THE USE OF CENTRAL PIVOT IRRIGATION SYSTEMS IN THE PRODUCTIVE RECOVERY WORKS OF THE LANDS AFFECTED BY DESERTIFICATION. AN OPPORTUNITY ANALYSIS FOR DOLJ COUNTY

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Abstract. *At present, larger and larger areas of land within the Romanian Plain are affected by the desertification phenomenon (in various stages, up to real deserts with dunes, for example in the southwest of Dolj County). This phenomenon, resulting from a combination of factors, such as poor management of agricultural land, intensification of erosion (especially wind erosion) on the background of deforestation of protective belts installed in the 60s - 80s of last century, and with an increasing contribution of climate changes (reduction of precipitation in general, prolonged intervals with high temperatures and lack of precipitations, high and sudden variations of temperatures, etc.), since it affects the main agricultural area of the country, is able to threaten the food security of Romania. In this context, it is necessary to identify solutions that are as fast as possible and at the same time technically and economically viable for the reintroduction of these lands in the productive circuits. Based on these considerations, but also taking into account some present realities (related to abrupt rise of energy and fuel prices, as well as a much discussed and expected food crisis), in this paper we set out to analyze, at a conceptual level, the possibility and the opportunity to use the central pivot irrigation systems as the main solution within the complex of works necessary for the reintroduction of the lands affected by desertification in the agricultural productive circuits. Also, we specify that the present study was restricted to the southwestern part of the Romanaților Plain (subdivision of the Romanian Plain), located in Dolj County, without excluding the possibility for this solution to be adopted in other regions affected by desertification in the country.*

Keywords*: central pivot, desertification, irrigation, degraded land, productive circuit*

INTRODUCTION

Desertification is a complex phenomenon being linked to the combination of natural causes and increased anthropogenic pressure on vulnerable ecosystems in arid, semi-arid and sub-wetlands. Among the natural factors, the climatic causes stand out, which include reducing the amounts of precipitation, changing their regime, warming the climate and intensifying the winds, the latter increasing the evaporation and drying of plants (BOCAN ET AL., 2018).

According to official figures in Dolj County over 6% (approximately 450 km^2) of its total area is considered to be desert, and in the absence of measures to stop the phenomenon and ecological reconstruction of land already affected this area will be constantly growing in the future (BOCAN ET AL., 2018; JURJ, 2018, 2019). Starting from this reality, in this paper we present the steps to be taken for the unitary ecological reconstruction of the lands in different stages of evolution of the desertification phenomenon.

Ecological reconstruction of any degraded land (regardless of the type of degradation suffered and the type of reconstruction pursued) requires special attention from the point of view of the legislative and normative framework, which allows a great flexibility of forecasts and the possibility to change the destination of land and takes into account the attractions and characteristics of the territory based on a complex process of analysis of the built landscape, through the most modern working methods (LAZĂR, 2010; LAZĂR ET AL., 2017).

The need for ecological reconstruction of lands affected by desertification (Figure 1) and their reintroduction into productive circuits in Dolj County is not necessarily related to the restoration of the ecosystem existing before the start of intensive agricultural activity but rather to restore its quality and support capacity of agricultural crops.

Fig. 1. Transformation of agricultural lands in Dolj County into a desert

All the planned ecological reconstruction works contribute to the restoration of the environmental factors affected by the desertification phenomenon, with the most important effects on the soil, local hydrogeology and vegetation.

Restoring the land surfaces to the productive level will have a significant role in restoring air quality (reducing the amount of sedimentable and suspended particles, reducing thermal amplitudes, increasing atmospheric humidity, increasing the amount of oxygen produced, etc.) in the area. Of course, improving air quality has positive effects on the health and mental state of the population. And the restoration of the landscape, specific to the anthropic-agricultural ecosystems, intervenes on the mental state of the population but also contributes to increasing the attractiveness of the area (BOCAN ET AL., 2018).

MATERIAL AND METHODS

Description of the studied area

The predominant character of the relief in the studied area is that of a plain, falling into the category of Danube areas (the Danube is the main agent that generated the relief forms). In more detail, the relief includes the meadow area of the Danube and part of the plain between Jiu and Olt rivers, the altitude increasing from 40 to approx. 100 m above sea level, from south to north of the area (Figure 2) (JURJ, 2019).

