payment, in their property/use, the secondary irrigation infrastructure. Therefore, these organizations, as well as the other land owners or persons who own land in administration or in use, become the beneficiaries of irrigation arrangements on a contractual basis.

At the level of the Dolj County, the existing irrigation infrastructure contains 273 km of canals for 296.962 ha of agricultural land. (NALI, 2019) However, irrigated areas represent only 17% of the area with infrastructure. This value fluctuates year by year depending on the water requirements. Defective use of agricultural land along with deforestation have led to soil degradation and amplification of geomorphological processes especially on sandy surfaces.

By Government Decision no. 793/2016, regarding the approval of the National Plan for the Rehabilitation of the Main Irrigation Infrastructure in Romania, NALI aims to restore the initial operating parameters of the stations and canals between 2017-2020. WUO and FWUO established and those to be set up can access European funds through sub-measure 4.3. The financial support is ensured by grant value up to 100.000 euro/project for the irrigation systems associated to the pressure stations and 1.500.000 euro/project for the irrigation systems associated with the pumping and repumping stations.

Irrigation arrangements are large-scale networks of structures, pumps, canals and pipelines used to draw water from authorized resources and to distribute irrigation water to one or more irrigation systems that include land, buildings, equipment, access roads and the related infrastructure, necessary to operate, maintain and repair the facilities. (Court of Auditors Audit Report, 2014)

Băilești Plain contains a number of nine territorial arrangements (NALI), which are easily extended to the surrounding units: Nedeia-Măceșu, Calafat-Băilești, Cetate-Galicea, Cornu-Caraula, Bistreț-Jiu, Ghidici-Rast-Bistreț, Calafat-Ciuperceni, Lipov-Radovan and Izvoare-Cujmir.

2. Study area

The study area is framed by the Danube meadow to the south and west, by the Jiu meadow to the east, by Sălcuța-Drănic Field and the Getic Piedmont to the north. (Fig.1) The dominant note of the landscape is the morphology created by the Danube, a succession of eight terraces set at different heights and covered largely by alluvial horizons, loess deposits and wind sands. (Fig.2) (Coteț, 1957; Ianovici et al., 1969)

Fig. 1. Geographical location of Băilești Plain

Altimetric values are below 200 m. The density of fragmentation has values below $1.4 \text{ km} / \text{km}^2$, only along the main valleys there is a more obvious fragmentation, with values ranging from 1.4 to $3.5 \text{ km} / \text{km}^2$. The depth of fragmentation is generally below 28 m / kmp, and the slopes have values below 3° , increasing to over 7° along the river valleys and on the northern border.

The hydrographic network consists of the main courses of the Danube and the Jiu and smaller rivers as Desnățui, Balasan and Drincea. The first three are the main suppliers for irrigation water.

Fig. 2. The Danube terraces in Băilești Plain
(processing according to the Geography of the Romanian Danube Valley, 1969)

3. Methods and data

The analysis of the irrigation systems in the Băilești Plain involved the careful study of the maps provided by NALI, the Dolj Branch to see the spatial distribution of the arrangements, the types of canals, their length, as well as the type of pumping stations. Additionally, the Geological Map of Romania was consulted, scale 1:200.000, 1968 edition, I.G.R.; Map of land use: European Environment Agency, CLC 2012 version 18.5.1; Topographic Map, scale 1:25 000, DTM (Military Topographic Direction), 1982; Google Earth 2012, 2016.

Starting from the typology of the existing canals in the irrigation arrangements and their characteristics (Fig. 3 a, b, c, d), from July to October 2019, field investigations were carried out in the Nedeia-Măceșu Irrigation System. The approximation of the volume of material deployed for the construction of irrigation canals was made based on their measured morphometric characteristics and the use of the following formula:

$$S = \frac{(B + b)}{2} \times h$$

where S = trapezoid section of the canal; B = large base; b = small base; h = height

Fig. 3. Types of canals and their morphometric parameters; **(a)** Canal built in a cut **(b)**, **(c)** Canal built in embankment; **(d)** Canal built in a cut – in embankment

For secondary distribution canals we used the average values evaluated by Cazacu E. et al. (1972). The estimated values of the volume of dislocated material for different types of lower distribution canals: unlined canals (120-250 m^3/ha), lined (120-220 m^3/ha), with gutter (10-50 m^3/ha), pressure pipes (50-100 m^3/ha). The volume of embankment required for the construction of the evacuation network was estimated between 70-200 m^3/ha , depending on the density of the canals, their depth and distance from the evacuation emitter.

