Spatiotemporal analysis and quantification of groundwater withdrawals in the Po basin: methodology and data homogenization within the "MidAS-Po" project

Riccardo Pinardi[1], Davide Sartirana[2], Simone Bruno[2], Sara Cazzaniga[3], Olfa Gharsallah[3], Martina Gizzi[4], Giulia Tarantino[4], Glenda Taddia[4], Cesare Vasini[5], Filippo Battaglini[5] and Fulvio Celico[1]

[1] Department of Chemistry, Life Sciences and Environmental Sustainability, University of Parma, Parco Area delle Scienze 157/A, 43124, Parma, Italy
[2] Department of Earth and Environmental Sciences, University of Milano-Bicocca, Piazza Della Scienza 1, 20126 Milan, Italy
[3] Department of Agricultural and Environmental Sciences, University of Milan, Via Celoria 2, 20133, Milan, Italy
[4] Department of Environment, Land and Infrastructure Engineering (DIATI), Politecnico di Torino, C.so Duca degli Abruzzi 24, 10129 Turin, Italy
[5] Autorità di Bacino Distrettuale del Fiume Po, Strada Garibaldi 75, 43121 Parma, Italy

INTRODUCTION

Groundwater withdrawal data collection for basin scale numerical models is often **critical**: information is rather fragmented, inconsistent, or incomplete due to the different administrative and geological character of different sub-areas within the basins. The work presented below is a summary of the results achieved by one of the six Tasks (in specific Task 3) designed for the implementation of **MidAS-Po**: a multi-year project coordinated by *Autorità di Bacino del Fiume Po (ADBPO) and* developed with the cooperation of 9 italian universities and several public agencies. This project aims to implement a supra-regional scale **numerical model** that can become a tool to support district planning for the qualitative-quantitative protection of groundwater. The area to be modelled is **the entire Po Plain** of Piemonte, Lombardia, Emilia-Romagna and Veneto with the border formed by Adige River. In this area water wells information are often absent: coordinates, elevation of the ground level, depth of screened sections, flow rates, and diversification of withdrawal volumes over time. A homogeneous codification of the whole dataset becomes a way to keep track of these critical features and find a method of resolution.

OBJECTIVES

The objective of Task 3 was to:

- Research, quantify, homogenize and spatialize all groundwater withdrawals that occurred within the Po basin from 2010 to 2022.
- Define the major complexities related to the nature and availability of the withdrawal data.
- Define a series of operational and conceptual methodologies to overcome potential deficits in data availability.

EXPLOITATION OF MISSING DATA: THE DEFINITION OF A METHOD

The method adopted is based on the data homogenization assigning a **code** to each withdrawal point. This code consists of the following information specific to each well: ***Region ID***, ***Municipality Code***, ***Progressive wells per Municipality***.
In addition, a series of representative **letters** were added to the end of the code whenever one or more deficits characterized the withdrawal data (see Fig.1).
The process leading to the assignment of each of the final "deficits" **letters** is detailed below.

L0120020001CFZ

Fig. 1 – Example of Task 3 homogenization code

STEP 1 – C - Coordinate allocation to withdrawal points with missing information

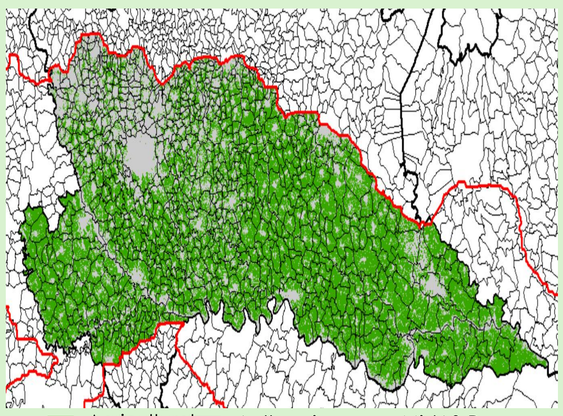


Fig. 2 – Example of Land use zoning

Using the "Create Random Points" function in the GIS software:

Each polygon, depending on the land use and the type of well, has been assigned the correct number of points (Fig. 3);

Definition of a minimum distance between randomly spatialized points: 1 m;

Extraction of virtual coordinates and assignment to the sampling points.