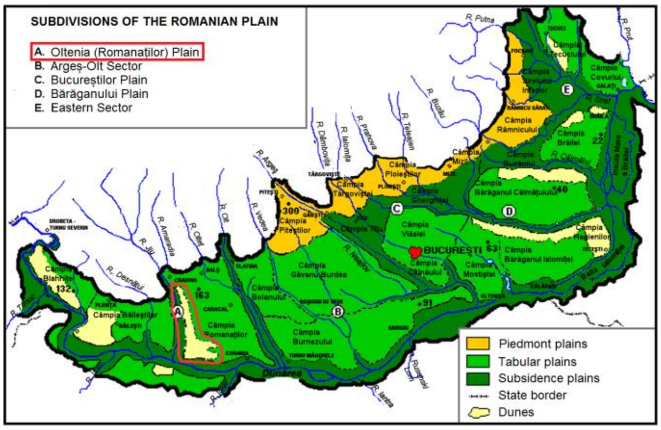

Fig. 2. Highlighting the studied area (***, 2020)

The studied area, until around 1960, was largely covered by mixed forests of deciduous trees on the western side and sparsely vegetated sands in the southern part, so that from that moment to undergo a radical transformation, in the sense that the forests were cleared in order to increase the surfaces of land for agriculture. From that moment until the end of the '90s, the land was part of an extensive area of Dolj County where intensive agriculture was practiced (JURJ, 2018).

Starting with 1969, the irrigation canals and the pressurization stations on the Danube were built, a work known as the Sadova-Corabia irrigation system, which served the 80,000 hectares of leveled sandy soils.

The work was carried out by British companies with special backhoe loaders between 1969 and 1972 (Figure 3), being completed by a massive operation of planting a network of protective vegetation curtains.

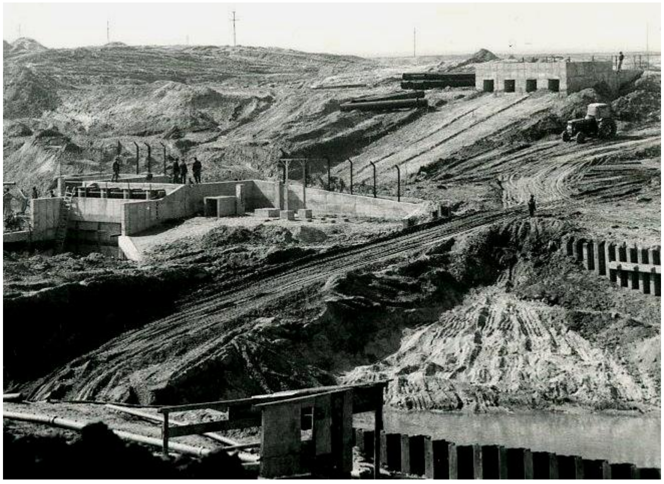

Fig. 3. Bechet-Corabia irrigation system site in 1972 (***, 2019)

The territory was organized for agroforestry cultivation, because these sandy soils are subject to wind deflation, ie winds that blow in early spring in the area, which dragging these light, mobile soils, entrained sand particles and hit the leaves, covering the young seedlings. Then it was decided to install a system of acacia protection curtains with a thickness of 10 m, because acacia is the most resistant to climatic conditions here.

The protective curtains were located at 580 meters for vineyards and tree plantations and at 280 meters for annual crops. Such a forest curtain protects behind it 10 times the height of the acacia. If the acacias are 15 meters high, it means that they provide protection for 150 meters on either side.

In addition to the permanent forest curtains, the establishment of annual curtains was considered, in which agricultural crops were arranged in strips: one third was cultivated with a hoe crop, one third with a straw crop that protected the hoe crop and a third, a perennial crop, such as alfalfa. For example, the rye strip where the seedlings already had a certain height, being cultivated since autumn, protected the neighboring strip, on which vegetables or melons were planted in the spring. It was a very well developed crop rotation system.

It was a mammoth irrigation system, a 2 billion $ systematization project.

