A MINIMUM INDICATOR SET FOR ASSESSING FONTANILI (LOWLAND SPRINGS) OF THE LOMBARDY REGION IN ITALY

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Abstract: This paper reports on the issue of *fontanili* assessment. A *fontanile* is a lowland spring, excavated by humans for the use of underground water for irrigation. From the XII century on, *fontanili* have been dug to extend water availability throughout the year and increase agricultural land use in the lowlands of Northern Italy. Because water of the *fontanile* stays at temperature without great changes throughout the year (between 8 and 15°C), this environment is host to a vast variety of flora and fauna and has ecological and landscaping value. Because these springs are typical and unique landscape features of Northern Italy, there is not an international background on assessing methods of *fontanili* functions inside the countryside. The first goal has been to define a set of simple and consolidated indicators to evaluate watering, ecological and recreational function of 1160 *fontanili* of the Lombardy Region. The second one has been to identify homogenous areas with groups of *fontanili* in close proximity and with similar indicator values using interpolation tools. This classification can be used by Regional Administration to assign money to recover and maintain *fontanili*. The most important areas will be protected by regional and local planning instruments.

Keywords: *Fontanile*, low land spring, functional assessment

1. Introduction

The *fontanile* (lowland water spring) is a phenomenon deriving from the rising up of phreatic strata, and it depends on the geological structure and the lithological composition of the great North Italian Plain. Historically, these plains were covered with a mosaic of wetlands, streams and ponds, but a drainage system was introduced starting in the 12th century to increase arable land area.

The *fontanili* are springs made and managed by humans. Through the excavation of "spring heads", the water flows out to the surface facilitated by tubes or “throats” stuck into the bottom. The raised water flows into the axis of the *fontanile*, which distributes it into the countryside for irrigation (De Luca et al., 2014) (Figure 1).
Associated with the term *fontanile* is often found the term *risorgiva*. The two terms, however, are not synonyms (Muscio, 2001); *risorgiva* is the natural surfacing of underground water due to the variation of the permeability of the sediments: the waters of the aquifer, which circulate freely inside the coarse-grained sediments (for example gravel), naturally surface when they meet the finer levels and therefore less permeable. While the *risorgiva* is a natural phenomenon, the *fontanile* is a product of human intervention that facilitates the waters flow out by the excavation and construction of a drainage channel.

While the temperature in most aquatic environments in the Po River plain varies from slightly above 0 to 30°C, the mean water temperature in the *fontanili* oscillates between 8 and 15°C. *Fontanili* waters reach their highest temperatures in autumn and their lowest during early spring. Water fluxes in the *fontanili* are quite constant throughout the year, pH is usually neutral, oxygen levels in the *fontanili* head do not reach saturation levels, and the groundwater that supplies the system is usually poor in nutrients (Kløve et al. 2011). Due to these conditions, this environment is host to a vast variety of wetland flora and fauna otherwise absent in the flat. Trees and shrubs, which are usually present on the banks and around the head, help to regulate temperature and provide shelter to wildlife. The *fontanili* are distinctive landscape features: woods and shrubs patches are landmarks in the flat landscape of the region (Figure 2).

The *fontanili* are relatively well studied in regard to their ecological and hydrochemical features (Battegazzore and Morisi 2012; Shestani et al. 2009) and their hydrogeological characteristics (De Luca, 2014), especially in Lombardy Region (Fumagalli et al. 2012; Gavazza et al. 2003; Laini et al. 2011; Laini et al. 2012; Vasileiadis et al. 2013). All of these studies are about the characteristics of a single spring: water, fauna and flora are studied but the relationships between the *fontanili* and their surrounding territory have not been investigated.