Macro Merge of sampling points without coordinates, in Agricultural, Anthropic and Land use zoning (Fig. 2);

Subdivision of withdrawal points with missing coordinates on a municipal basis: points falling within the Agricultural Polygon and points in the Anthropic Polygon.

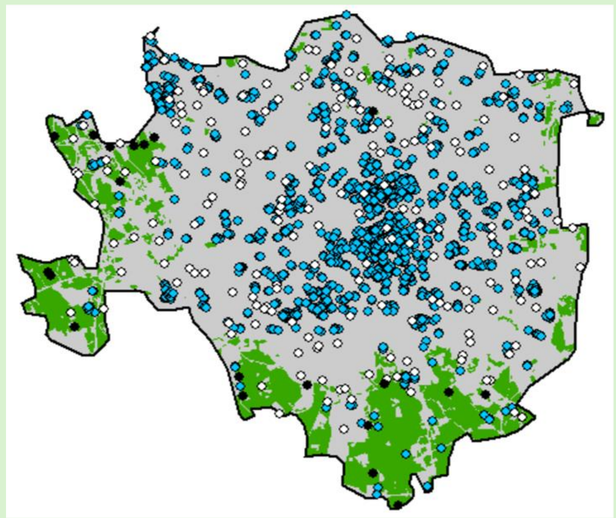


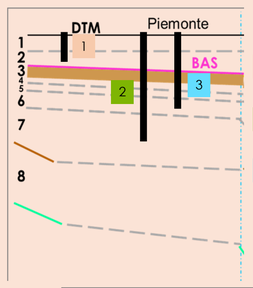
Fig. 3 – Example of assignation of points to the areas

STEP 2 – L and F :Allocation of well screen to withdrawal points where the information is missing

Screen Top/Bottom Attributed as Layers (L)

Information available on the pumped aquifer by the individual withdrawal points (e.g. "shallow" aquifer and "deep" aquifer;)

Intersection of the bottom well elevation (Groundwater Elevation – Well Depth) with the layer elevation for each withdrawal point (Fig. 4).



Screen Top/Bottom Attributed as Elevation (F)

Information available on the depth of screen top/bottom for different withdrawal points

- By type of use: industrial, irrigation, drinking, all other uses;
- Using the "Generate Near Table" GIS function;
- At each well without screen information has been assigned the screen elevation of the nearest withdrawal point of the same type (e.g. industrial - industriale, drinking-drinking,..) (Fig. 4).

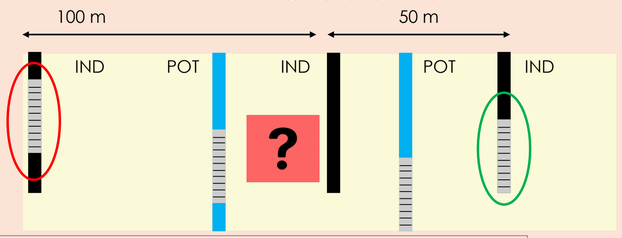


Fig. 4 – Conceptual model of screened Layers and Elevation attribution ratio.

STEP 3 – Attribution of the surface elevation to the withdrawal points where the information was missing (Z)

Using the GIS function "Extract Values to Points" : at each well with missing elevation information, has been assigned the value of the **DTM** (Fig. 5) sampled on the relative raster position;

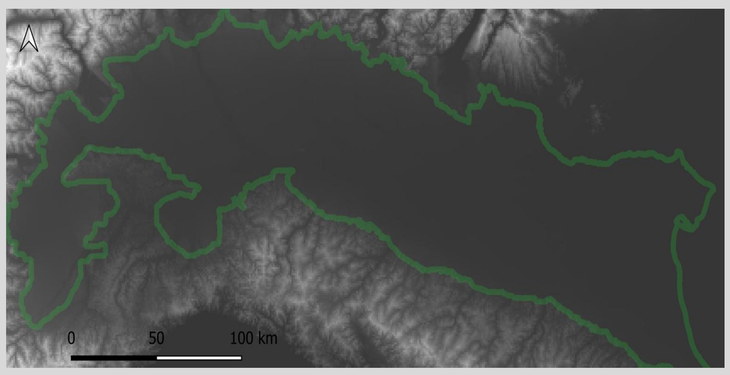


Fig. 5 – DTM and modelled area border (green line)