The estimation of the total volume of material relocated for the construction of the nine irrigation arrangements is made on the basis of the data provided by NALI regarding the length of the irrigation canals and the area of each individual arrangement. The volume of material obtained represent estimated values.

The data obtained were processed by GIS 10.5 software, Microsoft Excel, Photo Shop 6, Corel X7. The main objective of the study is identifying the areas crossed by the irrigation systems, the types of slopes resulted from the construction of the irrigation systems, as well as estimating the quantity of relocated materials.

4. Results and discussions

General aspects of the irrigation arrangements in the studied area

At the level of Băileşti Plain for Dolj County, nine irrigation arrangements have been identified, of which four are functional, one partly functional and four are non-functional. (Tab. 1) According to the surfaces they serve, four of the functional arrangements are large irrigation systems (25.000-50.000 ha), one

Tab. 1. Irrigation arrangements in Băileşti Plain

Irrigation System	Functional Irrigation System		
	Construction	Area (ha)	Length of irrigation canals / of which lined (m)
1. Nedeia-Măceşu (Danube basin)	1976-1982	55.384	Total 135.135 / 97.785 Adduction canals: 55.510 Distribution canals: 79.625
2. Calafat – Băileşti (Danube basin)	1967-1971	54.133	Total 580.382 / 361.984 Adduction canals: 22.000 Distribution canals: 331.572
3. Cetate – Galicea (Danube basin)	1973-1975	38.050	Total 144.719 / 144.269 Adduction canals: 84.555 Distribution canals: 60.164
4. Cornu – Caraula (Cornu Lake)	1975	540 ha	8.000/ -
5. Bistreţ-Nedeia-Jiu (Danube basin)	Partly functional irrigation systems		
	1985-1990	12.326	Total 30.300 / 30.300 Adduction canals: 27.600 Distribution canals: 2.700
6. Ghidici – Rast – Bistreţ (Danube basin)	Non functional Irrigation Systems		
	1989-1993	9.639	Total 26.200 / 26.200
7. Calafat – Ciuperceni (Danube basin)	1969-1976	6.808	Total 30.570 / 30.570
8. Lipov – Radovan (Desnăţui basin)	1974	2.204	Total 28.500 / 20.700
9. Izvoare – Cujmir (Danube basin)	1983	15.564	Total 31.200 / 31.200 Adduction canals: 21.693 Distribution canals: 81.562

(Source: NALI, National Program for the Rehabilitation of the Main Irrigation Infrastructure in Romania, Ministry of Agriculture and Rural Development, 2016)

is a medium-sized arrangement (10.000-25.000 ha), and the remaining four are small systems (below 10.000 ha). Their distribution in the territory covers the entire surface of the study area. (Fig. 4)

Nedeia-Măceșu is the largest irrigation system (55.384 ha), which represents 28% of the total surface arranged. (Fig. 5) It is connected to the Danube basin and has the largest number of pumping stations (106). The second largest is Calafat-Băilești Irrigation System, which serves a similar area (54.133 ha).

The largest length of irrigation canals belongs to Calafat-Băilești (580 km-57% of the total length of irrigation canals), followed by the Cetate-Galicea (144 km-14%) and Nedeia-Măceșu (134 km-13%). The smallest arrangement is Cornu-Caraula (540 ha-1%), with only 8 km of irrigation canals. (Fig. 6)

Fig. 4. Distribution of irrigation canals in territory
(Source: NALI map processing, ArcGIS 10.5)

The irrigation systems in Băilești Plain transport water from the sources of capture (Danube and Desnățui basin, Cornu Lake), to the irrigated land. Water transport is gravitationally and in cases where the height of agricultural land subjected to irrigation is higher than the height of water source, basic pumping

stations (BPS) are used in order to raise water to the level of irrigated land. These situations are found in the territory along the Danube at BPSs from the water inlet (Nedeia, Catane, Rast, Basarabi, Cetate), which push the water on the Danube terraces.

Fig. 5. Percentage of areas with irrigation systems (ha)

Fig. 6. Percentage of irrigation canals for each system (km)

The irrigation arrangements in Băilești Plain were carried out between 1967 and 1990, using the material found locally. The distribution canals are lined with concrete slabs of different sizes, a fact imposed by the large distance between the source, the agricultural land and the porous structure of the soil. These measures reduce large losses of water through infiltration and prevent the occurrence of soil degradation.

