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ORIGINAL ARTICLE

Coping with water scarcity: the case of the Calnistea catchment (Romania)

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Abstract The Calnistea catchment lies in the southern part of Romania in a region that has been confronted lately with serious water scarcity problems generated primarily by summer heat waves and long periods of drought. The high temperatures, excessive evapotranspiration and scant precipitation have a negative impact on water resources and especially on the river system, which is at the mercy of meteorological conditions, because all the streams in the area originate in the plain. Consequently, mean annual discharges are very low and more often than not, many rivers run dry. In order to avoid such an unwanted phenomenon people have built earth dams across the valleys thus creating chains of ponds, which are used to regulate the flow. Even so, however, most of the years the rivers look like mere threads of water oozing gently through their sediments. Under the circumstances, it is no wonder that irrigation systems are missing, which explains the low agricultural productivity. The most important asset of the region is the groundwater, as it represents the only source of drinking water for the population. Groundwaters are stored in superposed aquifers, most of them confined, generally having good hydrogeological properties. Water quality complies with the standards for drinking water and that is why groundwaters are used as such for domestic consumption. The problem is that in the past years, population increase has put more pressure on this resource and consequently water table sank. The growing depletion of groundwaters has brought about thirst, famine, poverty and despair, sad realities that local authorities are striving to control. Given this necessity the present study aims at making several proposals of what could be done on a short and middle term in order to increase the water supplies of the region and thus alleviate the people's suffering.

Keywords Calnistea catchment · Drought · Water scarcity · River · Groundwater · Well

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Introduction

In many parts of the world, global warming has brought about changes in hydrological cycle and precipitation regime, which resulted in water scarcity on large areas Falkenmark (1989). Problems are getting much worse in the case of the developing countries, where the authorities seem to be overwhelmed by the situation and therefore cannot find the appropriate solutions to leave the water problem behind (Human Development Report 2006), inasmuch as the water demand for domestic consumption, agriculture and industry is growing, while water resources are dwindling. Even when these countries do have significant amounts of water resources, the lack of financial means hinders them to put them to account and, consequently, a second-order scarcity arises (Ohlsson 1998). Under the circumstances, all economic sectors are affected and this has a negative impact on the GDP (IPCC 2007). If in certain areas, people have come to terms with this situation by means of a social adaptive behavior that helps them carry on with their lives, elsewhere water scarcity often generates social unrest, which threatens to develop into riots or even wars.

The countries of the European Union might also be faced with this menace, inasmuch as for more than 30 years they have been plagued by severe droughts, which affected at least 11% of the population and 17% of the territory (COM 2007). As far as Romania is concerned, it has been confronted with excessive droughts, heat waves and aridisation phenomena, which have drawn the attention to the fact that the country is on the verge of a major water crisis. But the scant precipitation and summer heat are not the only responsible for the water scarcity recorded at national level. According to the National Strategy for Sustainable Development of Romania (2008), a document ratified by the Government, there are other factors as well that make things worse. Pollution is one of these, as it affects the quality of surface and underground water sources to the extent they can not be used any longer to meet consumption needs. Thus, despite the fact that Romania has a potential of about 6,000 m^3 water per inhabitant per year, only 2,660 m^3 are available for utilization, which is less than the European average of 4,000 m^3. Likewise, bad management practices have brought about water scarcity, at least in some parts of the country, because the emphasis has not been on the efficiency, but rather on the economic development. In other words, the authorities have usually disregarded any sustainable considerations and allocated greater and greater amounts of water whenever the economic interests were at stake, thus confirming the theory that a developing country tends to overuse its environmental capital (Allan and Karshenas 1996). Finally, it should also be mentioned that the lack of funding has negatively impacted the water supply systems. Therefore, many cities still have an obsolete infrastructure, which explains why water loss through leaking pipes often amounts to 50%.

The past years' experiences have shown that water shortage affects especially the southern and eastern parts of the country. In these areas, droughts are so severe that the soil cracks and many wells run dry. In summer, people are desperate to see their crops withering in the fields and their animals dying of thirst. At nearly 40°C, every drop of water gets the gold value. This is true especially in the countryside where people quarrel and fight one another for an additional drop. Sometimes, these fights can get a dramatic turn, as it happened in a village where a man and his wife were stabbed by their neighbors because they did not want to share their water with them.

Confronted with such sad realities the Government will have to come up with viable short and middle term solutions to alleviate people's suffering. But these solutions will have to take into account the specific features of each area such as to maximize the efficiency of the actions that will have to be taken, because what is good for a certain locality might not be that good for another. Consequently, local authorities will have to play a major part in the overall effort to control water scarcity. Thus, they will have to commission a series of studies with the purpose of revealing the problems encountered at local level and to find the most feasible ways to overcome them, at least partially.

The present study is an example of how such an investigation could be carried out at small catchment scale. It explains the steps that need to be followed in order to get a clear picture of the whole territory and its related problems, but at the same time, based on its findings it offers an array of solutions that might be taken into account by local administrations in their effort to devise proper strategies to fight against water scarcity.

Study area

The Calnistea catchment is a rather small territory 1,644 km^2, which accounts for only 0.7% of Romania's total area. It lies in the southern part of the country (Fig. 1) in a physiographic unit that goes by the name of the Romanian Plain. The highest elevation of 204 m is found in the extreme northwest of the basin, on the water divide, while the lowest point is 46 m and marks the confluence with the Neajlov River. Most of the land falls inside the 50–100 m hypsometric step, which holds 65% of the catchment. The general gradient of the river basin averages 0°09′, which is typical for a plain area. However, values of more than 10° are common for the valley slopes, while gradients of 40–50° are rarely found at the junctions.

Hydrogeological maps of scale 1:100,000 and stratigraphic columns reveal that plain relief is underlain by Quaternary deposits, which are extremely important, inasmuch as their thickness, granulometry and composition explain the hydrochemical and hydrodynamic features of the aquifers.

