Drinking Water Demand forecasting using Artificial Neural Network in Tunisia

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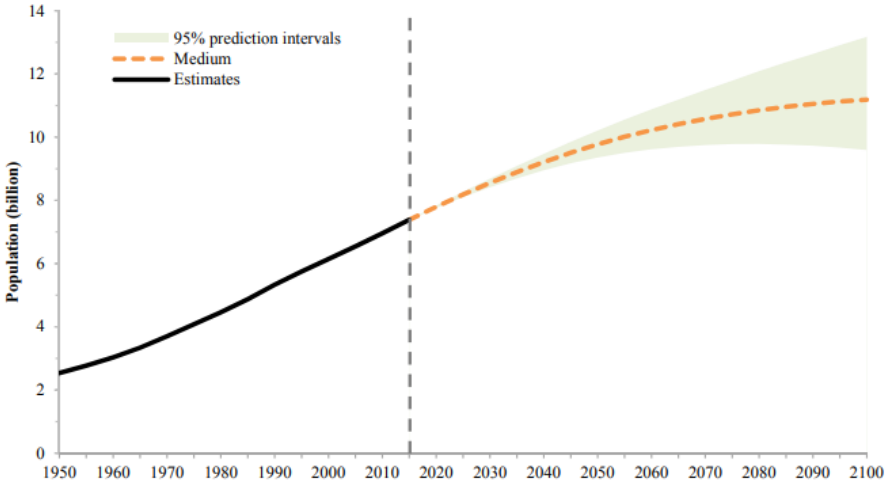
Overview

- Introduction,
- Methodology,
- Case study presentation,
- Results:
  - Statistical analysis and Artificial Neural Network (ANN) design,
  - Forecasting Drinking Water Demand (DWD),
- Conclusions.

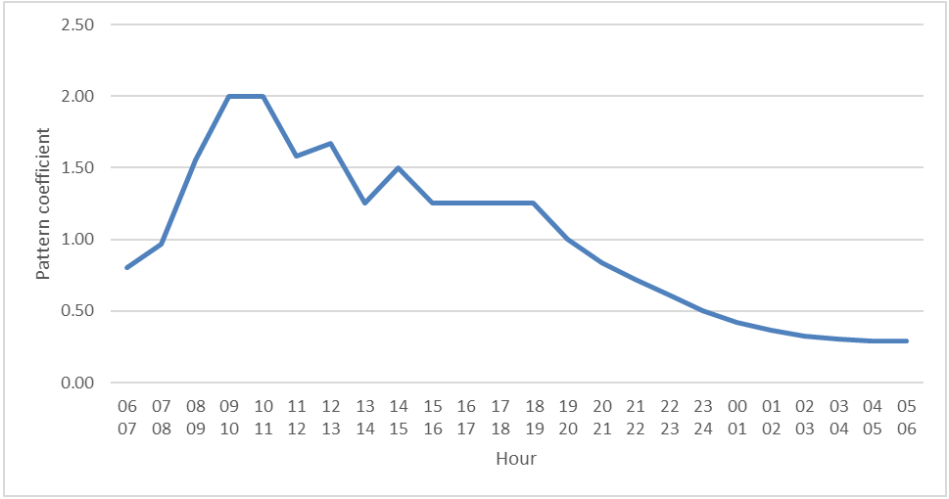
Introduction

- Long-term (yearly) trend of DWD **can be identified** using statistical analyses (population).



Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). *World Population Prospects: The 2017 Revision*. New York: United Nations.

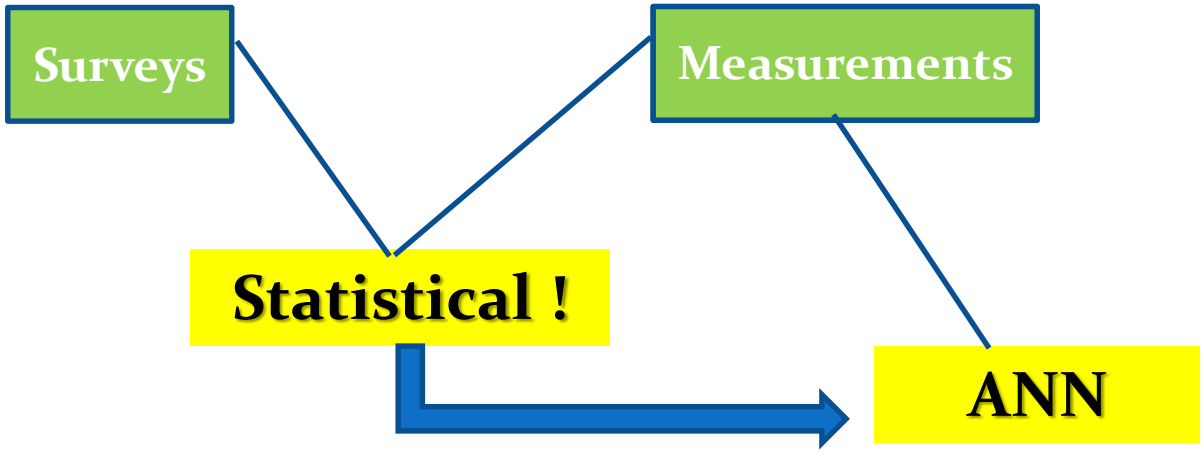
- Short-term (daily and hourly) patterns of DWD **are difficult to fit** with statistical approaches (Human behaviors).



Short-term patterns of DWD is useful for:

- Manage pumping stations,
- Operate water treatment plants as well as supply systems.

Approaches?