Irrigation systems represent a complex of works and arrangements through which the water flow is collected, transported and distributed on the ground. (Nedelcu, 2010) Each irrigation system contains a *capture node* (socket) that captures water by gravity or pumping and leads it to the main canal of adduction; a *network for transport* that links the main canal of adduction (master canal) with distribution canals; a *distribution network* that leads the water to the irrigated lands through main, secondary and sector distribution canals, by using repumping and pressure stations (RS/PS) stations for uneven terrain; a *drainage network* with terminal canals (all built in a cut); sector drainage canals (SDC), canals for sector groups (SGC), main drainage canals (MDC), main evacuation canals and master evacuation canals (MEC); *works of interior arrangement* through fixed/transportable pressure pipes, canals, gutters, submersible plots, etc; and different *constructions/facilities*: dams, bridges, gullies, various flow measurement installations, etc. (Cazacu E., 1972; Blidaru V., 1981)

The construction of the canals is linked to the orography of the territory, thus canals were built in a cut, in embankment or mixed. In order to estimate the volume of relocated materials, all types of canals in the hydrotechnical scheme were considered. The distribution network of canals complies with the

morphometric particularities of the landscape, the configuration of the microrelief, the slope line of the land, complying at the same time with the principles of territory systematization according to its functional importance.

Material resulting from excavations was used to build operating roads, side dams, and in case of large volume of material resulted, for the embankment of the adduction network, within the limits of the economic transport distances. (Cazacu et al., 1972)

Case study: Nedeia-Măceșu Irrigation System

Nedeia-Măceșu Irrigation System is located in the eastern part of Băilești Plain (Fig. 3. a) and it was built between 1976-1982. It was designed for 55.384 ha, through a network of 135 km of irrigation canals, of which 97 km are lined. It has a total of 106 pumping stations, of which 8 repumping stations (RP) and 97 pressure stations (PS). At present, an area of 41 ha is irrigated on a contract basis. (NALI, 1st quarter, 2019).

Fig. 7. (a) South section of Nedeia-Măceșu Irrigation System; BPS 1; (b) BPS 2
(Source: Google Earth, 2019)

The starting point of this irrigation arrangement is base pumping station (BPS 1 Nedeia), located in the south of Nedeia, on the Danube bank. (Fig. 7 a) It continues to the north with a master canal of 6 km in length, that crosses the Danube meadow and then connects with BPS 2, placed at the contact between the meadow and lower terrace, near national road 55 A. (Fig. 8 a) The link between BPS 2 and the main adduction canal (MAC) is made through a 0.75 km long underground section, which crosses the 2nd Danube terrace (Fig. 7 b).

The field study on the types of canals present in the Danube meadow reveals different structures: a master canal built in imbankment in its southern part and mixed near BPS 2, next to which distribution canals are present,

constructed in a cut and supplied with water through repumping stations linked with the main canal. (Fig. 8 a, b, c)

Towards the north, the morphometric characteristics of the canals change, the trapezoid section decreases as the distance from the source increases. The main adduction canal, with a length of 18 km, is built in imbankment. (Fig. 9 a, c). The calculation of the trapezoidal section based on its morphometric

characteristics and the 45° slope indicates an estimated value of $2.880.000 \text{ m}^3$ of relocated material for its construction. (Fig. 9 b)

The main canal of adduction continues to the east (Gângiova) and to the west (Măceșu de Sus) through a distribution canal, which has lower morphometric values. (Fig. 10 a, b) The western section, towards Măceșu, is built in a cut, and the volume of relocated materials over its length of 5 km is approximately 250.000 m^3 .

Fig. 10. Secondary irrigation canal from Nedeia – Măceș Irrigation System; (a) Side view; (b) Morphometric values (Source: field research, august 2019)

Based on the parameters measured in the field, the Google Earth measurements, ArcGis 10.5 and the data taken from NALI, the volume of relocated materials was estimated for five main sectors of the Nedeia-Măceșu Irrigation System. (Tab. 3) For estimating the values related to the other sectors of the irrigation network we used data provided by Cazacu et al. (1972) regarding the volume of relocated materials for irrigation of one hectare of land, in various soil conditions. By adding the resulted values we obtained the total volume of relocated material for the construction of Nedeia - Măceșu Irrigation System. It is $9.396.990 \text{ m}^3$ for 135 km of canal network and an area of 55.384 ha.