The Calnistea catchment shelters three distinct aquifers: the shallow aquifer, which is the first intercepted by the borings, and the middle and the deep aquifers, which have a confined character. The shallow aquifer is represented by the sediments of the floodplains and terraces. In the case of the Glavacioc, the Calnistea's main tributary, this aquifer is made up of mixed sand and gravel, 4–8 m thick. The complex lithology of the sediments has determined the formation of superposed aquifers, the first of these lying above the first permeable layer of the interfluves. The borings have revealed that water table depths are between 0.20 and 2.05 m from the land surface and that groundwaters have a slight rising tendency. In the Calnistea's

Fig. 1 Geographical location of the Calnistea catchment

floodplain, the aquifer consists of fine, middle and coarse sands with significant thickness (10 m on an average), in which the water table is at depths between 0.30 and 6.20 m.

The terrace aquifers found on the left of the Glavacioc and the Calnistea channels are made up of gravel and sands belonging to the Upper Pleistocene, with granulometric and hydrogeological characteristics similar to the floodplain deposits. Here, the water table lies at depths of 2–5 m.

On the interfluves stretching out north of the Calnistea line as far as the alignment Scurtu Mare-Silistea Mica-Silistea-Puranii de Sus-Cartojani the loessoid deposits specific for this area are underlain by a series of predominantly sandy horizons with thin intercalations of gravel of lacustrine origin, which hold insignificant amounts of water. From this reason, they are seldom used as water supply sources for the households in the region.

The middle and deep aquifers are well represented in the south of the catchment, but also to the north of the Calnistea axis, by the so-called *Fratesti Strata*, made up of sands and gravel of fluvial and fluvial-lacustrine origin. It seems that these formations are in fact old alluvial fans deposited by the former Balkan rivers, and even by the Danube, on top of the Romanian series consisting of clays and marls with clayey sands intercalations. In some areas, however, the *Fratesti Strata* are made up of fine, middle and coarse sands, as well as of gravel with sand, which show thin lenticular intercalations of clayey or marly dusts. This confined aquifer sinks gradually to the north until it meets in the central part of the Romanian Plain the aquifer complex of the *Candesti Strata*, deposited from the north by the Carpathian Rivers. The *Fratesti Strata* are capped by an impervious clayey horizon known as the *Uzunu Strata*, which from the geological point of view is synchronous with the *Marly Complex* (Liteanu 1953).

The study area has a mean annual temperature of 10–11°C. The graphs accomplished based on the data recorded at the four weather stations in the region generally reveal a normal evolution of the mean monthly temperatures, which show a continuous increase from January to July and a decrease tendency afterwards. Only at the Rosiori de Vede weather station, the highest value is specific for August. The mean annual temperatures of the coldest month (January) range from −1°C at Pitesti to −3.9°C at Videle, whereas the values of the hottest month (July) are between 20°C at Pitesti and 22.8°C at Alexandria.

In this area, summer days (with temperatures of 25°C or higher) occur from May till October, with a maximum of frequency in August. The average yearly number of summer days is 111. On the other hand, the number of hot days (with temperatures of 30°C or higher) amounts to 43. These occur from May to September, with a maximum of frequency in July. Summer days and hot days are usually a consequence of the tropical air masses that move into these latitudes.

As Fig. 2 shows, after 1970, the mean annual temperature evolution has a general rising trend which encourages

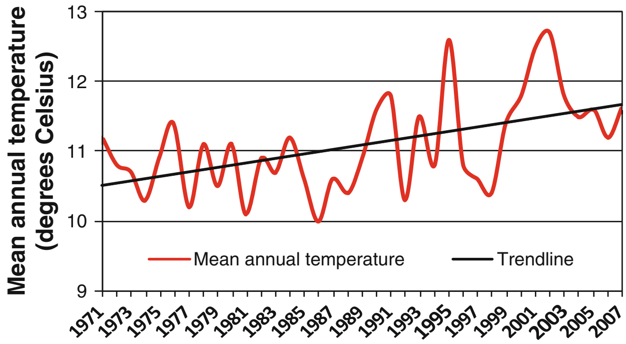

Fig. 2 Mean annual temperature evolution at Alexandria weather station (according to the data provided by the National Meteorological Administration)

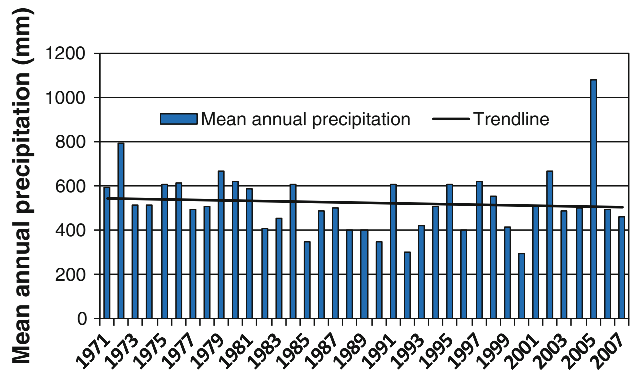

Fig. 3 Mean annual precipitation evolution at Alexandria weather station (according to the data provided by the National Meteorological Administration)

evapotranspiration and explains to a high extent the water deficit in the area and the aridisation phenomena.

The yearly amount of precipitation averages 550 mm. The pluviometric maximum is specific for June when the mean rainfall is 79 mm, while the minimum is recorded in February and March, when mean values reach only 32 and 33 mm, respectively. Summer is the wettest season (186 mm) and autumn and winter are the driest (113 and 112 mm, respectively).

The analysis of precipitation distribution for the last 110 years has shown that in the wet years (1941, 1966, 1972, and 2005) the amount of precipitation fallen to the ground exceeds 800–900 mm, while in the dry years it drops below 300 mm. From 1970 onwards, the evolution of mean annual precipitation has recorded a decreasing trend (Fig. 3), although in some years precipitation has been rather high. However, even in the wet years one can note significant periods of drought, especially in summer. Of the dry years of the period 1970–2007, recorded at Alexandria station, one can mention 1985, 1990, 1992 and 2000. Nevertheless, if we take into account a longer period of time and all the weather stations in the area, dry years for the Calnistea catchment or for parts of it may be considered 1961, 1962, 1963, 1965, 1977, 1982, 1983, 1985, 1986, 1988, 1989, 1990, 1992, 1994, 1996, 1999, 2000 and 2002.