A literature review confirmed the efficiency and the robustness of **Artificial Neural Network (ANN)** to forecast DWD:

- California (Ghiassi et al., 2008),
- Bangkok (Babel et Shinde, 2010),
- Mecca (Ajbar et Ali, 2015),
- Nigeria(Gwaivangmin, 2017),

- Tunisia:
  - Tunisian Agronomic Institute,
  - 2005 – Today,
  - Tunis – Sfax (3.5 Million inhabitants).

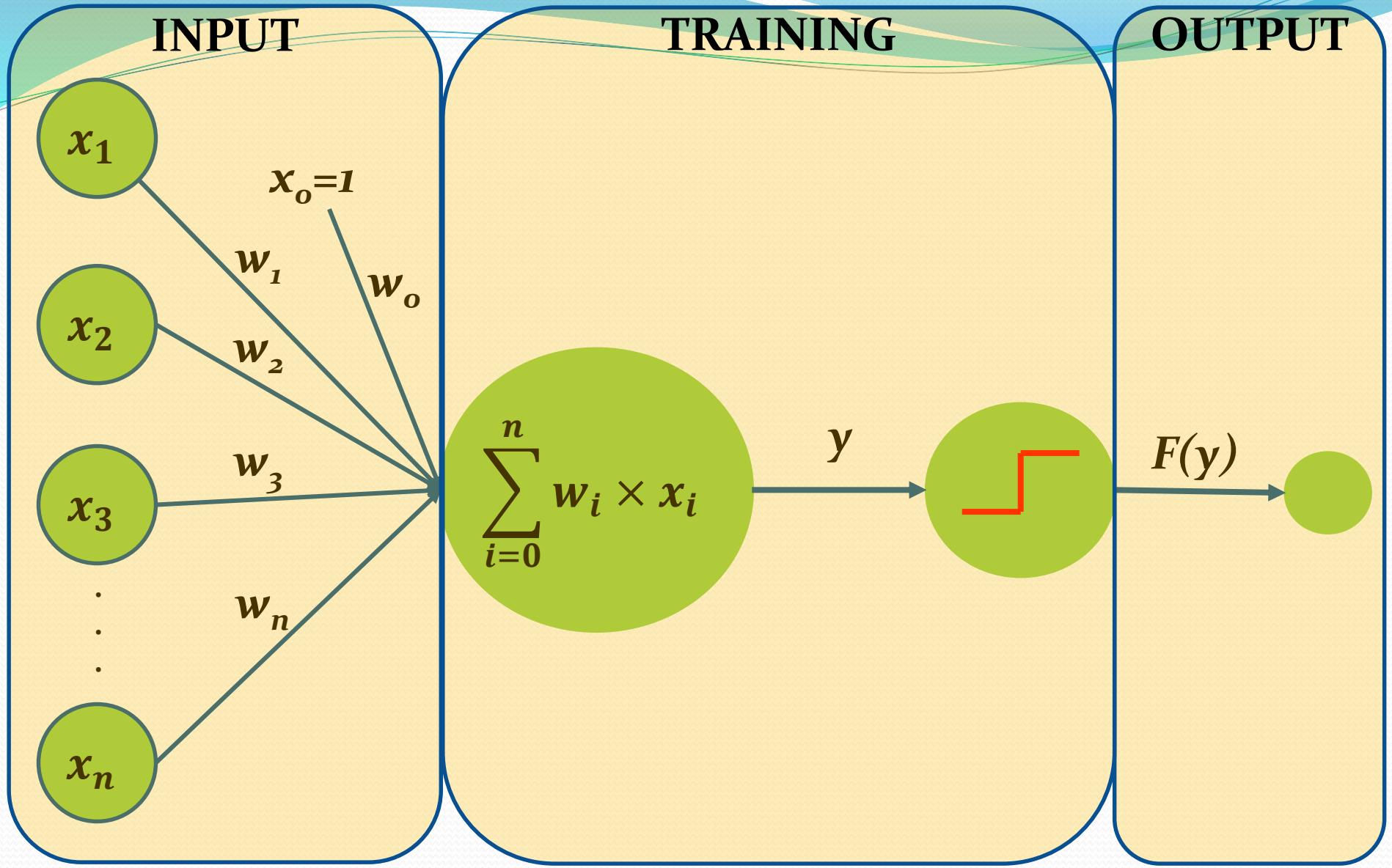
Methodology

1. Building a database of daily drinking water supply and the **min** and **max** daily **temperatures** (January 2008 to December 2017),