Three potential functions of *fontanili* have been identified: irrigation, ecological and recreational. Irrigation is the primary function: the *fontanili* have been excavated to supply water for agricultural uses. In addition to this, they allow for the recovery of irrigation water used in higher elevation agricultural fields that leaches through the soil and goes in the groundwater.
Fontanili provide an ecological function because they are semi-natural patches inside an agricultural matrix, therefore they offer protection and shelter to wetland wildlife and they can be part of an ecological network (Glazier, 2009). Lastly, the Fontanili are characteristic features of the rural flat landscape and can represent a recreational element and a point of access to rural world; Fontanili next to urban settlements are used as green parks (Treu et al., 2000).

Indicators are the appropriate tools for assessing the ecological function of the landscape surrounding Fontanili (Dramstad et al. 1996; Fry et al., 2009; Gustafson, 1998) and for classifying the recreational function and visual quality of the landscape (Dramstad et al., 2006; Ode, 2010; Uuemaa et al., 2013). However, there are no indicators for the assessment of the irrigation function of these flat springs. The irrigation function is very difficult to measure because the water regime is not strictly related to the conditions around the head of the spring, and there is little local or old data available (Piccinini and Patrizi, 1985; Gandolfi et al, 2006).

These springs are typical and unique landscape features of North Italian Plain, so there is not an international background on assessing methods of Fontanili functions. For this reason, our objectives were (a) to define a set of existing, simple and consolidated indicators to evaluate the irrigation, ecological and recreational functions of the 1160 Fontanili of the Lombardy Region and (b) to identify homogenous areas with groups of Fontanili in close proximity to each other and with similar indicator values using interpolation tools.
Our results should provide valuable criteria (1) for fontanili classification (2) for identifying the fontanili radius of influence on surrounding landscape and (3) for identifying areas most important for fontanili protection through interpolation techniques.

2. Materials and methods

2.1 Study area and database

We studied fontanili in the flat area of the Lombardy Region called the “spring strip”. This is a strip of 3800 km² between sandy soils to the north and fine-grained sediments and impermeable soils to the south. Because of this different permeability, the water of the phreatic stratum rises up. Other causes of this phenomenon are the geomorphology (a depression of the ground promotes the rise of water on the surface) and the presence of rivers and irrigation canals that enrich the aquifer (Muscio, 2001).

In the first step of this study, we have collected all previous censuses made by regional and provincial authorities (starting from 1990) to create a database including 1,650 fontanili. After that we have checked them by direct survey: 490 fontanili were disappeared and 1,160 fontanili were classified. For every point, we collected data about position, status (working, not working, underground, not accessible), accessibility (road, bike path, trail), presence of features of natural or historical interest, land use (wood, meadow, arable land, urban green area, residential area, quarry area, industrial area, abandoned area), presence of water, presence of spring water, shape, vegetation, measurements of spatial dimensions, number of heads, water uses, etc.

![Fig 3. Lombardy Region (in green) and the Study area (in blue) (source: Lombardy Region Geographical Information System, 2012).](image)

We created a GIS database (KML data), including 1,650 records and 45 fields, that is now available at the Regional Administration web site (www.cartografia.regione.lombardia.it/).

Other data have been used for the analysis of the surrounding area of the spring; they are available on the Geographical Information System of the Regional Authority in vector format. The description of the data and information is summarized in Table 1. In addition were carried out a series of direct surveys especially to verify land uses and type of vegetation.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Scale</th>
<th>Update</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrological network</td>
<td>Natural and artificial (SiBiTer) water system</td>
<td>1:10.000</td>
<td>2012</td>
</tr>
<tr>
<td>Road network</td>
<td>Road, rail, tube and other elements of transportation system</td>
<td>1:10.000</td>
<td>2012</td>
</tr>
<tr>
<td>Park system</td>
<td>National, regional and local natural park</td>
<td>1:10.000</td>
<td>2012</td>
</tr>
<tr>
<td>Land use</td>
<td>34 classes land-use vector map based on photo-interpretation</td>
<td>1:10.000</td>
<td>2011</td>
</tr>
<tr>
<td>Regional Landscape Plan</td>
<td>RER Rete Ecologica Regionale (Ecological network, green network)</td>
<td>1:10.000</td>
<td>2010</td>
</tr>
<tr>
<td>Natural system</td>
<td>Linear vegetation and natural land use map</td>
<td>1:10.000</td>
<td>2009</td>
</tr>
</tbody>
</table>
We use these data to define indicators and to calculate indices to evaluate the three functions mentioned above. We included non-functional fontanili in the studies as well because the potential function is more important than real function and an abandoned and partly underground fontanile can be recovered by simple maintenance work.