Liquid precipitation is dominant most of the year. In spring and summer, the rains usually have a torrential character. Starting with November or in some years even with the end of October, until March or in the beginning of April, solid precipitation occurs. The mean thickness of snow layer is usually between 5 and 8 cm, but sometimes can reach 10 cm. There are years when in January snow layer can reach 190 cm, but also years when in March it is only 3 cm thick. Heavy snowfalls moisten the soils and recharge consistently the aquifers.

The natural vegetation of the area has suffered in the past 220–230 years radical alterations because of human interventions. The forest has been almost completely destroyed and replaced by agricultural fields and secondary grasslands. Only here and there, patches of the former woods have managed to survive, their present area totalizing only 11,459 hectares (which is 6.5% of the territory in comparison with 50–60% at the end of the 18th century). The cleared lands are cultivated mainly with cereals (wheat, corn, barley and oat), but also with sunflower, soybeans, fodder plants and, to a lesser extent, potatoes and vegetables. However, despite the fertile soils the productions are usually low, because of the long periods of drought and the absence of irrigation systems.

The Calnistea catchment overlaps a region that during Pliocene was flooded by a lake. As the lake shrank, a stream system came into existence, whose development has been subsequently influenced by local and general factors. Consequently, even though downcutting and lateral erosion have not been active enough to produce impressive flowing channels, they managed, however, to create the well-organized stream system that can be seen today (Fig. 4).

At present, the total length of the watercourses in the Calnistea catchment is 389 km. The longest permanent and semi-permanent streams are the Glavacioc (99 km), the Calnistea (87 km) and the Milcovat (45 km), while the shortest are the Valea Taudor (1.7 km), Valea Cuscrei (2 km), the Bratilov (2.2 km) and the Valea Casariei (2.3 km). In summer, due to the long periods of drought and the high evapotranspiration (750 mm) the streams become mere threads of water or chains of pools. When climatic conditions are more excessive, most of them dry up completely inasmuch as the contact with the water table is lost. Striving to fight against water scarcity people have built dams across the streams thus creating many ponds with elongated shape, sinuous aspect and depths that can reach 2–3 m. Following the creation of these water pools the hydrological regime of the rivers changes. During the flood events the water is stored behind the dams, whereas in the drought periods it is released so that to maintain the

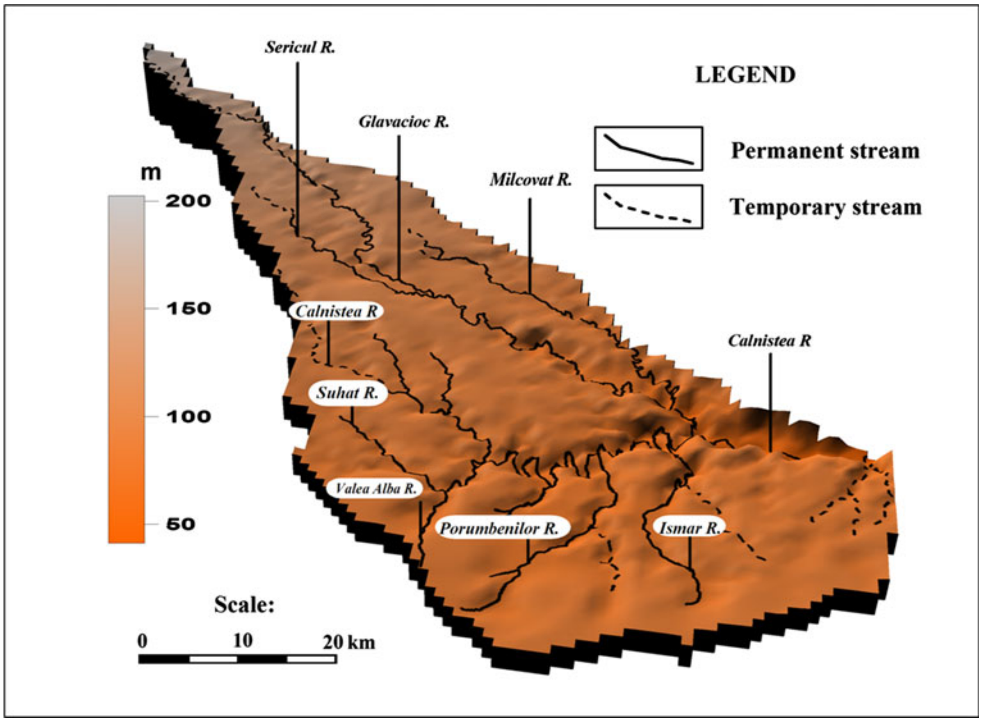

Fig. 4 The stream system in the Calnistea catchment

flow. At present, the ponds are used especially for fish breeding.

The region is highly accessible thanks to the big number of transportation routes that cross it. These routes have encouraged the appearance of many settlements, most of them with agricultural functions and numerous population. The most important settlement is Videle, a town developed on the banks of the Glavacioc, which has flourished especially after 1964, when oil exploitations in the area began. Since then the population has been continuously growing reaching at present 12,331 inhabitants. Apart from this town, there are only rural settlements, which count 18 communes and 42 villages with a total population of more than 60,000 people (Ghinea 2002).

Methodology

The quantitative analysis of surface water sources has been accomplished on the basis of hydrological data recorded at the three gauging stations in the area, of which one is placed on the trunk river, the Calnistea, and the other two on its main tributary, the Glavacioc.

The gauging station with the longest recording interval for discharges is Crovu, on the Glavacioc, which has been continuously in operation since 1962. Although the time span would have been enough for a proper analysis the period of record has been extended back to 1950 based on the correlations with the mean amounts of precipitation fallen yearly over the catchment. Under the circumstances, Crovu station has been considered representative for the Calnistea catchment and therefore it has served as a basis to extend the data records of the other two stations. These statistical data have been processed with the computer and turned into annual and monthly hydrographs, which allowed a pertinent analysis of the flow variations. At the same time, field investigations have emphasized the drought's effects on the environment and on the people living in this area.

Qualitative issues have been dealt with by processing the analysis bulletins kept in the archives of the two Water Management Bureaus that monitor the river system and the groundwaters in the region. Water samples are collected on a regular basis from several representative monitoring sections situated on the Glavacioc, Milcovat, Sericu and Calnistea rivers.