2. Pre-processing and statistical analysis to identify the explanatory variables,

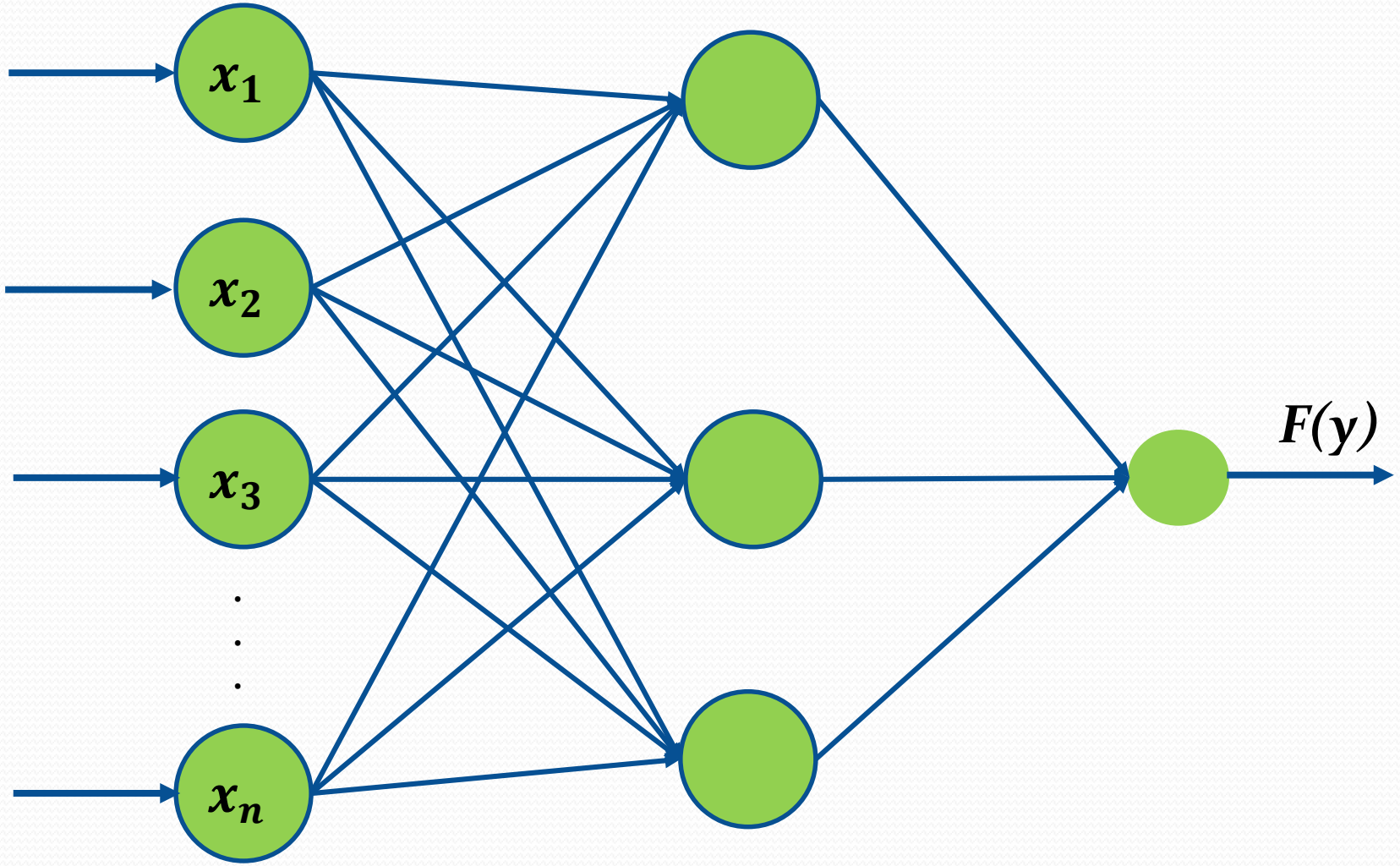
3. Building, training and validation of the designed ANN:
   - MATLAB script,
   - Training set,
   - Validation set.

i) Correlation coefficient.
ii) Average absolute error.
iii) Maximal absolute error.