The second major irrigation system is Calafat-Băilești. It was calculated the volume of material for four main sectors and the values for the rest of the surface was estimated. The value of $28.697.826 \text{ m}^3$ was obtained, for a total length of 580 km and an area of 54.133 ha. (Table 4)

The two irrigation systems have 715 km of irrigation canals, which represents 70% of the total length of the canals from the 9 arrangements located in Băilești Plain. For their construction a total volume of $38.094.819 \text{ m}^3$ of material has been relocated. Based on this value, the total quantity of relocated material was estimated for the nine systems of 1.012 km in length. From our calculations, the estimated value of relocated material is $53.918.820 \text{ m}^3$.

Tab. 3. Estimated values for relocated materials-Nedeia-Măceșu Irrigation System

Nr. crt.	Sections	Estimated values (m ³)
1.	Master Canal BPS 1 - BPS 2 Nedeia	1.200.000
2.	Main adduction canal towards Valea Stanciului	2.880.000
3.	Main adduction canal towards Măceșu	250.000
4.	Adduction canal Măceșu de Sus - Bârca	450.000
5.	Adduction canal Valea Stanciului - Segarcea	850.000
6.	Distribution canals of different order	3.766.990
Total	135 km	9.396.990

Tab. 4. Estimated values for relocated materials-Calafat-Băilești Irrigation System

Nr. crt.	Sections	Estimated values (m ³)
1.	Main adduction canal from Basarabi - Golenți-Băilești	3.520.000
2.	Distribution canal Golenți-Hunia	3.360.000
3.	Distribution canal Golenți-Basarabi - Smârdan	1.600.000
4.	Distribution canal Cetate- Dobridor- Giubega	4.800.000
5.	Distribution canals of different order	15.417.826
Total	580 km	28.697.826

Current situation of the irrigation systems and sustainable land use

Due to its morphometric and morphographic characteristics, Băilești Plain represents an area designed largely for agriculture. The irrigation systems built during the communist period create a dense network in the territory and validate that its best use was thought for agricultural purposes. The political situation that followed and the lack of maintenance, so necessary for these irrigation systems, gradually led to degradation.

Currently only four of the nine systems are functional: Nedeia-Măceșu, Calafat-Băilești, Cetate-Galicea and Cornu-Caraula. However, these systems serve by irrigation a much smaller area than the one for which they were designed. Nedeia-Măceșu System irrigates 41.328 ha, with 14.056 ha less than the surface for which it was designed, being used at 70% of its capacity. In the case of Calafat-Băilești System, the situation is even more disadvantageous, with only 24.593 ha irrigated, 29.540 ha less than its service capacity, being used only 45%.

There are also situations where, although the system is functional, it is not used. For example, Cetate-Galicea System last worked in 2010, and Bistreț-Nedeia-Jiu worked until 1993 and partly until 2017 (BPS 1 Rice plantation,

2.287 ha). A similar situation is for Cornu-Caraula System, which last operated in 2012. Therefore, only 31% of the areas arranged for irrigation are used. (Fig. 11)

Fig. 11. Percentage of irrigated land in relation to the surface arranged for irrigation

Irrigation systems that are not currently functionable have ended their activity long ago: Izvoare-Cujmir (1989), Ghidici-Rast-Bistreț (1993), Calafat-Ciuperceni (1995), Lipov-Radovan (1995)

Seven out of the nine irrigation systems have created WUO's/FWUO's which took over the secondary irrigation infrastructure (the PS and buried pipeline network, related to the plots served by the PSs. (Tab. 5) The benefit of such an organization is that the aim of the WUO is to submit projects for accessing European funds in the National Programme for Rehabilitation 2014-2020, submeasure 4.3, for the rehabilitation and modernization of the PS's and the buried pipeline network. The arrangement with the largest number of WUO's is Nedeia-Măceșu (11). Cornu-Caraula and Lipov-Radovan are the only ones that so far have no such organizations.

Five irrigation systems have contracts for rehabilitation investments according to The National Investment Plan (GD 793/2016). The only ones that have no investment contract to date are: Cornu-Caraula, Ghidici-Rast-Bistreț, Calafat-Ciuperceni, Lipov-Radovan. Nedeia-Măceșu Irrigation System was the only one that managed to modernize the floating base station and a repumping station from 2012 to 2019.