The analysis of hydrogeological parameters of the aquifers has been accomplished on the basis of the existing information offered by the shallow, middle-depth and deep wells, which are rather uniformly distributed throughout the catchment. To assess the flowing directions and the groundwater accessibility the water table contour map and the depth-to-water table map have been worked out. In addition, the natural variations of water table level have been monitored in various parts of the catchment in order to see the extent to which the groundwaters suffer the influence of meteorological conditions.

The quality of underground sources has been evaluated based on the regular analyses accomplished by the specialized institutions. However, random samples have been taken from all the wells in the catchment in order to check the results.

Quantitative and qualitative assessment of surface waters and groundwaters has been followed by an estimation of total water demand of the region.

Finally, bearing in mind the management practices employed by the people and local authorities, the consumption levels, the availability of water resources and their quality recommendations have been made regarding the measures that should be taken in the near future in order to curb the water scarcity problems.

Results and discussion

The analysis of the mean pluriannual discharges computed for the three gauging stations in the catchment reveals a small value for the Glavacioc at Videle (0.69 m^3/s), which is understandable if one takes into account that the gauging stations lies in the middle reach of the river and the drained area is only 220 km^2. Upstream of this point the Glavacioc receives eight tributaries, of which seven experience temporary flow and only one is semi-permanent (the Sericu). Near the junction of the Danube, at Crovu station, due especially to the contribution of its main tributary, the Milcovat, the mean pluriannual discharge of the Glavacioc grows to 1.1 m^3/s.

On the Calnistea River, at Stoenesti station, which is placed in its lower reach, the mean pluriannual discharge is 2.95 m^3/s. For a drained area of 1,644 $km^{2,}$ this value is rather low, which confirms the aridity of the region.

Because of the great variability of local meteorological conditions, with wet years or wet intervals alternating with dry years or dry intervals, the mean discharges show significant variations from year to year. At Videle, for instance, of the 54 analyzed years 41 fall into the 0.207–1.17 m^3/s interval, while 13 are considered extreme years. Four of the last have values below 0.207 m^3/s and nine exceed the upper limit of the interval. But the variability of meteorological parameters is also mirrored by the monthly discharge distribution. Thus, the highest flow occurs in March (6.88 m^3/s) and February (5.04 m^3/s), when the snow melts, whereas the minimum runoff is specific for August (1.26 m^3/s) and September (1.37 m^3/s) (Fig. 5).

In some years, the scant precipitation makes the flow drop significantly and the rivers become mere threads of water oozing gently through their sediments. The phenomenon is further enhanced by the high summer evapotranspiration, which is responsible for the loss of great amounts of water, and by the faint slopes, which turn many river stretches into stagnant waters. When the droughts persist longer, most of the streams in the Calnistea catchment run dry. However, on the Calnistea and the Glavacioc such phenomena have been less frequent since the baseflow is rich enough to maintain a thread of water even under the semi-arid conditions specific for the southern part of Romania.

In general, the surface waters in the Calnistea catchment are fresh. The analysis of the anions and cations has shown that from the hydrochemical point of view these waters belong to the sodium-bicarbonate, calcium-bicarbonate and magnesium-bicarbonate types.

Unfortunately, pollution affects many river stretches and ponds. However, even though contamination sources are manifold and diverse, only five of them have been identified as major threats, because of the high amounts of substances of various natures they produce. It is the case of two public utility services, one in Videle and the other one in Draganesti-Vlasca, of two facilities located in Poeni and belonging to an oil company, as well as of a health center operating in Ghimpati. The analyses of water samples collected downstream these units have shown the main pollutants are ammonium, ammonia, chlorides, phosphorous and phosphates. At the same time, suspensions have been in excess and chemical oxygen demand has recorded values above the accepted limit.

As mentioned previously, the main use of the surface waters in the Calnistea catchment is fish breeding. However, this activity is practiced under pretty harsh conditions because the ponds that chain along the valleys require discharges able to refresh the waters and this cannot be accomplished solely by the rivers that feed them. Consequently, an increase in fish production will be possible only when water derivation canals bringing water from neighboring catchments will be created.

Although there are no irrigation networks in the area to compensate the water deficit in the dry season, the locals, by their own and rather rudimentary means, withdraw water from rivers and ponds in order to use it on the adjacent agricultural fields. Unfortunately, more often than not waters are improper for such a use, inasmuch as their low quality may adversely affect the plants and the health of the humans who eat them. Despite this situation, if pollution effects induced by domestic and industrial effluents were eliminated the waters would become proper for agricultural use, both in terms of physical properties and in terms of salt content. This is confirmed by the field analyses that have emphasized the waters can be used for irrigation purposes without requiring special measures to prevent salt accumulation in soil. However, there are also river stretches and numerous ponds where waters have a higher amount of salts, which makes them tolerable for irrigation provided that parallel measures to prevent salt accumulation are taken. In the case of the soils with good drainage, this is not a problem, since percolation waters can leach the salts from the soil profile.

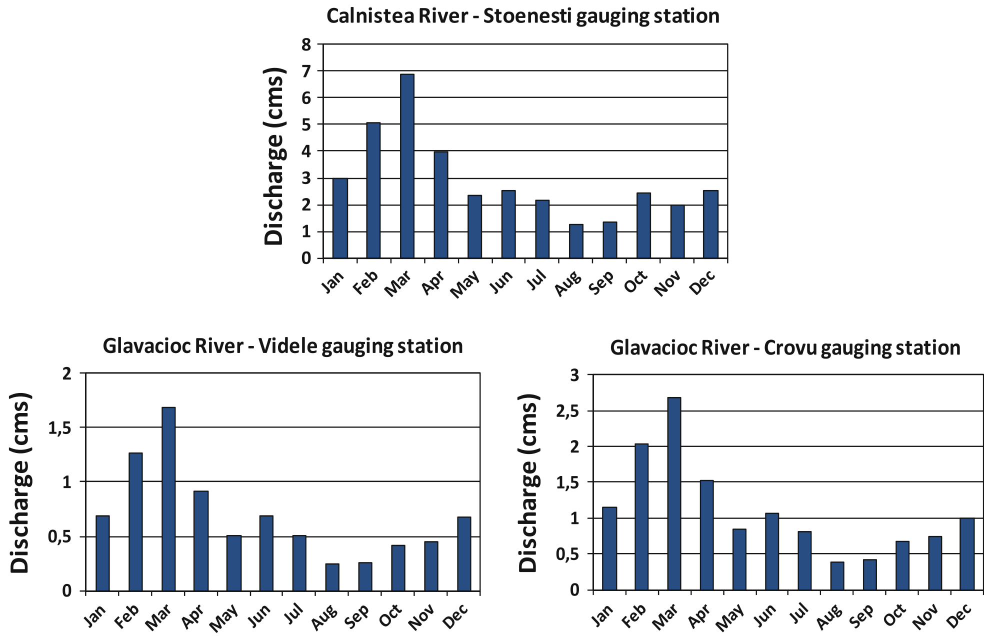

Fig. 5 Mean monthly discharges at the three gauging stations in the Calnistea catchment (1950–2009)