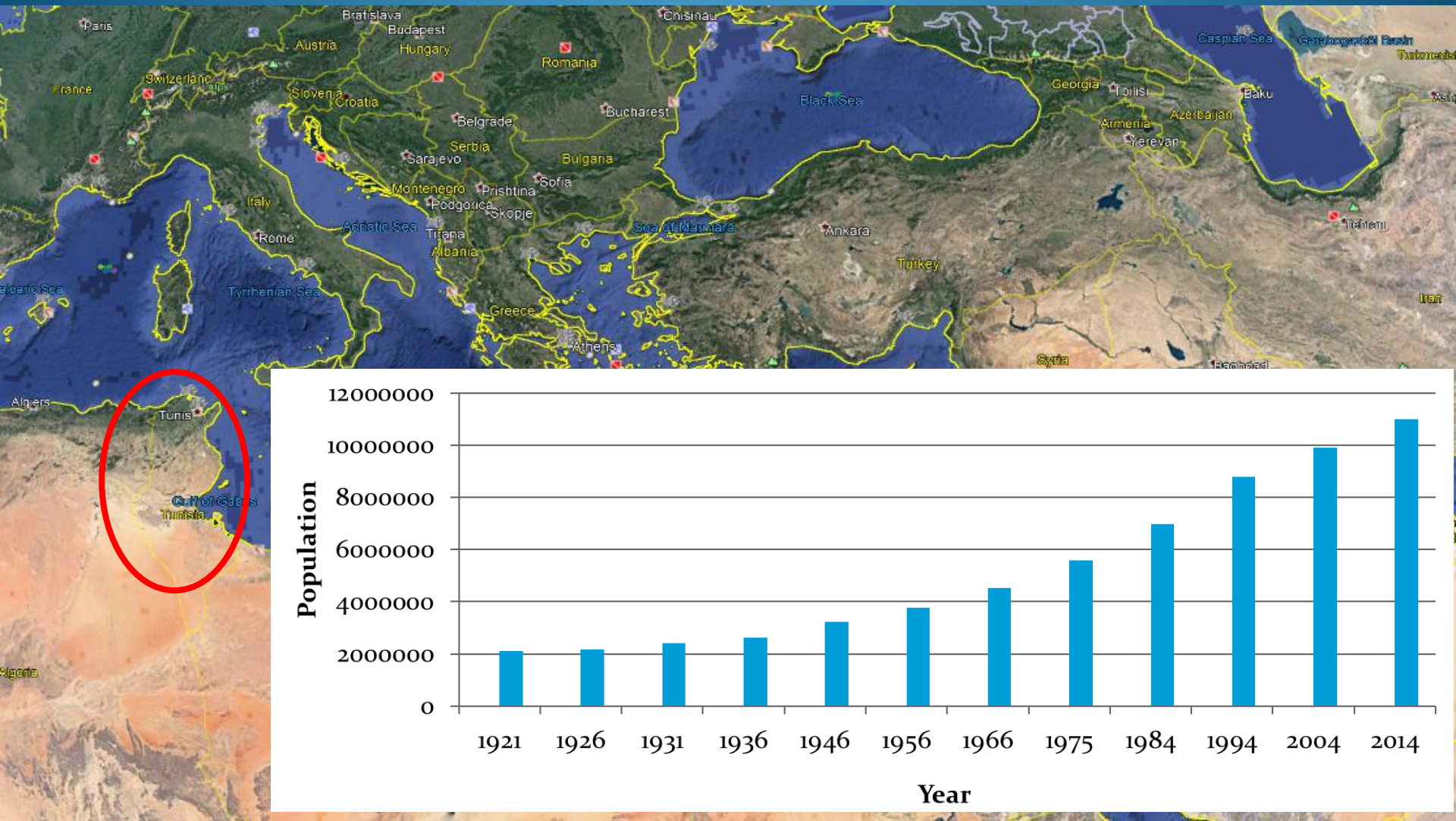


The simplest network

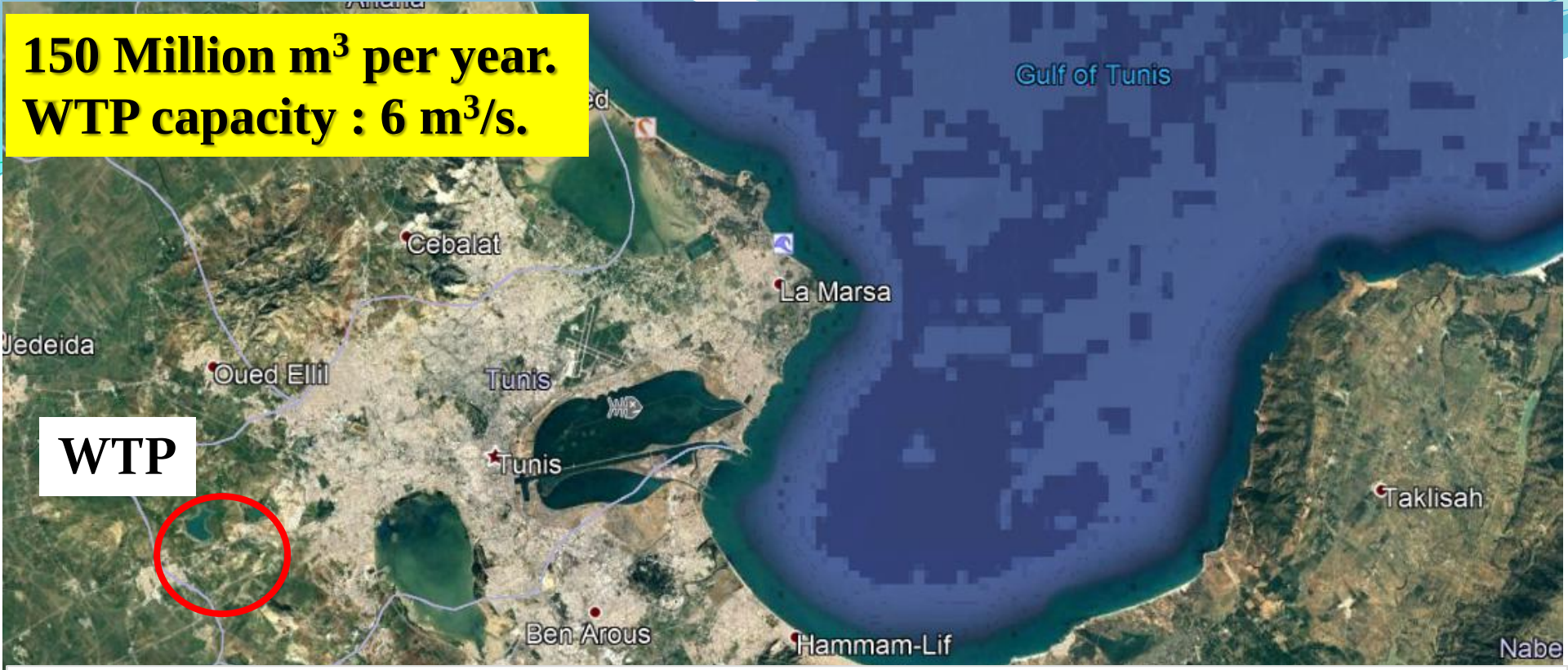
The multi-layers network

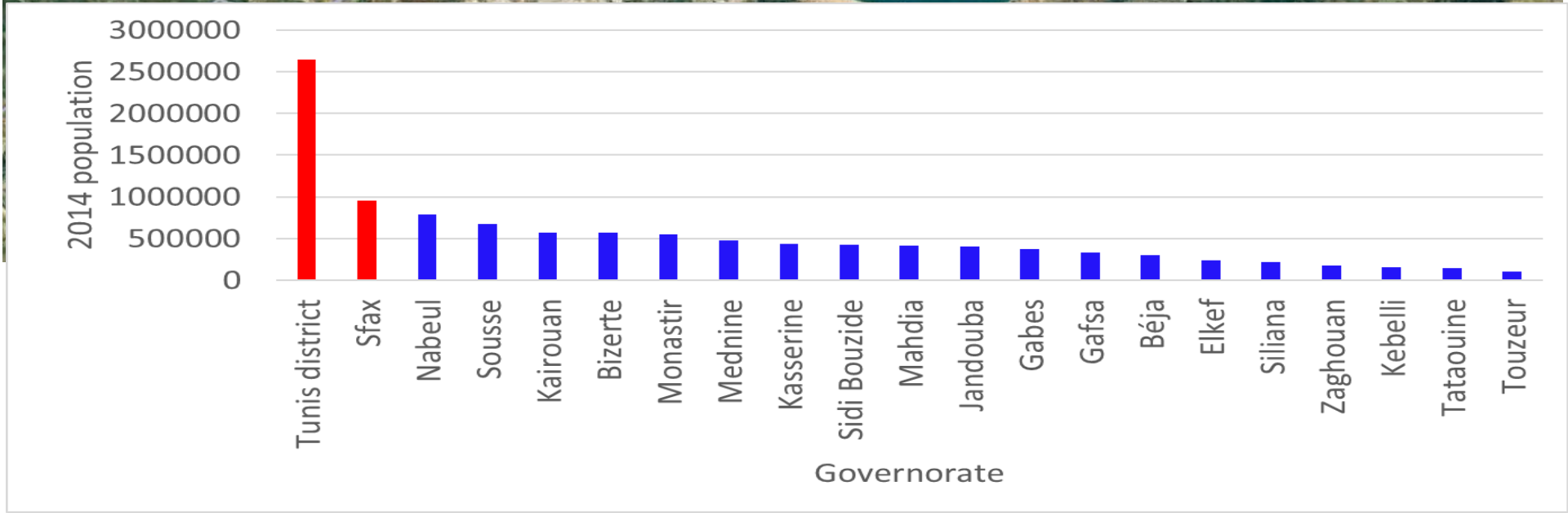


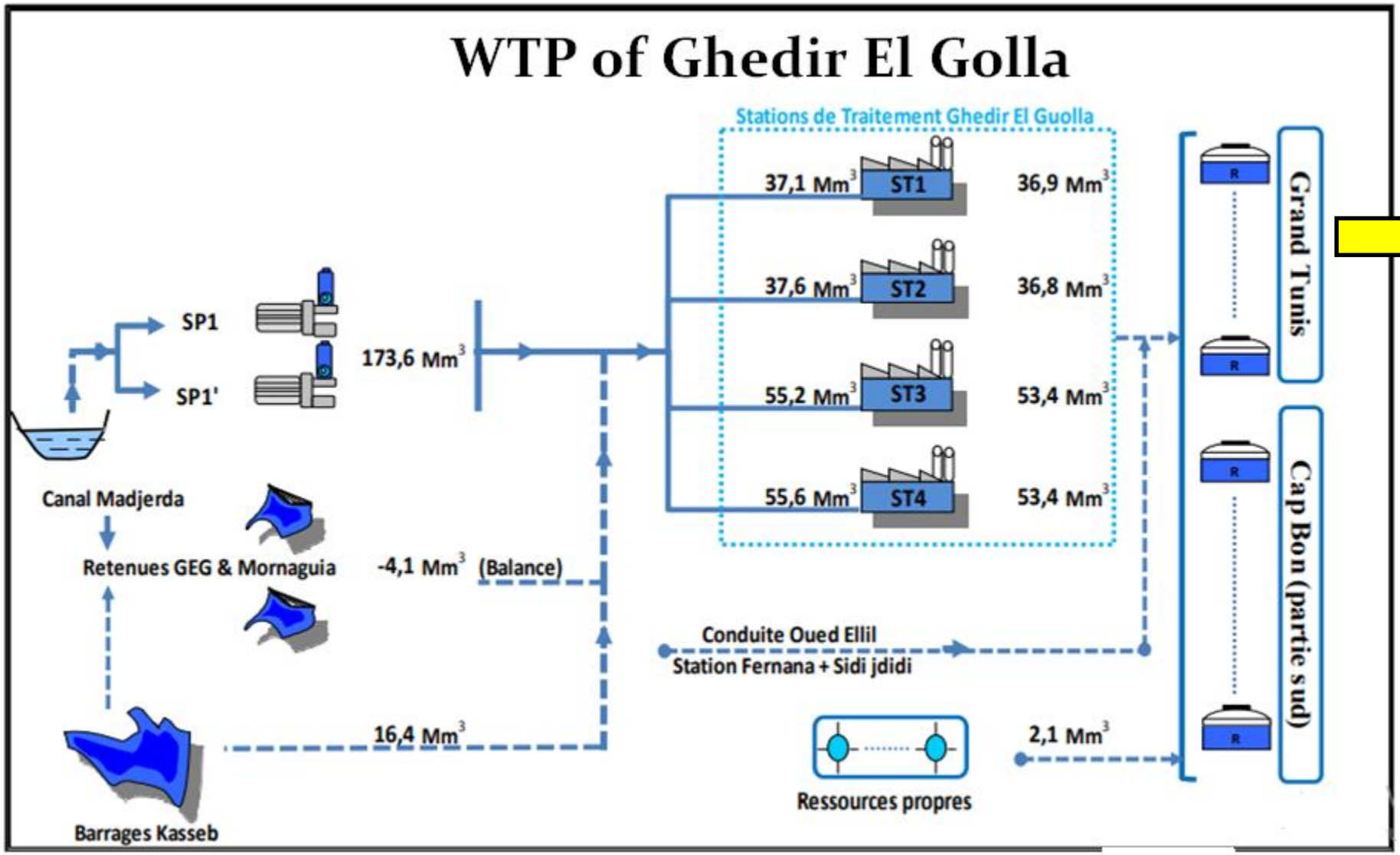
Case study presentation



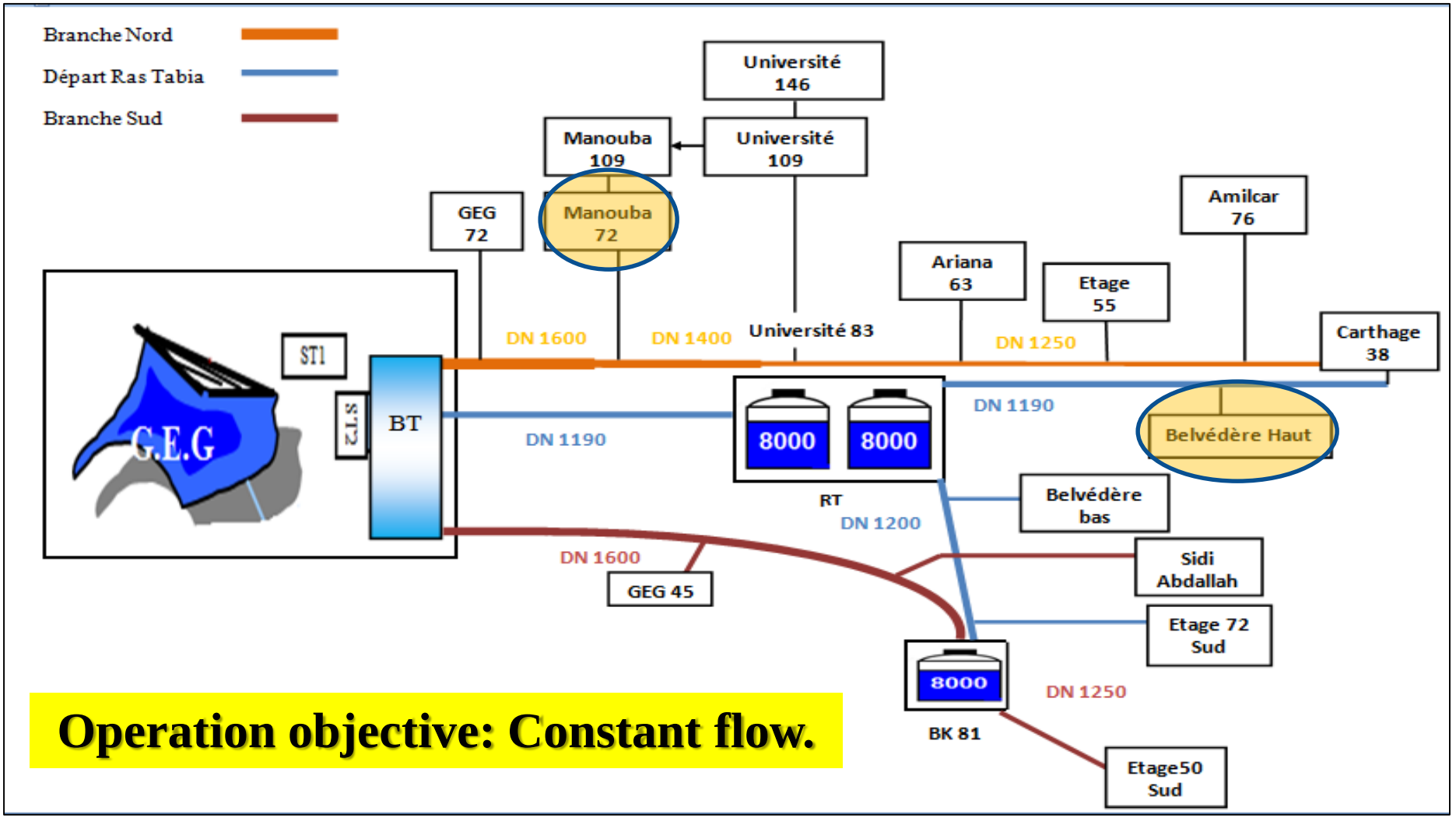
150 Million m^3 per year.
WTP capacity : 6 m^3/s.






WTP of Ghedir El Golla
Stations de Traitement Ghedir El Guolla
37,1 Mm3
ST1
36,9 Mm3
37,6 Mm3
ST2
36,8 Mm3
55,2 Mm3
ST3
53,4 Mm3
55,6 Mm3
ST4
53,4 Mm3
SP1
SP1'
173,6 Mm3
Canal Madjerda
Retenues GEG & Mornaguia
-4,1 Mm3 (Balance)
Conduite Oued Ellil
Station Fernana + Sidi jdidi
16,4 Mm3
Barrages Kasseb
Ressources propres
2,1 Mm3
R
Grand Tunis
Cap Bon (partie sud)

Drinking Water system



Operation objective: Constant flow.

- **The aim**:

To develop robust models to forecast short-term DWD for Tunis city, using ANN.

- **The challenge**:

To optimize management of 21 tanks and the Water Treatment Plant (WTP).