For every spring and every function, we considered different buffer areas to investigate (50, 100, 300, 500 m radius) to understand the fontanile influence on the value of surrounding area.

2.2 Irrigation function

The fontanili are springs made by humans for irrigation, and many of them are currently used for this function. The irrigation value of fontanili is given by their water flow rate (from 10 l/s to 1000 or more l/s). The flow rates change during the year, and unfortunately, measurements are not available for all of the fontanili of the Lombardy Region. Regardless, there appears to be a link between the fontanili water flow and the irrigation activities that induce water infiltration from the soil to the groundwater (De Luca et al, 2014).

Gandolfi et al. (2006) identified 50 m as being the maximum distance of influence of the fontanili. We overlaid a canals network layer and a layer representing fontanili 50 m buffer areas. From this, the irrigation function is calculated using Irrigation index (I_IRR):

\[ I_{\text{IRR}}[0,1] = \frac{L_{\text{network_buf}}}{L_{\text{network_max}}} \]  

where:

- \( L_{\text{network_buf}} \) is the length of canals inside the 50 m buffer, and
- \( L_{\text{network_max}} \) is the maximum value of \( L_{\text{network_buf}} \).

2.3 Ecological function

Ecology of landscape is founded on the criteria that there is a link between spatial ecological patterns and ecological processes. Several spatial indicators have been developed to study this link, using concepts of disturbance, island biogeography and information theory (Gustafson, 1998, O'Neill et al., 1988, and Turner et al., 2001).

These indices are commonly related to density of patches, size of patch, complexity and diversity. Density indexes measure the density of natural patches in the matrix. Size-related indices measure patch size characteristics. Complexity-related indices measure how complicated patch shapes are. Diversity-related indices measure how diversified patches are. Detailed mathematical descriptions of these indices are available in McGarigal et al. (2012).

In the rural matrix landscape, plant and animal habitats increasingly appear in scattered patches and corridors. The percentage of land area occupied by patches and corridors is the first measure of landscape ecological quality (Dramstad et al, 1996 and Baranyia et al. 2011).

We measured the ecological function of fontanili, using:

1) Patches index (I_patches) representing the percentage of patches area inside the buffer:

\[ I_{\text{patches}}[0,1] = \frac{A_{\text{patches_buffer}}}{A_{\text{patches_max}}} \]  

where:

- \( A_{\text{patches_buffer}} \) is the sum of patches areas (broad-leaved forest, mixed forest, natural grassland, moors and heathland, transitional woodland-scrub, inland marshes and peat bogs) inside the buffer
- \( A_{\text{patches_max}} \) is the maximum value of \( A_{\text{patches_buffer}} \)

2) Corridors index (I_cor) measures the length of corridors inside the buffer:

\[ I_{\text{cor}}[0,1] = \frac{L_{\text{cor_buffer}}}{L_{\text{cor_max}}} \]  

where:
L_cor_buffer is the sum of corridor lengths (hedges, rows, wooded strips) inside the buffer
L_cor_max is the maximum value L_cor_buffer
3) I_font (0,1). (4)

The presence (1) or absence (0) of vegetation around the fontanile head is important because it offers sustenance or animals and because it keeps the water temperature constant. The minimum mapping unit (MMU) of the land use map is 20 m x 20 m, and the MMU of linear elements is 20 m in length.