Groundwaters are an important asset of the region, as they represent the only source of drinking water. By analyzing the water table contour map (Fig. 6) one can see that in the extreme north of the catchment water table lies at 160 m, whereas in the nearness of its southern borderline it is found at only 80 m. The aspect of the water table contours shows the existence of two main drainage directions: from northwest to southeast, for the regions lying north of the Calnistea, and from southwest to northeast, for those stretching out to the south. In the south, there is also a secondary drainage on a north–south direction imposed by the Calnistea River, which acts as a local base level. Generally, groundwater flow velocity is low, inasmuch as water table gradients average 1‰, both in the north and in the south.

The groundwater accessibility has been assessed based on the depth-to-water table map. Its analysis has shown that the most accessible groundwaters (0–5 m deep) are those stored in the floodplain formations as well as those found at small distance from the watercourses. By contrast, the less accessible groundwaters (deeper than 15 m) are specific mainly for the southern extremity of the catchment. The vertical oscillations of the water table are quite significant. For instance, in 2004 the oscillation range in the southern part of the area was more than 5 m (Fig. 7). This relatively high value points at the close relationship between the groundwaters and the amount of precipitation falling yearly upon the ground.

Generally, on the interfluvial surfaces the water table sinks when the drainage is higher than the recharge and rises when the situation is opposite. When the two are more or less alike, the water table is in relative equilibrium. Along the valleys and especially within the floodplains the variation range is small (<1 m), due to the hydraulic relations between the rivers and the adjacent aquifers. Thus, during dry periods the seepage in the river beds makes up for the water deficit in the atmosphere.

In order to estimate the amount of water stored in the aquifers, specific discharge, permeability and transmissivity have been taken into account. These parameters have been computed based on experimental pumpings performed in the region.

The specific discharge of floodplain aquifers is 3.9 l/s/m at a pumping discharge of 5.6 l/s. For the middle-depth aquifer distributed over the entire catchment the values range from 0.03 l/s/m at Ciuperceni well to 1.9 l/s/m at Toporu, under pumping discharges of 2.6 and 6 l/s, respectively. In the case of the deep aquifers intercepted at depths between 60 m (Bujoreni) and 401 m (Videle) no determinations of specific discharges have been made, but the pumping discharges ranged from 7 to 18.8 l/s.

The aquifers in the floodplains generally show a good permeability, with values ranging from 9.9 m/day (at Calugareni 5 well) to 72.16 m/day (at Calugareni 6 well). On the interfluves, the values are lower. Thus, in the case of the middle-depth aquifer the lowest permeability has been found at Ciuperceni (1.5 m/day), while the highest values have been recorded in the south of the basin, at Tomulesti and Cucuruzu (21 m/day), as well as on the left bank of the Glavacioc, near Purani and Blejesti (20 m/day).

The floodplain aquifers have a transmissivity of 43.5 m^2/day at Calugareni 5 well, 339.1 m^2/day at Calugareni 6 well and 400 m^2/day at Videle. In the case of the middle-depth aquifers the lowest values have been specific

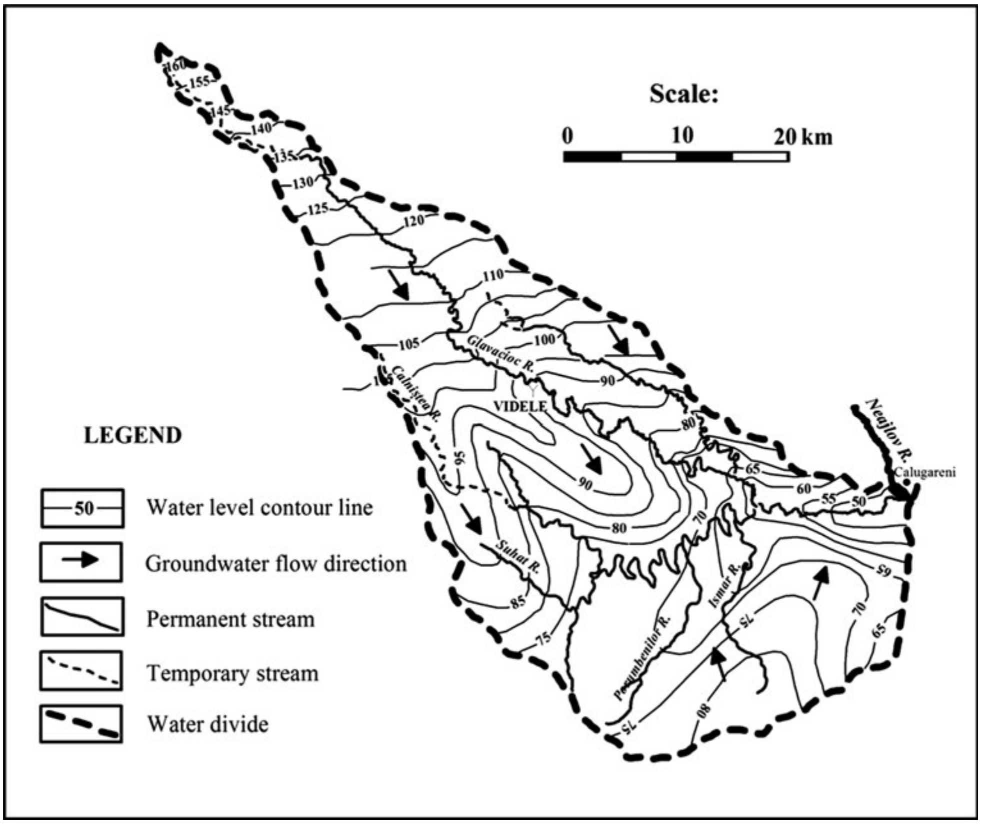

Fig. 6 Water table map of the Calnistea catchment

for Ciuperceni well (2.64 m^2/day), whereas the highest values have been recorded at Purani (329.5 m^2/day), Mereni (256.3 m^2/day), Cucuruzu (233.7 m^2/day), Glavacioc (228.8 m^2/day) and Videle (226.7 m^2/day).

