The contribution of watershed management to the integrated flood protection of the Athens basin. An example: the torrent of Chalandri

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Abstract

The Athens basin along with the nearby massifs constitutes a single geomorphological entity, consisting of four mountains (Egaleo, Parnetha, Penteli, Hymettus) arranged in the shape of a horseshoe, with maximum altitudes ranging between 468 m and 1400 m, and of lowlands beginning at the foot of the mountains and stretching out to the sea. These mountains however are mostly deforested, due to fires or man-made influences. Thus, the geomorphological singularity of area, assisted by lack of vegetation, results in the creation of an intensely torrential environment, in spite of the fact that the relief is not very intense, the geological base is fairly resistant and annual precipitation depth is not high. Needless to say that the solution of the problem requires full management of all the torrents that contribute to its occurrence. One of the main categories of watershed management works in mountainous basins are technical works with the use of plants. These works, which lead to the partial recovery, often neglected in our country, usually serve more purposes than that of protection simply (aesthetics, recreation, etc.). The present paper investigates the effects of watershed management of the torrents’ drainage basins on the prevention of the flood problem in Athens, using as an example the basin of the Chalandri torrent. Subsequently, by extending the conclusions of the research to the rest of the currents in the broader area, light is shed on the overall contribution of watershed management to the integrated flood protection of the basin.
1 Introduction

Nowadays it is finally acknowledged that there is a great problem in the Athens' basin, due to the torrents' action, and that it is in need of flood protection. However, even if the flood events of the last two years - or even the earlier ones thanks to which the intensity of the problem was determined - had not taken place, a closer observation of the area and of some of its parameters is sufficient to establish the great degree of torrential danger in the area.

This basin, along with the surrounding massifs, constitutes a single geomorphological entity (Maratos [1]), which consists of four mountains (Egaleo, Parnetha, Penteli, Hymettus) arranged in the shape of a horseshoe, with maximum altitudes ranging between 1400 and 468m and of lowlands beginning at the foot of the mountains and stretching out to the sea (Figure 1).

Figure 1: The Athens basin, established in broader mainland Greek area.

Apart from its climatic, morphological, etc. singularities, this entity is particularly interesting in terms of hydrology, as well.

It is a “closed” hydrologic system, where approximately 45-50 distinct torrents flow down the surrounding mountains, as well as many nameless smaller ones. These torrents, which have been known since antiquity (Papadakis [2]) and they are mentioned in Plato (see Plato - Temaos) for their damaging activity, contribute quantities of water and brought materials to an area which is not particularly broad anyway. In addition, if we take into consideration the dramatic change of the scenery that has taken place up to now, due to the dense and uncontrolled building, we can easily comprehend the intensity of the problem.

On the other hand, the entity's mountains, which also serve as the plain's feed-gear (in terms of water and brought materials), are mostly deforested, carrying along all the well-known effects of deforestation.
Thus, the geomorphological singularity of the area, assisted by the lack of vegetation, results in the creation of an intensely torrential environment, in spite of the fact that the relief is not very intense, the geological settlement is fairly durable and the annual precipitation is not high (Margaropoulos [3]).

Needless to say that the solution of the problem requires full management of all the torrents that contribute to its occurrence. However, when such managements take place, great emphasis is usually placed on the plain-flood part of the torrent, with the use of widenings, alignments, bedstone revetments. The area around the drainage basin is ignored, while it is known for a fact that a full management system presupposes intervention to be made first in the mountainous area, which also supplies the corresponding plain with water and brought materials. One of the main categories of watershed management works in a mountainous basin are technical works with the use of plants. These works, often neglected in our country, also serve other purposes (aesthetic, recreational ones, etc.) The present paper aims at presenting the most appropriate system of watershed management in the drainage basin of a particular torrent that represents the average torrential conditions of the basin. Furthermore it aims at investigating the possibility to extend this system to other neighboring basins of equal interest, albeit with small modifications for their improvement. In the light of the above, the torrent of Chalandri and its basin were chosen.

2 Research area

As it has already been mentioned, the research area is the drainage basin of the Chalandri torrent and especially its mountainous part (see figure 2).

Figure 2: Rough drawing of the drainage basin of the Chalandri torrent with the mountainous area shaded.
In table 1, the morphometric features of the aforementioned basin are given.