The area of vegetation around the fontanile head is often smaller than MMU, so we included information about presence or absence from the direct survey database.

We measured habitat density inside each buffer area considering patches, edges and fontanili vegetation:
I_hab[0,1] = [I_patches *2 + I_cor + I_font (0,1)] / 4 (5)
The factor 2 is used to consider the greater importance of patches for ecological stability (Evans et al. 2012).

Linear infrastructures are the most important barriers in the rural matrix; roads have many general detrimental ecological effects: mortality from road construction, mortality from collision with vehicles, modification of animal behaviour, alteration of the physical environment, alteration of the chemical environment, spread of exotics and increased use of areas by humans (Trombulak and Frissell, 2000).

The measure of disturbance depends on road length and road characteristics (Jaarsma, 1997):
I_barriers[0,1] = \[\sum_{i=1}^{n} \text{Density class } [0,3] \times \text{weight class } [1,3] \] / 18 (6)
where:
1) Density class score depends on the ratio “length roads/buffer radius” as shown in Table 2 (a)
2) Weight class score depends on road characteristics as shown in Table 2 (b)

Tab 2. Length of barriers scores (a) and barrier weight (b).

<table>
<thead>
<tr>
<th>a) Length of barriers</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of barriers is &gt; 2*radius of buffer area</td>
<td>3</td>
</tr>
<tr>
<td>Length of barriers is &lt; 2r and &gt; radius of buffer area</td>
<td>2</td>
</tr>
<tr>
<td>Length of barriers is &lt; radius of buffer area</td>
<td>1</td>
</tr>
<tr>
<td>Length of barriers is 0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>b) Barriers characteristics</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highways, railways, tube</td>
<td>3</td>
</tr>
<tr>
<td>Other roads</td>
<td>2</td>
</tr>
<tr>
<td>Rural roads</td>
<td>1</td>
</tr>
</tbody>
</table>

Finally the Index of stability of the buffer is:
I_stab[0,1] = I_hab[0,1] * (1 - I_barriers [0,1]) (7)

The I_stab (7) measures the ecological stability value inside the buffer area at the landscape level. This value can be increased or decreased at the regional level by connectivity with other elements of the ecological network (Li et al, 2005).

The RER (Rete Ecologica Regionale) is the ecological network planned by the Lombardy Region Administration to protect and connect the most important natural areas (national parks, regional parks, rivers, wetlands and so on) of the Lombardy. To assign different levels of importance to RER elements, we overlaid the RER and fontanili datasets and applied these values:
I_rer = 1 if the fontanile point is inside a RER primary element (gangli)
I_rer = 0.9 if the fontanile point is inside a RER other element (minor patches or corridors)
I_rer = 0.8 if the fontanile point is outside RER area
This is the index used for the assessment of ecological values of *fontanili* (I_ECO):

\[
I_{\text{ECO}}[0,1] = \text{stab}[0,1] \times \text{I}_{\text{rer}}(1, 0, 0.9, 0.8)
\]  

(8)

### 2.4 Recreational function

The farming land at the fringe of the urban areas had a greater recreational role than constructed parks. Traditional farms and preserved nature areas were preferred to constructed parks for residents living in the urban fringe (Hietala et al., 2013). Traditionally, *fontanili* next to urban centres are used as green areas. The trees provide shade, and the flowing water and sounds of birds create a place with good microclimate conditions, especially during the hot season.

The description of landscape characteristics related to spatial patterns and the prospects for the quantification of spatial patterns has become an important topic in landscape ecology (Turner et al., 2001). Dramstad et al. (1996) stated that the use of landscape indices is necessary with the increasing need for quantitative assessment of impact and change. Different landscape metrics are recognized, although no generally accepted classification is available. Two types are used: the first measures patch characteristics, such as size, shape and edges. A second type addresses the spatial arrangement of adjacent patches and needs an aggregating spatial context to be calculated (Antrop and Van Eetvelde, 2000).