The Videle 1 and Videle 2 wells drilled in the Glavacioc floodplain have intercepted slightly acid waters (pH of 6.7–6.8) with carbon dioxide contents of 22 and 44 mg/l, respectively, and mineralization values around 1 mg/l. The ionic content has been dominated by the presence of bicarbonate anion (HCO_3^-), which accounts for 40% of the total mineralization in the case of Videle 1 and 58.7% in the case of Videle 2, followed by calcium cation (Ca^{2+}), with percentages of 14.5 and 10.6, respectively. The values of fixed residue have been rather low at Videle 2 well (420 mg/l) and nearly thrice higher (1,234 mg/l) at Videle 1. Likewise, water hardness has been high (54 dH), but it has been exclusively carbonic, which means it can disappear completely through boiling.

The shallow aquifers in the Calnistea floodplain have been intercepted by the wells Bila 1, Bila 2, Calugareni 5 and Calugareni 6. The waters stored here have been slightly alkaline, with pH values ranging from 7.31 to 7.83, whereas dissolved oxygen contents have been higher than 7 mg/l. Interesting is the fact that bicarbonate anion has been completely absent, its place being taken by chloride (Cl^-) and to a lesser extent by sulphate (SO_4^{2-}) (Fig. 8). However, mineralization has been less than 500 mg/l, which means the waters are fresh. Due to the low amounts of organic matter the chemical oxygen demand has varied between 2.52 mg/l (Bila 1 well) and 13.4 mg/l (Calugareni 6 well). As far as the middle-depth groundwaters are concerned, their pH has been slightly alkaline (7.3–8.5), while carbon dioxide content has varied from month to month, ranging from 11 mg/l (Mereni) to 72.6 mg/l (Blejesti). The major ions present in the water have been bicarbonate anion (HCO_3^-) together with calcium (Ca^{2+}) and magnesium (Mg^{2+}) cations. Waters are generally fresh, although sometimes mineralization can exceed 1 g/l (Mereni 1,148 mg/l, Naipu 1,075 mg/l, Prunaru 1,364 mg/l, Blejesti 1,289 mg/l and Bila 1148 mg/l). Mineral suspensions have shown values between 290 mg/l (Baciu) and 980 mg/l (Blejesti), while total hardness has been between 12.2 and 49.5 mg/l, respectively, with a share of carbonates and calcium bicarbonate of 80–100%.

The most recent wells drilled at Ciupagea, Glavacioc and Valea Ciresului highlight the fact that in spring and summer pH values are rather similar, but the major cations and anions suffer significant quantitative changes. For instance, at Ciupagea, the values determined in September have been a great deal higher than those found in May, i.e. thrice higher with respect to calcium (Ca^{2+}), more than 10 times to magnesium (Mg^{2+}), 2.5 times to sulphate (SO_4^{2-}), 4 times to bicarbonate (HCO_3^-) and thrice higher with respect to chloride (Cl^-). At the same time, mineralization

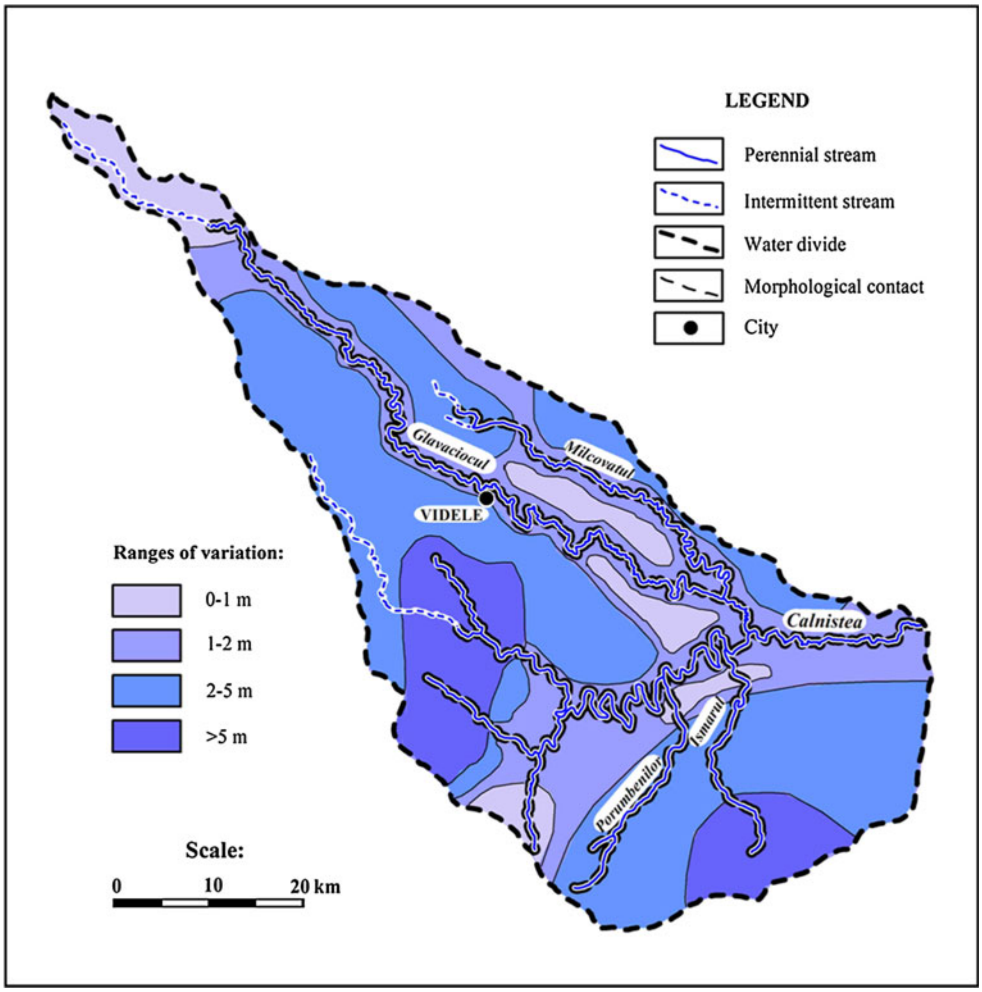

Fig. 7 The range of variation of the water table in the Calnistea catchment in the year 2004

has been usually higher in autumn, with values of 198.5 mg/l in May and 888.7 mg/l in September. The highest values of fixed residue and chemical oxygen demand (16.9) have been specific for September, too.