Table 1. Morphometric data of the main bed of the Chalandri torrent

<table>
<thead>
<tr>
<th>DRAINAGE BASIN</th>
<th>SURFACE F (km)</th>
<th>ALTITUDES</th>
<th>HYDROGRAPHIC NETWORK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chalandri</td>
<td>18.41</td>
<td>Hmax: 1108</td>
<td>Main</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hmin: 164</td>
<td>Main Slope</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DH: 944</td>
<td>Bed's</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hm: 410</td>
<td>Bed's Slope Net.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Length Net.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Density (km)</td>
</tr>
<tr>
<td></td>
<td>20.48</td>
<td>11.38</td>
<td>5.49</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40.82</td>
<td>2.21</td>
</tr>
</tbody>
</table>

The factors that shape a torrential environment are four: the climate, the relief, the geological settlement and the vegetation (Kotoulas [4]). In particular, for the present research area we have the following:

a. Climate

In order to determine the climate, we have used the data collected from Philadelphia’s Weather Station and from Athens’ Observatory, as well as the bioclimatic maps of Mavromatis (1980) (Mavromatis [5]).

The average monthly and annual precipitation, the annual air temperature, as well as the thermostatic amplitude of the area are given in tables 2 and 3.

Table 2. Average monthly and annual precipitation in the stations of the research.

<table>
<thead>
<tr>
<th>STATION</th>
<th>AVERAGE MONTHLY AND ANNUAL PRECIPITATION (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>J</td>
</tr>
<tr>
<td>Philadelphia’s</td>
<td>43.8</td>
</tr>
<tr>
<td>Observatory</td>
<td>40.7</td>
</tr>
<tr>
<td></td>
<td>J</td>
</tr>
<tr>
<td></td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>4.2</td>
</tr>
</tbody>
</table>

Table 3. Average monthly and annual air temperature and thermostatic amplitude in the research area.

<table>
<thead>
<tr>
<th>STATION</th>
<th>AVERAGE MONTHLY AND ANNUAL AIR TEMPERATURE AND THERMOSTATIC AMPLITUDE (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>J</td>
</tr>
<tr>
<td>Philadelphia’s</td>
<td>10.1</td>
</tr>
<tr>
<td>Observatory</td>
<td>9.4</td>
</tr>
<tr>
<td></td>
<td>J</td>
</tr>
<tr>
<td></td>
<td>28.4</td>
</tr>
<tr>
<td></td>
<td>27.2</td>
</tr>
</tbody>
</table>
According to Mavromatis’ Bioclimatic Maps (1980) the climate in the southern part of the research area is light to intense, Mediterranean and warm, with 100-150 dry days, while in the northern part the climate is intense, mediocre Mediterranean to light Mediterranean with 70-125 dry days.

b. Relief

The relief of the torrent’s drainage basin is illustrated in Figure 3, and it provides the axonometric survey of the drainage basin in a 3-dimension model.

![Axonometric survey of the drainage basin of the Chalandri torrent given in a 3D model.](image)

The remaining relief data have been given in table 1.

c. Geology – Soils

The Pentelikos massif consists mainly of limestones and marbles. Other metamorphic rocks appear only in certain places (Maratos [1]). In terms of soils, the research area is divided into five different cartographic units, based on a general classification for Greek soil conditions by the Ministry of Agriculture. For our research area, this classification is given in table 4 according to the Ministry system.
Table 4. Chartographic units arranged in categories of soil capacity in the research area (GSHA Map by the Ministry of Agriculture).

<table>
<thead>
<tr>
<th>INTERVENTION ZONES</th>
<th>AVERAGE SURFACE INCLINE</th>
<th>ORIENTATION</th>
<th>TYPE OF SOIL (classification by the Ministry of Agriculture)</th>
<th>GENERAL DESCRIPTION AND CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>41%</td>
<td>SW</td>
<td>Rocky soils and rocks</td>
<td>Areas of intense relief, dry and warm, almost rocky.</td>
</tr>
<tr>
<td>2</td>
<td>45%</td>
<td>S</td>
<td>Rocks and rocky soils</td>
<td>Same areas as above, with an even more unfavourable relief and no soil.</td>
</tr>
<tr>
<td>3</td>
<td>27%</td>
<td>SE</td>
<td>Shallow soils with hard limestones</td>
<td>Areas of a fairly smooth relief, medium humidity, with poor and immature grounds, without potassium and phosphorus, and a high CaCo content.</td>
</tr>
<tr>
<td>4</td>
<td>22%</td>
<td>E</td>
<td>Shallow to medium soils with colluvia of limestones</td>
<td>Areas of a smooth relief with a fairly good humidity and plenty of soil.</td>
</tr>
<tr>
<td>5</td>
<td>33%</td>
<td>W</td>
<td>Shallow soils with hard limestones</td>
<td>Areas of medium relief, dry, with poor and immature grounds, similar to zone 3.</td>
</tr>
</tbody>
</table>