The water supply canals were built, every 2 kilometers, and then every 2 kilometers there were pressure stations, each station serving 500 hectares.

From there started the irrigation antennas, ie a network of buried plastic pipes of different diameters, which ensure the distribution of water evenly over the 500 hectares. The whole network of buried irrigation pipes was made of plastic pipes imported from England.

The main antenna was buried 1.5-2 m underground, and the secondary antennas 1.5 m and come to the surface through hydrants arranged every 72 meters.

Thus, 4 hydrants served 16 hectares, 8 on one side and 8 on the other. It is interesting that the whole system was calculated in such a way that the water returns to the same surface in 7 days.

The most efficient irrigation system, plundered even before completion.

It was considered one of the largest irrigation systems in Europe at that time, not only the largest in Romania. Initially it was supposed to serve 120,000 hectares, but at one point the communist regime got upset and stopped the works when the facilities for about 80,000 hectares were functional.

The irrigation system was automated, the canals were protected with geotextiles, but as early as 1974, ebonite tiles began to be stolen from the automation, the tiles were set aside to steal the geotextile for wedding tents.

The commissioning of the huge Sadova-Corabia irrigation system allowed the valorization of the sandy soils like never before in the history of the economically poor south of Oltenia.

After 1989, gradually, these irrigation systems were either abandoned or destroyed, so that land productivity began to decline from year to year (BOCAN ET AL., 2018).

Of course, in these conditions, ie in the absence of irrigation systems, given the intensive practice of agriculture, climate change has become even more extreme in recent years (decreasing rainfall or going through periods of extreme drought, rising temperatures, intensifying winds etc.) or in other words of a faulty way of land management, they lost their ability to support the vegetation (agricultural crops, orchids or vine cultivation) and gradually turned into desert (Figure 4) (JURJ, 2018).

Fig. 4. The aspect of the lands from the south-west of Dolj County

The climate is specific to the Oltenia Plain, with an average multiannual temperature (at Bechet Meteorological Station) of 10.8ºC, and with average annual amplitude of 24.9ºC. The average multiannual amount of precipitation is of 520.9 mm (or l/m^2), but it should be noted that if we analyze the total amount of rainfall only in the last 20 years, it has a much lower average value of only 470.1 mm. Also during this period, there are more and more frequent episodes of prolonged and extreme drought. The wind blows most frequently from the west and east, these two directions having an almost equal frequency and totaling about 44% of the number of observations. The highest average speeds belong to the same directions (4.3 m/s for the east and 4.2 m/s for the west), while the average annual speed is about 3 m/s.

Geology consists of soft, young rocks, partly unconsolidated: reddish clays, sands, gravels and loessoid deposits, arranged in relatively homogeneous horizons and with weak or moderate geodeclivity.

Clays (sandy clays) predominate on approx. 53% of the surface, followed by medium - fine materials (dusty clays and clays) interspersed with medium coarse materials (coarse sands) on approx. 26.6%, on the rest of the lands, approx. 20.4% have medium coarse materials (clayey sands and sands), sometimes interspersed with medium materials (clays and sandy clays) (BOCAN ET AL., 2018).

Morphological transformations took place due to water and wind erosion, and as a result the "vegetal (fertile)" factor disappeared, so that now, depending on the degree of desertification, the land surface looks like a crust (Figure 4 left) or as a desert itself (Figure 4 right).

In this context, it goes without saying that few species of plants have spontaneously settled on the ground (thistles - *Cyrsium arvense*, wind grass - *Aspera spica venti*, mohor - *Setaria sp*., Turita - *Galium sp*., etc.), and rare in number of individuals (BOCAN ET AL, 2018).

The situation is very different from the initial one, when these lands were covered with forests, but also compared to more than 25-30 years ago when these lands were cultivated and exploited agriculturally. Obviously, the disappearance of vegetation leads during periods of drought accompanied by wind to the formation of dust clouds that affect the health of the inhabitants of the area.

Productive recovery (ecological restoration)

In order to achieve the proposed objective, namely the ecological reconstruction and the reintroduction in the productive circuit of the land affected by desertification in Dolj County, it is necessary to go through several stages: 1. Parceling the land and setting up forest curtains on these alignments; 2. Land fertilization (by adding material with a high content of organic substances); 3. Construction of central pivot irrigation systems; 4. Establishment of planned crops.