Considering both issues, the recreational index includes an accessibility index and a visual landscape quality index.

**Accessibility index (I_Acc).** Recreational areas can be reached by foot, bicycle, car or public transportation. However, recommendations regarding distance or proximity to recreational landscapes tend to focus on pedestrians and walking distance. Walking distance to recreational areas for everyday use is recommended to have a maximum of 250–300 m. 250–300 m is a critical distance for children and elderly to reach recreational areas by foot within an adequate amount of time (Neuvonen et al, 2007). On the basis of these recommendations, thresholds of 100 m, 300 m and 500 m were chosen as critical distances for recreational use in our analysis. Using population survey data (census data) combined with spatial data (land use map), we calculated how many people live within the buffer area (Koppen et al. 2014). The presence of roads (I_road) is necessary for people access to *fontanili*. We included information about presence (value 1) or absence (value 0) of rural roads, trails or bike paths to access from the direct survey database.

\[
I_{\text{acc}}[0,1] = (I_{\text{road}}(0,1) + I_{\text{pot-users}}[0,1]) / 2
\]  

(9)

where:

- \(I_{\text{road}}(0,1)\), value is 1 with access, value is 0 without access
- \(I_{\text{pot-users}} = \frac{N_{\text{people_buffer}}}{N_{\text{people_max}}}\)

(10)

where:

- \(N_{\text{people_buffer}}\) is the number of people living inside the buffer
- \(N_{\text{people_max}}\) is the maximum value of \(N_{\text{people_buffer}}\)

**Landscape quality index (I_qual).** Because of the intensity of land usage, the areas of intensive agricultural production and other modern land uses are void and empty with regard to natural structures and/or filled up with large-scale building structures. These areas are among the aesthetically most unattractive landscapes. Sustainable landscapes contain areas and places where nature can develop freely and spontaneously. That means that areas close to spontaneous nature let the beholder participate in perceptual processes, which may lead to a particular aesthetic attractiveness (Nohl, 2001).

We evaluated these aspects using Index of composition of landscape (I_comp):

\[
I_{\text{comp}}[0,1] = \left[\sum_{i=1}^{n} \left(\frac{a_i}{A_{\text{buf}}} \right) \times w_i + \sum_{i=1}^{n} \left(1 - \frac{a_i}{A_{\text{buf}}} \right) \times w_0\right] / 2
\]  

(11)
where:
$A_n$ is the area of land use class in the buffer
$A_{buf}$ is area of the buffer
$w_v$ is the weight of class increasing visual quality of the landscape
$w_d$ is the weight of class decreasing quality of the landscape

In accordance with Nohl (2001), we extracted the following from the land use vector map:
1) natural land use classes characterizing *fontanili* landscapes (increase the visual quality):
   - fairly characterizing: water-meadow, bank vegetation
   - characterizing: broad-leaved forests
   - highly characterizing: riparian vegetation, inland marshes vegetation, peat bogs.

Different weights were assigned using a pairwise comparison method (on the basis of the Saaty scale) (Saaty, 1980) (Table 3 a).

2) artificial surface land use classes (decrease the visual quality):
   - continuous artificial surfaces: industrial, commercial and transport units, mines, dumps and construction site
   - discontinuous dense artificial surfaces: dense and medium dense urban fabric, unvegetated land without current use, sports and leisure facilities
   - low density artificial surfaces: low density urban fabric, rural isolated structures, camping areas.

Different weights were assigned using a pairwise comparison method (on the basis of the Saaty scale) (Saaty, 1980) (Table 3 b).