In order for this classification to be better understood, figure 4 is also provided, where we show the cartographic units which also constitute the corresponding intervention zones (as it will be shown further on in the paper). The study of those leads to the conclusion that the drainage basin in its whole includes types of land with shallow, rocky and even non-existent soil.

d. Vegetation

Within the research area and up to a 600m height, we encounter the warm Mediterranean formation (*Oleo ceratonio*), while in the northern part and to a lesser extent there is the Mediterranean formation of the *Quercus ilex* (*Quercion ilicis*), which is substituted by *Quercus coccifera*. The area’s natural vegetation has been subject to great damage in the past due to fires and grazing. The research area is to a great degree deforested and bare. Only sporadically and in the lower section of the mountainous basin are there clamps of pine-trees (*Pinus halepensis*) and evergreen broad-leaved units. In this area we come across the following species: *Quercus coccifera*, *Olea oleaster*, *Juniperus oxycedrus*, *Juniperus phoenicea*, *Quercus ilex*, *Pistacia lentiscus*, *Cercis siliquastrum*, *Transactions on Ecology and the Environment* vol 46, © 2001 WIT Press, www.witpress.com, ISSN 1743-3541
Ceratonia siliqua, Erica verticilata, Arbutus unedo. We also encounter, in a great stretch of land, many phrygana, as the ultimate level of the retrogressive evolution of vegetation. The main species of phrygana are: Genista acanthoclada, Thapsia garganica, Notobasis syriacus, Phlomis fruticosa, Thymus atticus, Satureia thymbra. In the area, there are also a few mossy plants such as: Medicago spp., Trifolium spp., Bromus madritenis, Cynodon dactylon etc. Finally, very crucial is also the flora of the area’s geophytes, such as Asphodelus microcarpus, Cyclamen graecum, Tulipa montana, Scila autumnalis, Crocus crewei, Cladiolus segetum etc.

To sum up, we have reached the conclusion that the torrential environment of the Chalandri current is typical of the Attic environment. This means that we have a mediocre and only in parts intense relief, a poor presence of soil and vegetation, and the famous semiarid Attic climate.

3 Research method

Technical works with the use of plants are methods of watershed management in which live organisms are used as materials and in particular, live plant materials, in opposition to agrotechnical works in which dead plant materials are used (Emmanouloudis [6], Fang [7], Brofas [8]).

The up-to-date international and Greek experience in technical works with the use of plants, dictates that there are numerous advantages in comparison to technical and agrotechnical works. These are briefly the following (Emmanouloudis [6]):

- works with use of plants do not become subject to damage after their construction as the technical and especially the cross-sectional works do. On the contrary, they increase in stability and effectiveness in the course of time.
- they are better than technical works in terms of aesthetics, adaptability to the natural environment and preservation of the landscape.
- apart from their primary aim, they also have other beneficial effects such as aesthetic, sanitary, recreational, military ones and other.

Apart from the advantages, however, there are also some disadvantages, the most important of which is that the works’ viability and efficiency depend on the station conditions (the area’s climate – soil) and also on the suitability of these conditions for the evolution of the chosen species.

In the present paper, the station’s quality has been examined with the aid of tables 2 and 3, along with the help of the soil map drawn on a scale of 1:50,000 by the (1994) (Ministry of Agriculture [9]). With the station features given, a primary selection of the most suitable plant species has been made. Then we have chosen the kind of watershed management with the use of plants that is appropriate for each case, which is presented through the condensed analysis of the way this management is carried out. The main aim for the planting of vegetation is the soil protection and stabilization. At the same time, vegetation can improve the soil and the landscape’s aesthetic characteristics and it can provide fauna with food and shelter. With the aid of technical works with the use of plants, the present ecosystem which is poor in organization and productivity
will be upgraded into one which would be rich in organization and productivity. We are going to use mostly species from the local flora. However, in order to achieve an increase in stability and biodiversity, we will also add some foreign species, in a proportion of no more than 10% - 20% of the surface. Such foreign species have been successfully used in the past in Attica's broader area (Sagias [10]).

4 Results

The study of the area's rainfall station and temperature features (after the necessary adaptions have been made), along with the analysis of the terrain data of the mountainous drainage basin, have led to the conclusion that this research area can be divided into 5 intervention zones, following exactly the same borders with the above mentioned of Ministry of Agriculture classification. Each one has different station conditions and ranging levels of difficulty for the implementation of watershed management with the use of plants. The characteristics of these zones, whose borders and description are the same as those have been given before by the Ministry of Agriculture, are given in table 4, while their borders in Figure 4.