1. Parceling the land and setting up forest protection curtains

In order to obtain the best possible results in the process of reintroducing the land affected by desertification in Dolj County in the productive circuit, a unitary approach of the ecological reconstruction process is necessary.

In other words, at least for a period of time, it is necessary to change the ownership of the land, so that the process of ecological reconstruction is not hindered by the boundaries of land perimeters owned by different people.

After solving this problem, it is possible to proceed with the topographic measurements and the division of the land into rectangular sectors, with the size of 4000 (5000) m x 2400 (3000) m (this size of the lots is also dictated by the proposed irrigation system, briefly described next in the paper).

In the delimitation areas of the sectors, on a width of 8 - 10 m, the new vegetal curtains of anti-erosion protection (wind erosion) will be established. For this purpose, acacia trees (*Robinia pseudoacacia*) will be used along the alignments that separate the land sectors. On the new alignments established for planting trees, a 3-row planting scheme will be used, alternately, and then, on a width of approx. 2 m on either side of the rows of trees, will be planted shrubs, of the *Prunus spinosa* species. There must be connecting roads between the land sectors, which will allow the access of agricultural equipment and people, for this purpose being provided openings in the tree curtains (Figure 5).

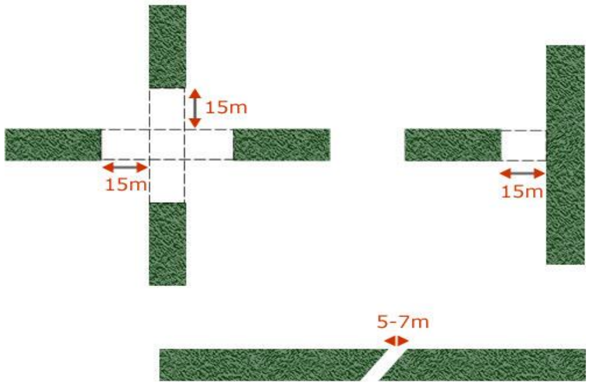

Fig. 5. Typical openings in the tree curtains

Considering the conditions offered from the land in question, for the recommended species (acacia - *Robinia pseudoacacia*) the 2/1 planting scheme is recommended, ie 5000 forest seedlings/ha. In the case of shrubs (*Prunus spinosa sp*.), the planting method will be similar, ie in rows, alternately, the planting scheme being 1.5/1, ie 7500 forest seedlings/ha. Planting will be carried out in autumn (October - November), in small pits of 30/30/30 cm for both species, with borrowed soil at the root.

2. Land fertilization

Land fertilization aims primarily to increase the content of organic matter. Depending on the degree of desertification, in advance, for the inlaid lands (Figure 4 left) scarification works are also required (for weeding).

As a filler material, with a high content of organic matter, we have identified two main sources and a third secondary one, which do not exclude one another, being complementary.

1. The use of the material resulting from the clearing of the accumulations on the Jiu river (from Gorj and Dolj Counties). In order to support this statement, we specify that, for example, the accumulation at Ișalnița currently operates at 10% of the projected capacity, the rest being clogged with sediments. As the clearing of these hydrotechnical constructions is necessary to ensure the designed functionalities and as the high fertility of the sediments that accumulate in them is well known, we recommend that the material resulting from the clearing of the accumulations be used to fertilize the lands affected by desertification.

2. Use of fermented sludge from domestic wastewater treatment plants in Gorj and Dolj Counties. It can be transported and deposited on previously prepared land surfaces.

The major disadvantage resulting from the use of sludge from sewage treatment plants is related to the relatively high content of heavy metals (LASSOUED ET AL., 2013; NYAMANGARA AND MZEZEWA, 1999; USMAN ET AL., 2012), which requires the application some agricultural processes for their extraction, recommended in specialized papers (BOCAN ET AL., 2018; JURJ 2018; 2019).

Regardless of the chosen variant, after the deposition of the material with a high content of organic material, it is necessary to make a mixture of it with the decomposed and fragmented material. This operation will be performed with the help of plug machines.