Results

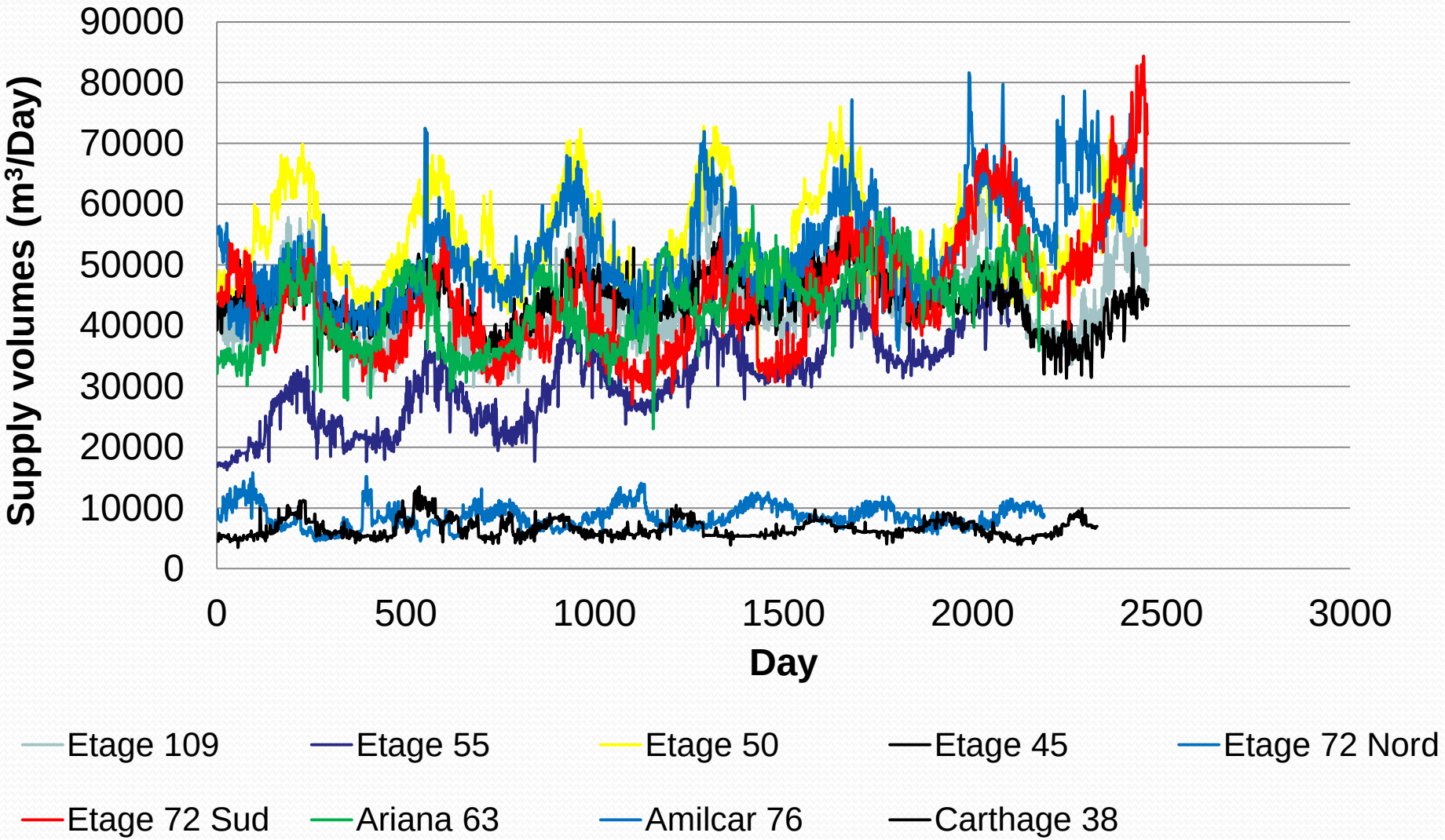

Supply volumes (m³/Day)
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0
500
1000
1500
2000
2500
3000
Day
Etage 109
Etage 55
Etage 50
Etage 45
Etage 72 Nord
Etage 72 Sud
Ariana 63
Amilcar 76
Carthage 38

Figure. Daily supply of “Mannouba” tank (01/2008 to 12/2017)