<table>
<thead>
<tr>
<th>a) natural land use classes</th>
<th>Fairly characterizing</th>
<th>Characterizing</th>
<th>Characterizing very high</th>
<th>Saaty scale value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fairly characterizing</td>
<td>1</td>
<td>0.5</td>
<td>0.20</td>
<td>0.12</td>
</tr>
<tr>
<td>Characterizing</td>
<td>2</td>
<td>1</td>
<td>0.33</td>
<td>0.23</td>
</tr>
<tr>
<td>Characterizing very high</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>0.65</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>b) artificial use classes</th>
<th>Not dense artificial surface</th>
<th>Discontinuous dense artificial surfaces</th>
<th>Continuous artificial surfaces</th>
<th>Saaty scale value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not dense artificial surface</td>
<td>1</td>
<td>0.5</td>
<td>0.13</td>
<td>0.10</td>
</tr>
<tr>
<td>Discontinuous dense artificial surfaces</td>
<td>2</td>
<td>1</td>
<td>0.33</td>
<td>0.21</td>
</tr>
<tr>
<td>Continuous artificial surfaces</td>
<td>8</td>
<td>3</td>
<td>1</td>
<td>0.69</td>
</tr>
</tbody>
</table>

Land cover structure and composition play significant roles in the visual quality of the landscape. Two main categories of indices have been suggested: composition indices which quantify the variety and abundance of patch types within a landscape, but not their spatial arrangement, and configuration indices, which quantify the spatial distribution and the shape of patches within the landscape (McGarigal et al, 2012).

Of all spatial metrics of the landscape, legibility and heterogeneity are perhaps the easiest to relate to human perception of the environment. Greater coherence is generally thought to be positively related to scenic value (Kaplan and Kaplan, 1982 and Palmer, 2004). The fractal dimension should provide an indication of visible landscape complexity, which is thought to contribute to scenic value (Purcell et al., 2001).

To perceive high visual quality in a small view, a certain overall order has to be discovered (Staats et al., 1997) and a limited number of elements must be present in the landscape, allowing the observer to understand the scene (Todorova et al., 2004).
In accordance with these papers:

\[ I_{\text{conf}}[0,1] = \frac{(I_{\text{patches}}[0,1] + I_{\text{shape}}[0,1])}{2} \]  
(12)

where

1) \( I_{\text{patches}}[0,1] = \frac{1}{\text{N}_{\text{patches buffer/Max}}} \)

with:

\( \text{N}_{\text{patches buffer}} \) is the number of patches inside the buffer

\( \text{N}_{\text{patches max}} \) is the maximum value of \( \text{N}_{\text{patches buffer}} \)

2) \( I_{\text{shape}} = \frac{\sum_{n=1}^{N} \text{SI}_n}{\text{SI max}} \)

with

\( \text{SI} \) is the Shape Index of the buffer area

\( \text{SI max} \) is the maximum value of \( \text{SI} \)

and

\[ \text{SI} = \frac{p_i}{2 \sqrt{\pi a_i}} \]  
(14)

with

\( p_i \) is the patch perimeter

\( a_i \) is the patch area

\( \text{SI} \) values close to 0 indicate that the landscape is aggregating to form simple shape, values closer to 1 indicate that the landscape is fragmented and has convoluted shapes.

The landscape quality index is:

\[ I_{\text{qual}}[0,1] = \frac{(I_{\text{comp}}[0,1] + I_{\text{conf}}[0,1])}{2} \]  
(15)

Finally the Index of recreational function \( I_{\text{RECR}} \) is:

\[ I_{\text{RECR}}[0,1] = \frac{(I_{\text{acc}}[0,1] + I_{\text{qual}}[0,1])}{2} \]  
(16)

3. Results

We used above-mentioned indexes to classify 1,160 fontanili of the Lombardy Region and investigate the relationship between the fontanili and the territory in which they are included (Table 4).