STEP 4 – Attribution of flow rates to withdrawal points (--/Q/M/S)

1. Presence of the measured data, no letter is applied. (**--**)
2. Presence of the only licensed data (to be modulated by applying the percentage ratio calculated between granted/measured data, see Tab. 1): **Q**
3. Complete deficit of data (neither licensed nor measured, the average for the type of use applies): **M**
4. Presence of extraction estimates: **S**

Tab. 1 - Percentage ratio calculated between granted/measured data

Well use	Number of wells	Declared volume/Licensed volume
Irrigation	2080	58%
Industrial	1361	54%
Drinkable	2022	59%
All other uses	9776	63%

STEP 5 – Attribution of a temporal variability to the irrigation withdrawal

Average seasonal volumes normal years = 32.4 Mm^3
Average ratio of seasonal volumes normal years to seasonal volume 2022 = 51%
2017 seasonal volume/2022 seasonal volume ratio = 78%
Example of withdrawal variability in 52 irrigation wells are shown in Tab. 2.

Tab. 2

Year	SEASONAL VOLUME FROM WELLS MONITORED FOR IRRIGATION USE (52 wells) Mm^3/year
2016	30
2017	49
2018	32
2019	32
2020	30
2021	38
2022	63

RESULTS AND CONCLUSIONS

- Creation of a **homogeneous database** containing **86.404** wells spread throughout the Po Valley, finalized to numerical modeling (Fig. 6);
- Definition of a **useful method** for the requalification of incomplete withdrawal data at basin scale.

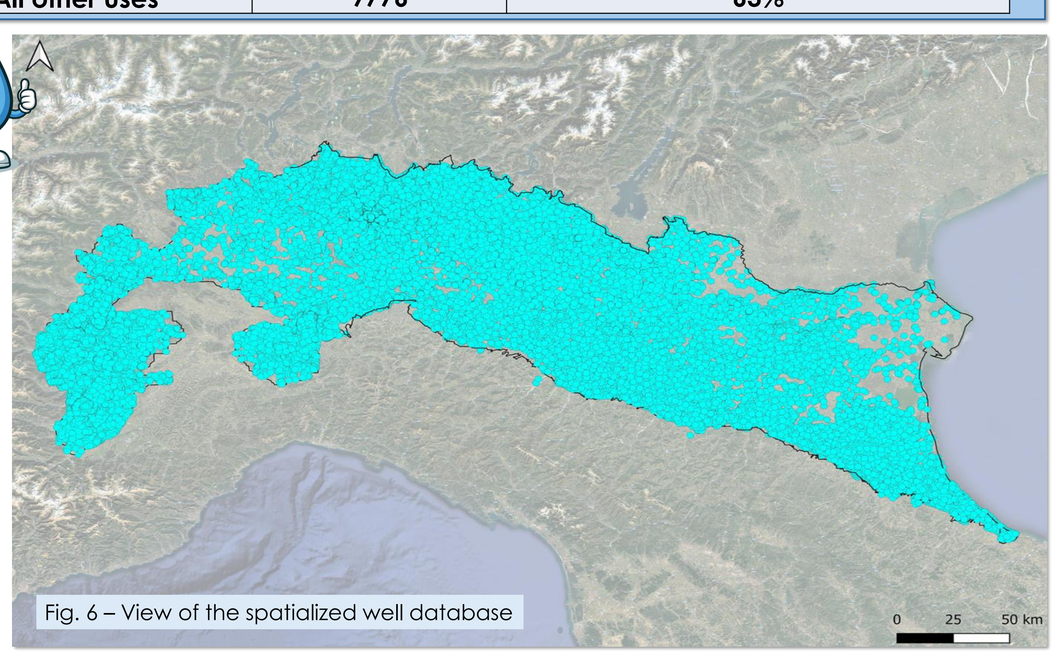


Fig. 6 – View of the spatialized well database