Figure 4: Intervention zones in the research area.

These are the borders that have been used for these zones in the present paper.

The study of Figure 4 and table 4 results in the discovery that the station conditions in intervention zones 1 and 2 are extremely unfavorable, because there
are strong and intense restrictions for an increase in productive forests. In zones 3 and 5 the conditions are less unfavorable but there are also intense restrictions for an increase in productive forests. Only in zone 4 are conditions fairly good and there are medium, although in parts intense, restrictions for an increase in productive forests.

However, given that the choice of plant watershed management depends on the station conditions, it is only natural that this choice should differ between individual zones. Therefore, given the internationally (Karakatsoulis [11], Tsogas [12], Papamichos [13], US Soils Conservation Service [14], Wilde [15]) approved and accepted facts and taking into account the data from table 4, we have come up with the following choices for each zone:

ZONE 1: For this zone and for the surfaces of the slopes, the construction of mosaic clusters is recommended, which is a method of direct securing of the surface, even on occasions when its slopes are steep. Mosaic clusters are live technical plant material made up of Salix species sprouts and branches that are implanted in ditch-like grooves of 0.5 – 1.0m depth. These grooves follow the contour-interval and the distance between them usually ranges from 2 to 4m. In the case of zone 1 and because of the almost non-existent soil, we must take precautions to fill the ditches with soil material from other areas, which should be enriched, if possible, with potassium and phosphorus.

In the same zone and for the gullies of tributaries, we recommend the construction of belt-stakes which are considered to be works of great stability. The belt-stakes are live materials made of Salix and Platanus stakes, 1/3 of which is stuck into the riverbed at a distance of 10-15cm from each other and which are further stabilized with the aid of horizontal beams which are embedded into the riverbed sides. Not only are the aforementioned works going to result in the retention of the soil in the slopes and along the gullies and on both their sides, but they will also aid in the accumulation of new soil (within the riverbeds). The existence of soil is going to become the necessary presupposition for the success of the recovery of shrubs or the reforestation, which is going to follow in a few years’ time and it will become the second phase of the intervention in zone 1.

The recommended mossy species for the recovery of shrubs by basic sowing are: Lolium rigidum, Sanguisobra minor, Onobrychis sativa, Medicago sativa and Anthyllis vulneraria. These species have been successfully used by Brofas (2001) in similar environments and soils. A different variety can also be used: the one used by EGNATIA ODOS A. E. for the recovery of shrubs at the sides’ of the roads in similar semiarid environments (Papanastasis et al. [16]). This variety consists of perennial grasses (Cynodon dactylon 35%, Festuca rubra 15%, Agrostis tenuis 5%, Lolium rigidum 20%), legumes and other species (Phacelia tanacetifolia 10%, Sangisorba minor 5%, Trifolium subterraneum 10%), while for those parts which are to be filled with soil (trenches) we recommend frugal shrubs of small heights, such as: Medicago arborea, Spartium junceum, Anthyllis hermanniae, Juniperus oxycedrus and Quercus coccifera). Along the gullies and on both sides of the riverbeds, we can also have, except for the previously mentioned shrubs, plants with a greater need for humidity (Lonicera ertusca,
Nerium oleander) as well as trees like: Robinia pseudoacacia, Pinus brutia, Cupressus sempervirens, Sorbus torminalis and Quercus aegilops.

ZONE 2: The same system, as in zone 1, is recommended for this zone, as well. The only difference is that in the gullies, the contribution of small technical works is essential due to the steep slopes and the boulder coarse materials. It would also be useful if a greater number of shrub recoveries on the slopes was recommended.

ZONE 3: For this zone and for the basin’s surface, we recommend the combined constructions of mosaic clusters and envelopments. The former are constructed as instructed above, and they are recommended for the area’s zones with the steepest inclines. The latter are recommended for areas with smoother inclines and they, as well, are live plant materials, half of which are stuck into small trenches of 10-20cm depth and they are stabilized with iron or wooden stakes 0.80cm long. For the same zone and for the gullies’ area, the construction of belt-envelopments is recommended, which are works used for the restraint of gravel, stones, as well as of thin materials, and also for the securing of the riverbed. Their construction is almost similar to the one of the envelopments. In the slopes of this zone, range plants, appropriate for semiarid environments, could also be sown. These plants also have an adequate anti-erosive action. The variety of seeds to be used is the same as the one recorded for zone 1. Finally, along the gullies and on both sides of the riverbed, the following species, which also aid in the work of envelopments are recommended: Robinia pseudoacacia, Spartium junceum, Olea oleaster, Quercus ilex, Gledischia triacanthos, Ceratonia siliqua and Quercus aegilops.