<table>
<thead>
<tr>
<th>Buffer area</th>
<th>50 m radius</th>
<th>100 m radius</th>
<th>300 m radius</th>
<th>500 m radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Ecological</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Recreational</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

For the irrigation function, we measured \( I_{\text{IRR}}[0,1] \) inside a 50 m radius buffer to find links with canal systems (Figure 4).
The I_IRR measures the length of canals inside fontanile's 50 m buffer. Unfortunately irrigation channels network database is not complete and uniform for the study area so 30% of fontanili result not connected with irrigation network. This can means the water from fontanili is no more used for irrigation or, most probably, that the network database is uncorrected. Excluding this percentage the medium value is 0.20 with a standard deviation of 0.15. A great number of unconnected fontanili are concentrated in the central part of study area.

For the ecological and recreational functions, we measured $I_{ECO}[0,1]$ (8) and $I_{RECR}[0,1]$ (16) inside 100 m, 300 m and 500 m radius buffers. Then, we applied ANOVA analysis and Dunnett's C Post Hoc test to confirm different index values for increasing buffer radius:

- ecological function: the values decrease significantly between 100 m and 300 m buffer radius (Mean difference of Dunnett's PHT = -0.7665)
- recreational function: the values maintain similar magnitudes between 100 m and 300 m (Mean difference of Dunnett's PHT = -0.0489) and decrease significantly between 300 m and 500 m buffer radius (Mean difference of Dunnett's PHT = -0.2694)

The maps of Figures 5 and 6 show the distribution of fontanili with ecological and recreational values inside 100 m buffer for the ecological one and 300 m buffer for the recreational one.

Only the 2% of fontanili doesn't have ecological value ($I_{ECO} = 0$). The medium value is 0.30 with a standard deviation of 0.15. The Province of Milan has the greater concentration of highest values.

The $I_{RECR}$ has values higher than other indices. The media is 0.48 and there aren't fontanili without recreational value. The proximity to the main urban centres determines the value increasing.

The graphs of Figure 7 show the values measured for these different indexes wit the trend described above.

To identify homogenous areas with groups of fontanili in close proximity and with similar indicator values, we used interpolation tools. For all three functions, interpolation was made using the ArcMap GIS kriging tool, setting a maximum distance of 1000 meters.
Fig 5. Ecological index values of fontanili.

Fig 6. Recreational index values of fontanili.

Fig 7. Values of calculated indexes.
4. Discussion

For the first time, we have classified all fontanili of the Lombardy Region territory, using:
- direct survey to collect data on every fontanile
- an existing geo database to evaluate the areas around the springs.

We have ranked irrigation, ecological and recreational values. Because of the method of creating indexes, they are not absolute values but relative ones. Unfortunately, there is no other published research about fontanili function assessment, so it is not possible to compare our results and our indices with different approaches.

Any way:

- I_IRR seems to be not able to describe the irrigation value of fontanili. It is necessary to complete the assessment using a more complete channels network geo-database. The Regional authority is implementing this database;
- I_ECO seems to be able to measure the ecological value of fontanili. Fontanili with very different values are spread in the entire study area. The media value of 0.30 is not very representative of great variability of index value;
- I_RECR seems to be able to measure the recreational value of fontanili. The great part of fontanili present values around the media value (with a standard deviation of 0.09).

5. Conclusions

Ecological and recreational indices are based on consolidated parameters used in other studies:
- connectivity level and patches, corridor and barrier density for spatial ecological pattern evaluation
- accessibility level for recreational use, land cover structure and composition for visual quality evaluation.

The parameters used to calculate the irrigation index, however, are instead overly simple. The lack of flow rate measurements is the main problem for building an index with greater significance. The weakness of this index is the most important limitation of the study. This is the reason because we have decided to not calculate a synthetic index including the three functions.

The assessment of fontanili functions has permitted to determine the independence of every fontanile from his surroundings. The value of every single index seems not to be influenced by the presence of other fontanili. Fontanili with low, medium, high quality can be closed to each other.

The next step is to compare the results of this assessment with the regional and local planning instruments.

This classification can be used by the Regional Administration to assign resources for the recovery and maintenance of fontanili. The most important areas, identified using the kriging tool of ArcMap GIS, are going to be protected by regional and local planning instruments.

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