3. Although it is not the most recommended method of fertilizing the land, the application of chemical fertilizers may be necessary on certain surfaces of land, in order to minimize the time required for their reintroduction into the production circuit.

3. Construction of central pivot irrigation (CPI) systems

In 1940, farmer Frank Zybach from Strasbourg, Colorado invented CPI, the procedure being patented in 1952. It is now recognized as one of the most effective methods of improving water distribution on land (MORGAN, 1993).

The CPI (or water wheel irrigation, or circular irrigation), as a method of irrigating farmlands, involves the use of rotary equipments, while the crops are effectively watered by different types of sprinklers. The irrigated area by CPI systems creates, often, a circular pattern in crops when observed from above (Figure 6) (named crop circles that must not be confused with those resulting by the circular flattening of crop portions).

Fig. 6. Crops irrigated with central pivot systems (aerial view - left; satellite view - right) (***, 2021)

CPI systems are beneficial because they have the ability to efficiently use water and optimize the productivity of a farm. The systems are proven to be efficient when applied on large areas.

Irrigation with central pivot systems is a type of irrigation that uses sprinklers. The system is constructed of pipe segments (aluminum or galvanized steel), with sprinklers mounted along them, joined together. The assembly is supported by beams and mounted on wheeled structures (MADER, 2010). In motion, the installation describes an approx. circular shape being supplied with water from the pivot point located in the center of the system.

For a CPI system to be used, the land must be relatively flat, but, as a major advantage of this type of irrigation system over alternative ones is represented by the use gravitational flow, giving it the ability to operate on moderately wavy terrains. This advantage is translated by increased irrigated land areas and more the efficient use of water in some cases (parts of the United States, Australia, New Zealand and Brazil, and also in desert areas such as North Africa and the Middle East) (***, 2008).

CPI systems usually have a length of less than half of a kilometer (radius of the circle). The standard, and most common, size being of 1/4 mile (400 m). A typical crop surface with a radius of 400 m covers about 50 hectares of land.

Initially, CPI systems were driven by water. These motion systems were gradually replaced by hydraulic or electric operated systems. Most present systems are powered by electric motors mounted on every tower.

The outer set of wheels gives the speed of rotation. The interior wheel sets are mounted on hubs, between 2 segments. Angle sensors are used to detect when a certain threshold of the bend at the joints is exceeded. In order to keep the segments aligned, when the angle is very large, the wheels move to keep a relatively constant alignment of the segments. Typically, a full rotation period is of three days (there are also systems for which the exterior edge of the structure moves 2-3 m/minute, which would be equivalent to 14-21 hours for the full rotation of a standard system) (MORRIS, 2003).

In order to achieve a uniform application, the central pivots require a uniform flow of the transmitter within the installation. Because the outer structural elements (or towers) travel more over a period of time than the innermost ones, the dimensions of the nozzles increases from the interior towards the exterior elements.

Most CPI systems now have drippers hanging from a U-shaped pipe called a goose neck. These are attached at the top of the pipe, and the sprinkler heads that are located a few meters (maximum 2 m) on top of the crop, thus limiting losses due to evaporation and/or wind drift. There are many nozzle configurations available, including static, movable and semicircular plates.

Upstream of each nozzle pressure regulators are usually installed (Figure 7).These regulators ensure that every nozzle operates at the designed (recommended) pressure.

Fig. 7. Types of nozzles used for central pivot irrigation systems (***, 2021)

Drippers can also be fitted with firing hoses or bubbles which deposit water on the ground. Such a system is known as LEPA (Low Energy Precision Application). Often, this system is associated with the arrangement of small dams on the entire length of the furrow (called furrow dams). Crops can be planted in linear rows or in circles to correspond to the trajectory of the CPI system.

4. Establishment of planned agricultural crops

On newly developed areas (subject to ecological reconstruction and after reducing the content of heavy metals in the soil if necessary), the land can take over the agricultural function, ie the final objective of ecological reconstruction works is achieved, namely its reintroduction into the productive circuit. The type of crops will be chosen according to pedoclimatic conditions and economic priorities.