ZONE 4: In comparison to the other zones, this one presents the best conditions of all. It is the only zone, which exhibits some soil presence, and therefore, the exclusive construction of envelopments is recommended because they are the best works available for the immediate securing of leached soil masses.

For the same zone and for the gullies’ area, the construction of belt clusters is recommended. They are also the simplest of all the lateral technical works with the use of plants, giving the greatest emphasis on the retention of thin material due to their special inhibitory effect on the speed and sweeping power of the water. Also, with the aforementioned presupposition for the condition of the presence of soil material, shrubs, which are resistant to dry soils and can improve soil formation, could also be planted in the riverbeds. The recommended species are: Medicago arborea, Coronilla emoroides, Cotutea arborescens, Calycotome villosa, Cotinus coggyria, Rosa sempervirens, Pistacia lentiscus, Phillyrea latifolia. During these shrub recoveries, instead of planting there could also be taken place a direct sowing (in the autumn), after the seeds undergo the necessary treatments (Takos & Merou [17], Takos [18]). In the parts where there is more soil Cercis siliquastrum, Ceratonia siliqua, Sophora japonica, Ailanthus altissima and Carpinus orientalis could also be used. Finally, in order to help the belt clusters in the gullies, more demanding species can be planted such as: Nerium oleander, Pinus pinea, Cupressus sempervirens, Cupressus arizonica.
Olea oleaster, Vitex agnus castus, Fraxinus ornus, Laurus nobilis, Albizia julibrissin, Elaeagnus angustifolia, Platanus orientalis, Quercus ilex.

ZONE 5: The same system, as in zone 3, is recommended for this zone, as well, with the only difference that the construction of the mosaic clusters is expected to be less frequent than the one of the envelopments.

This recommended system of technical works with the use of plants can be applied to the other mountainous drainage basins of the entire area, with slight modifications. These modifications concern the selection or rejection of some of the aforementioned methods and their only criteria are the surface’s slopes, the soil’s existence or non-existence and the area’s orientation.

However, the general axis of a watershed management system on which we can act on an Attic level, is the following:

a. For the slopes’ areas: The construction of mosaic clusters in the unfavorable occasions where we have steep inclines, with a limestone or marble geological settlement. The plant material must be composed of pioneer species, resistant to limestone rocks, which can endure in aridity and, at the same time, improve the soil. However, in more appropriate areas of smoother inclines with a shale geological settlement, the construction of envelopments is recommended for the retention of the valuable soil material, which is so rare in Attica.

b. For the minor glens’ areas: The primary factors here are the axial inclines of the tributaries and the materials they carry. Starting with the smoother slopes and moving towards the steeper ones and the coarser materials, we have: belt clusters – belt-envelopments – belt-stakes. In these areas trees, which can be less or more demanding, could be planted according to soil conditions.

5 Conclusions

In the present paper, an integrated management system of technical works with the use of plants is recommended for the drainage basin of a torrent, which is typical of the average torrential conditions of Attica. This system consists of various works on the slopes and in the bed of the torrent. Their construction aims, in the short term, at achieving the retention of the soil and the amortization of the brought materials’ production centers. In the long term, it aims at the basin’s reforestation and recovery of shrubs, as well as at the initiation of the process of soil formation. As a result, it is estimated that there will be a drop in the surface drainage co-efficient and ultimately a decrease in the quantity of surface discharged waters, an enrichment of aquifers, etc.

To sum up, we arrive at the conclusion that watershed management systems which employ technical works with the use of plants serve a dual purpose, and therefore, they are superior to technical works. On the one hand, they play a protective role and, on the other, a hydrogeonomic one (in other words a water-balance regulating role) (Emmanouloudis & Filippidis [19]). For this reason the fact that the first intervention (in 1995) in torrential basins of Attica which included technical works or only technical works should be reconsidered.
All of the above lead up to the fact that if we construct technical works with the use of plants in the drainage basins of torrents in Attica’s broader basin with planning and proper selection (because some works have already been done), then it is certain that the flood peaks of the corresponding torrents will become smoother and the underground aquifers will increase their reserve. Furthermore, there will also be a change in the landscape which will resemble more the time Plato was writing about the same area: “There was a time when our land had soil so thick and our mountains were filled with forests whose traces can still be visible…”

References