The pH of the deep groundwaters in the Calnistea catchment is slightly alkaline (7–8) and the amounts of carbon dioxide range from 4.4 mg/l (Blejesti) to 33 mg/l (Videle). Bicarbonate (HCO_3^-) and calcium (Ca^{2+}) are the most representative ions, but mineralization is rather low (280–483 mg/l). Likewise, the amount of fixed residue is low (204–380 mg/l) and chemical oxygen demand varies between 4.4 mg/l (Stefan cel Mare) and 33.5 mg/l (Videle). As far as the hardness is concerned, it ranges from 3.2 to 11 mg/l, which certifies that waters are soft or slightly hard. In general, temporary hardness is greater than permanent hardness, because carbonates and calcium bicarbonate present in the water are prevalent.

Even though at first sight it may seem the groundwaters are exempt from the harmful effects of the human activity in reality things are different. Because of the seepage processes, many undesirable substances can contaminate, sometimes very seriously, the waters stored in the aquifers. In the Calnistea catchment, the contamination comes from domestic, industrial and agricultural sources.

Domestic sources produce solid and liquid wastes containing easily degradable organic compounds, which are discharged either in the sewerage systems, and further in the rivers as degraded waters or partly cleaned effluents, or directly into the ground in non-septic pits. Whatever the case, the contamination is done by percolation. If one takes into account that most settlements in the area are rural and lack sewerage systems it is then understandable that domestic sources pose a serious threat to rivers and groundwaters.

Industrial sources in the region are represented by the oilfields Videle and Letca Noua, as well as by the economic units mentioned previously. The effluents they discharge contain hard degradable organic compounds (detergents, petroleum derivatives, etc.), biologic compounds (bacteria, viruses, etc.) or mineral compounds.

In the absence of irrigation systems agriculture brings its contribution to the groundwater impairment through chemical fertilizers and pesticides, which are carried downwards by percolation waters. Thus, the groundwaters get contaminated with compounds such as nitrites, nitrates

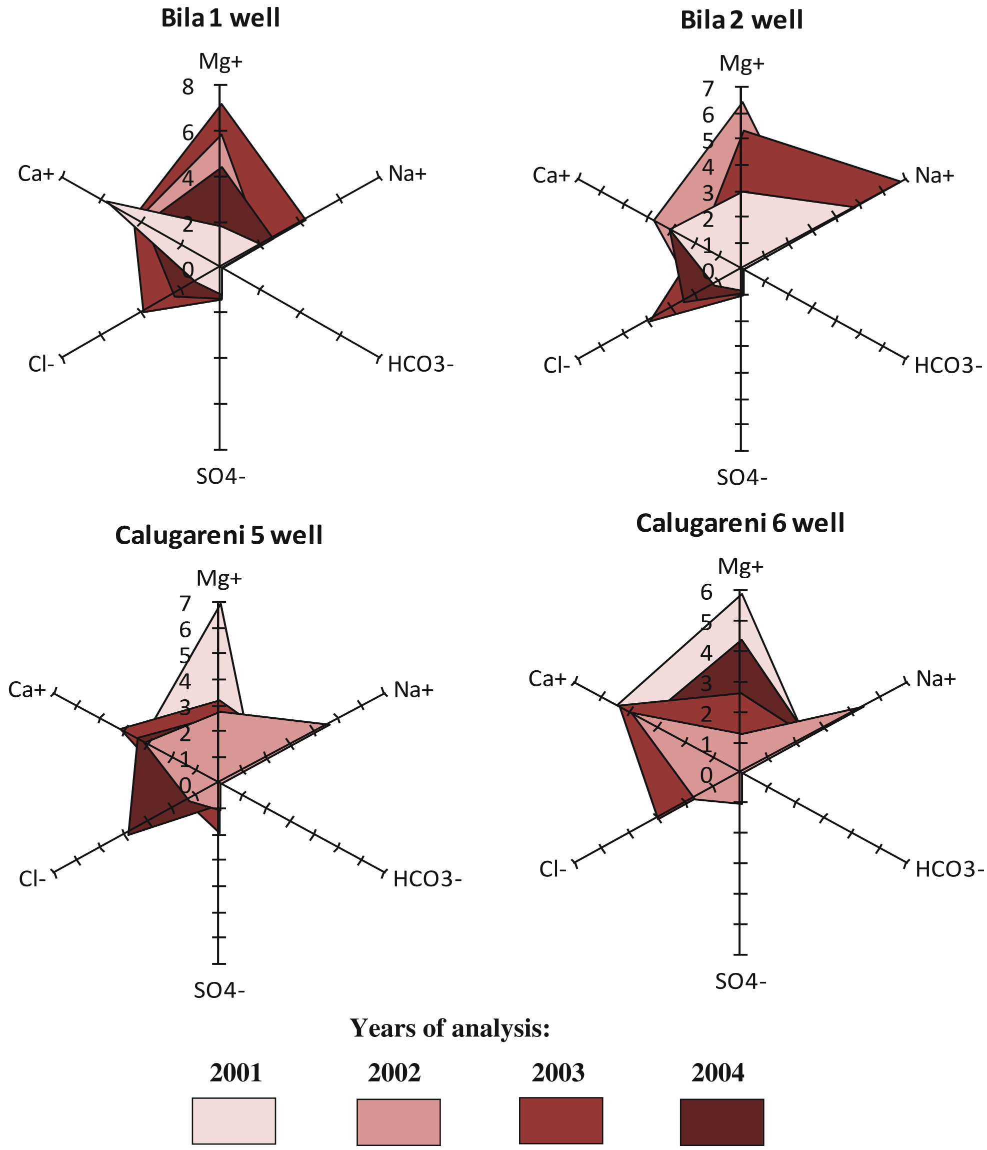

Fig. 8 The main anions and cations present in the groundwaters stored in the Calnistea floodplain (the values are given in miliequivalents per liter)

and pesticides. Fortunately, the cases of groundwater contamination beyond the accepted limits for drinking water are rare, and this is good news for the people living in this area who drink water from underground sources.