Irrigation, draining and combating surface soil erosion are all part of the complex of hydro-ameliorative measures that create beneficial effects on the environment. Through irrigation, salts and amendments in the irrigation water are transported from the surface of the soil. Thus, the degradation of the nutrition regime in the soil, physical, chemical and biological pollution can be prevented. (Nedelcu, 2010)

Both The National Strategy for the Sustainable Development of Romania 2030 and The Strategy for the Economic and Social Development of Dolj County for 2014-2020, identifies the progressive degradation of the lands and soils as major problems demanding urgent measures. The causes of this reduction in their quality are natural (frequent and prolonged droughts, extension of sand, erosion, excessive humidity, acidification, as a result of improper use of irrigation facilities) and anthropogenic.

Tab. 5. Water User's Organizations and the status of the accessed projects

Irrigation System	FWUO/WUO	Projects *
1. Nedeia - Măceșu	11 WUO	11(NPR 2014-2020) 1 st phase of rehabilitation
2. Calafat – Băilești	1 FWUO with 8 WUO	8 (NPR 2014-2020) 3 rd phase of rehabilitation
3. Cetate – Galicea	1 FWUO with 4 WUO	1 (NPR 2014-2020); FWUO accessed European funds in the (NPR 2007-2013); 2 nd phase of rehabilitation
4. Cornu – Caraula	-	-
5. Bistreț - Nedeia –Jiu	1 WUO	2 nd phase of rehabilitation
6. Ghidici – Rast – Bistreț	1 WUO	-
7. Calafat – Ciuperceni	1 WUO	-
8. Lipov – Radovan	-	-
9. Izvoare – Cujmir	3 WUO	2 nd phase of rehabilitation

* Projects submitted for accessing european funds

(Source: NALI, NPR, Ministry of Agriculture and Rural Development, 2016)

Dolj County's Economic and Social Development Strategy regards the entire Băilești Plain as a area facing drought and water deficiency, which lower agricultural production. As such, support is needed through subsidy policies for agricultural producers. At the same time it is also necessary to update the territorial planning and elaborate a plan for the intercommunal territory aimed at properly matching the regulations regarding the use of land between the component localities.

However, sustainable land use management cannot be achieved without the rehabilitation of all irrigation systems. Their benefit translates itself in terms of productivity and proper land use, contributing to social stability, mitigates adverse environmental effects and improves competitiveness. Sustainable land use is a national priority axis that requires political and public support, through integrated land management.

5. Conclusions

Băilești Plain benefits from nine irrigation arrangements spread across its territory. These were designed and built during the communist period to irrigate 194.648 ha of land. Currently, only some of the facilities, which can irrigate 150.394 ha, have remained functional. In reality, from our calculations, only 68.208 ha are irrigated.

The construction of the irrigation canals, with a total length of 1.012 km, brought a series of changes in the appearance of the landscape, due to the quantity of relocated materials for their construction. Several types of canals were identified in the study area (i.e. adduction, distribution, desecation, evacuation), built in different ways (in a cut, in embankment, mixed) imposed by the morphology of the landscape. Each type of canal has its own morphometric characteristics which helped us to determine the volume of relocated materials. We estimated that 53.918.820 m³ of material has been relocated for the nine irrigation systems.

For the functional arrangements, the main problem identified is the loss of water due to the degraded infrastructure and the fact that there are unlined canals, where the losses can reach 50% of the quantity of transported water, compared to 15% for the lined canals.

The current climatic conditions and the practice of a modern and sustainable agriculture implies the need to rehabilitate and modernize all the existing facilities. This can be achieved by continuing the establishment of WUOs at the level of each arrangement that will submit projects for accessing European funds. The most important investment is concentrated in the pumping, repumping, pressure station and the main canals.

Investments made by the beneficiaries are very important. Thus, the place of the inefficient, manually joined aluminum pipe installations with sprinklers, was taken by drum sprinkler installations and most recently, "rain wings", which bring water almost naturally on top of the plant.

The modernization of all irrigation arrangements about 40 years after their commissioning is a necessity for Romania, in order to use the "green gold" of the plains, to prevent the extension of sand dunes and to maintain the "food independence" of our country.

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