RESULTS AND DISCUSSIONS

Benefits

Compared to other methods of surface irrigation, CPI requires less labor. Subsequent, it involves smaller labor costs compared to ground irrigation technologies that require excavation of irrigation canals and ongoing maintenance. Also, irrigation in a CPI system can reduce the amount of disturbed (mobilized) soil. It reduces surface runoff and soil erosion, shortcomings that may appear when irrigating the soil with linear or transverse systems. Reduced soil mobilization also leads to better accumulation of organic matter and crop residues (which decompose on the spot) and re-enters the soil, maintaining its fertility and high production capacity. It also reduces the intensity of the soil compaction phenomenon.

Another advantage is related to the possibility of obtaining two or even three harvests per year:

- 1 harvest for human consumption + 1 fodder crop that requires fruiting;
- 1 harvest for human consumption + 2 fodder crops that do not require fruiting;
- 1 fodder crop that requires fruiting + 2 fodder crops that do not require fruiting.

The practice of such a cultivation system also allows an independent rotation of crops on each crop circle.

Possible disadvantages

Fossil water (by this we mean captive water - aquifer horizons that are not fed or that are fed very slowly and require a very long period of time to fill) is a non-renewable resource.

If the extraction rate of CPI systems exceeds the recharge rate of such aquifers, then underground water levels fall drastically (even to extinction).

To illustrate this issue, we briefly present the situation in the US:

A study from 2013 showed that with the increase of the efficiency regarding water consumption of the CPI systems, the land was more intensively farmed, on larger surfaces, at the same time being cultivated more "thirsty" crops (WINES, 2013).

After more then 60 years of profitable intensive agriculture, in some regions of the United States (South Dakota, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas, under the great plains of the United States), the use of huge CPI systems dried out parts of the Ogallala Aquifer (also known as the High Plains Aquifer - one of the largest aquifers in the world, covering an area of about 45 million hectares) (COLE, 2006).

In 1950, irrigated farmland covered more then 100,000 hectares. According to the same study, in 2013, by using of CPI systems, almost 1.22 million hectares of land were irrigated just in Kansas. In some regions, the water table was lowered by more than 1.5 meters per year during the period of maximum extraction. There were cases when the wells were seriously deepened in order to reach groundwater, whose level is constantly decreasing (WINES, 2013). In some parts of the Texas Panhandle, the underground water was totally drained (dehydrated). Extensive areas of Texas cultivated land, situated on top of the aquifer can no longer support irrigation. In the western and central parts of Kansas, up to 20% of the irrigated land along a 100-mile (160 km) the aquifer formations are already dried out. It is appreciated that the period of time necessary to restore the dehydrated aquifer from rainfall will expand over hundreds to thousands of years (COLE, 2006; WINES, 2013).

The solution

In order to prevent the occurrence of such a situation, for the studied area in Dolj County, it is recommended that the supply of central pivot irrigation systems be made from surface sources (from the Danube and Jiu Rivers), the supply from aquifers in the area being viewed only as an additional source to compensate, in certain periods, the necessary quantities of water.

In any case, this input from deep sources (groundwater) must also be made from phreatic and/or pressurized aquifers that are fed back at a rate at least equal to that of extraction. This is only possible through a good knowledge, in detail, of the hydrogeology of the area in question.

CONCLUSIONS

In order to identify the ecological restoration works of the land in question, so that it is reintroduced into the economic (productive) circuit, the existing physical, chemical and pedological conditions were analyzed, and the solutions for their restoration were identified by establishing the necessary works. In this process, the needs of local communities, the plans to combat desertification developed by the UN, the European Union and the central authorities in Romania and the extent to which these plans have already been included in land use plans developed by local authorities were taken into account.

The proposed irrigation solution is a modern one, allows a superior management of water resources, involves low energy consumption, leads to a substantial increase in land productivity, involves minimal risks to the soil (in the sense of minimizing soil losses through mobilization) and allows the accumulation of organic substances.

This solution can be applied in other regions of Romania affected by desertification, but in the current global and European context (energy crisis, a potential food crisis and implicitly an economic one) the feasibility of central pivot irrigation systems should also be analyzed for the rest of agricultural trains in the country.

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