A particular attention should be paid to the Cretaceous aquifer lying in the Southern part of the Calnistea catchment. Its existence was proved in 1992 when the borings performed in the surroundings of the Uzunu commune found water at depths of more than 600 m. This water is stored in an aquifer made up of limestones with cave-like hollows with excellent properties for water circulation, which extends from the Danube up to the Carpathian foothills. Experimental pumpings have shown the aquifer holds 7.2 billion cubic meters of water, which could allow an annual production of 220 million cubic meters. Unfortunately, the waters have a high content of hydrogen sulphide, which cannot be eliminated efficiently because the only two desulphurization stations in Romania are quite a distance away. Otherwise, the waters correspond to drinking standards, as the aquifer is well isolated from pollution influences. In the past years, this aquifer has been looked at as a potential water supply source for Bucharest City (Cocos and Cocos 2007), because in its rapid expansion the Romanian capital will need soon to raise its water production. But it can be assumed that as soon as a treatment station will be built in this area, part of the water could be used to supply the settlements in the Calnistea catchment, too.

Conclusions

The total demand for water in the Calnistea catchment is about 16,000 m^3/day. Apart from a small amount that comes from rivers as well as ponds which is used by local people to water their crops, the water used for covering domestic, public and industrial consumption comes from underground sources. The ongoing pressure on the groundwaters, which often is greater than the recharge capacity of the aquifers, confirms the existence of a water-stressed territory, with a water scarcity index of 0.7–1 suggesting that water resources are heavily exploited (Water Scarcity Index 2009).

Most of the settlements in the study area are rural and therefore do not possess centralized water supply systems. Consequently, the inhabitants need to dig individual wells in order to secure water for drinking and for supporting household activities. However, the social and economic development of some settlements has led to the drilling of many wells and to the creation of groundwater pumping station fronts, which favored the appearance of centralized water supply systems.

Despite all these efforts, water scarcity continues to plague the whole region. Its symptoms can be seen all over the place: cracked soils, dry valleys, withered plants, people carrying barrels of water in their horse-drawn carts to water their crops, declining groundwater levels, thirsty people and dying animals. So many problems in front of which local authorities seem rather lost. One requires therefore a good strategy with concrete measures in order to cope with the situation.

First and foremost, the local authorities will have to identify as many potential sources of funding as possible. This might be very difficult to accomplish in a period when the global recession has already had a negative impact on Romanian economy. An option could be to try to secure funds through the European programs for Romania. Once the budgets are secured, the priority would be to build new centralized water supply systems for as many settlements as possible. This should be done first for Ghimpati, Copaciu and Naipu villages, which form together the Ghimpati commune, as the number of their inhabitants will make the investment efficient. The works should begin with the drilling of two wells, 70 m deep, for Ghimpati and four wells, 50 m deep, for Copaciu and Naipu. The pumped water will be stored in concrete cisterns with capacities of 400 m^3 each for Ghimpati and Naipu, and 300 m^3 for Copaciu. The distribution network, which will carry water to the consumers, will consist of tubular pipes with a total length of about 780 m. In the case of Ghimpati village, it is estimated that the centralized water supply system will ensure a daily discharge of 736 m^3, which can be increased during peak intervals to 956 m^3. The corresponding figures for Naipu are 497 and 646 m^3, and for Copaciu 738 and 960 m^3. At the same time, the local authorities will have to take the necessary approaches in order to get a share of water from the Cretaceous aquifer when this will be turned to account.

Another concern for local authorities should be the building of sewerage systems and treatment stations so that to stop the discharge of wastewaters directly into the streams. In the case of the already existing treatment stations, emphasis will be put on their modernization and especially on their capacity increase.

As mentioned before, the scant precipitation, high evapotranspiration and low baseflow explain the low stream discharges and the reason why rivers dry out during drought periods. To prevent the risk of occurrence of such an undesirable phenomenon people have built earth dams and created chains of pools that succeed to a certain extent to regulate the flow. But the compensation of discharges and the safeguarding of water for various uses can also be done through the cutting of diversion channels that will bring water from the neighboring catchments. The most cost-effective course of action would be to cut a channel between the Dambovnic and the Glavacioc, more exactly between Fierbinti and Catunu villages. With a length of 5.2 km, the channel will ensure a gravitational flow of 17 m^3/s. Once inside the Calnistea catchment, the water could be diverted further from the Glavacioc to the trunk river through another channel that will have to begin 1.5 km upstream the Blejesti dam, then cross in its way the Sericu valley, reaching finally the Calnistea River through one of its tributaries. The water will flow gravitationally at an estimated discharge of 12 m^3/s.

A more complex and costly solution to regulate the flow of the rivers in the Calnistea catchment would be to bring water from the Danube. In this case, however, the channel will have to be built from a lower elevation to a higher one and consequently powerful pumps will be needed to push the water upstream.

Apart from these measures that focus exclusively on surface waters and groundwaters the authorities should be aware of the fact that rainwater can be harvested and used later for various purposes (Gould, 1992). Thus, big reservoirs will need to be built especially in the areas where the demand is very high. At the same time, people who live in the countryside could build their own reservoirs, either alone or with qualified support, so that to meet part of their domestic consumption. In fact, this is an old practice in the piedmont areas bordering the Southern Carpathians, where the inhabitants dig pits in the ground and cover their bottoms with clay so that to render them impermeable.

Last but not least, the authorities should engage in educational activities meant to raise people's awareness of the importance of water saving and water conservation. Only through a joint effort of all the actors involved life will get better on this territory.

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