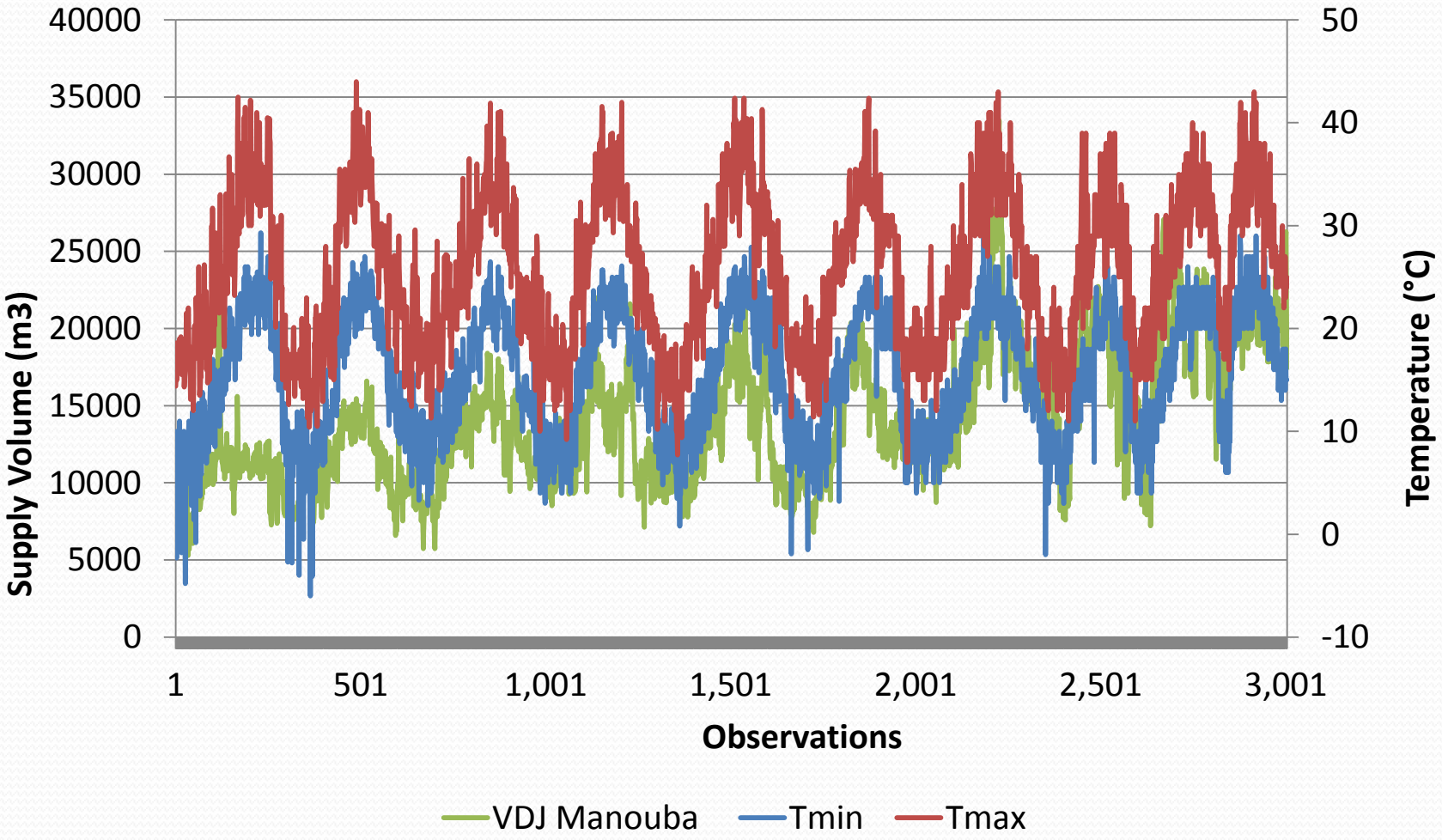


Figure. Daily supply of “Belvédère Haut” tank (01/2008 to 12/2017)

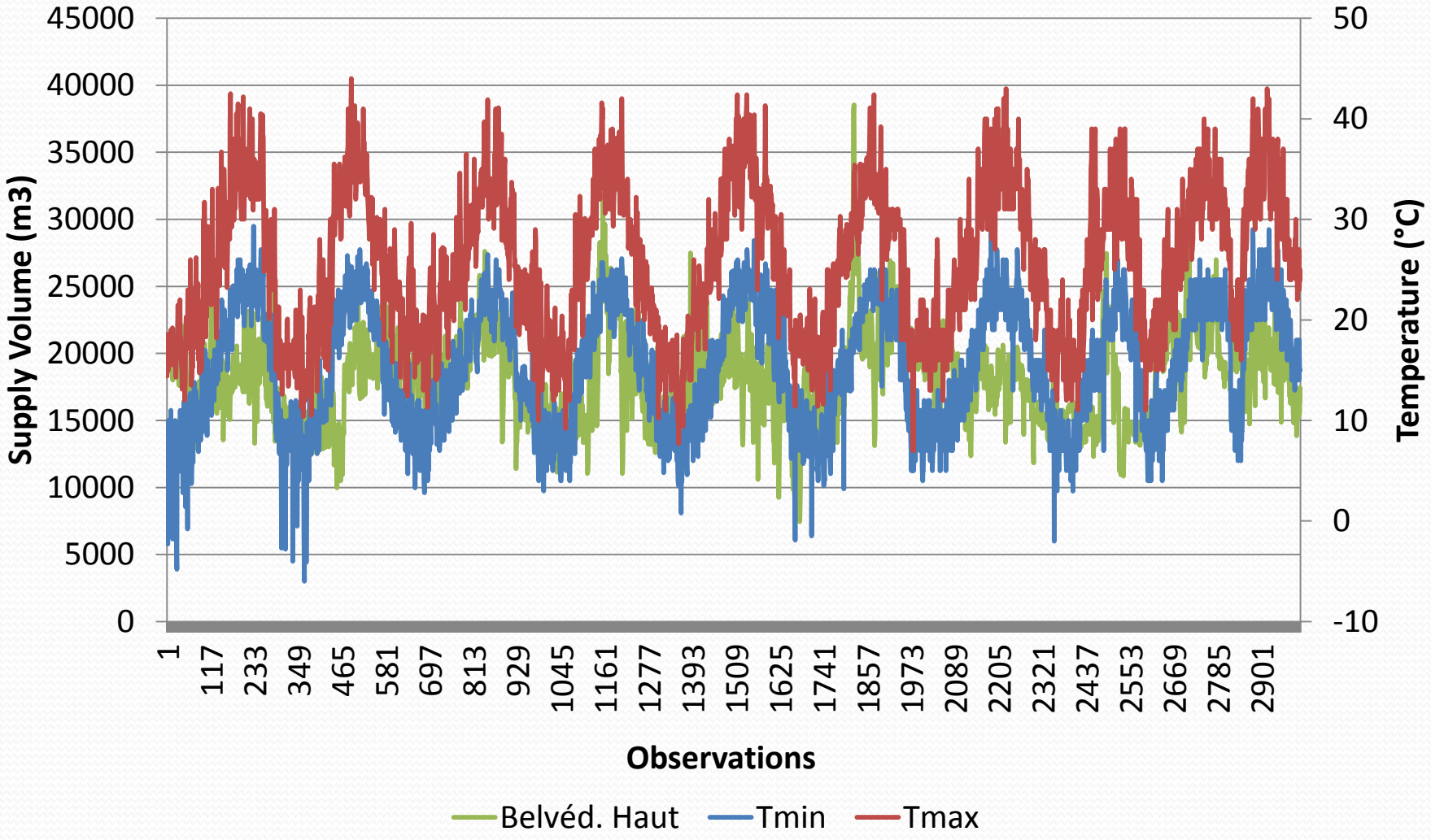


Table. Matrix of correlation coefficients.

Manouba 72

Variables	Tmin	Tmax	VDJ1	VDJ-1	VDJ-2	VDJ-3	VDJ-4	VDJ-5	VDJ-6	VDJ-7
Tmin	1									
Tmax	0.882	1								
VDJ1	0.574	0.580	1							
VDJ-1	0.572	0.576	0.958	1						
VDJ-2	0.571	0.572	0.928	0.958	1					
VDJ-3	0.572	0.573	0.904	0.928	0.958	1				
VDJ-4		73	0.888	0.904	0.927	0.958	1			
VDJ-5		75	0.873	0.888	0.904	0.927	0.958	1		
VDJ-6		0.574	0.861	0.874	0.888	0.904	0.928	0.958	1	
VDJ-7	0.573	0.574	0.85	0.862	0.874	0.888	0.905	0.928	0.958	1

Tmax

VDJ-1

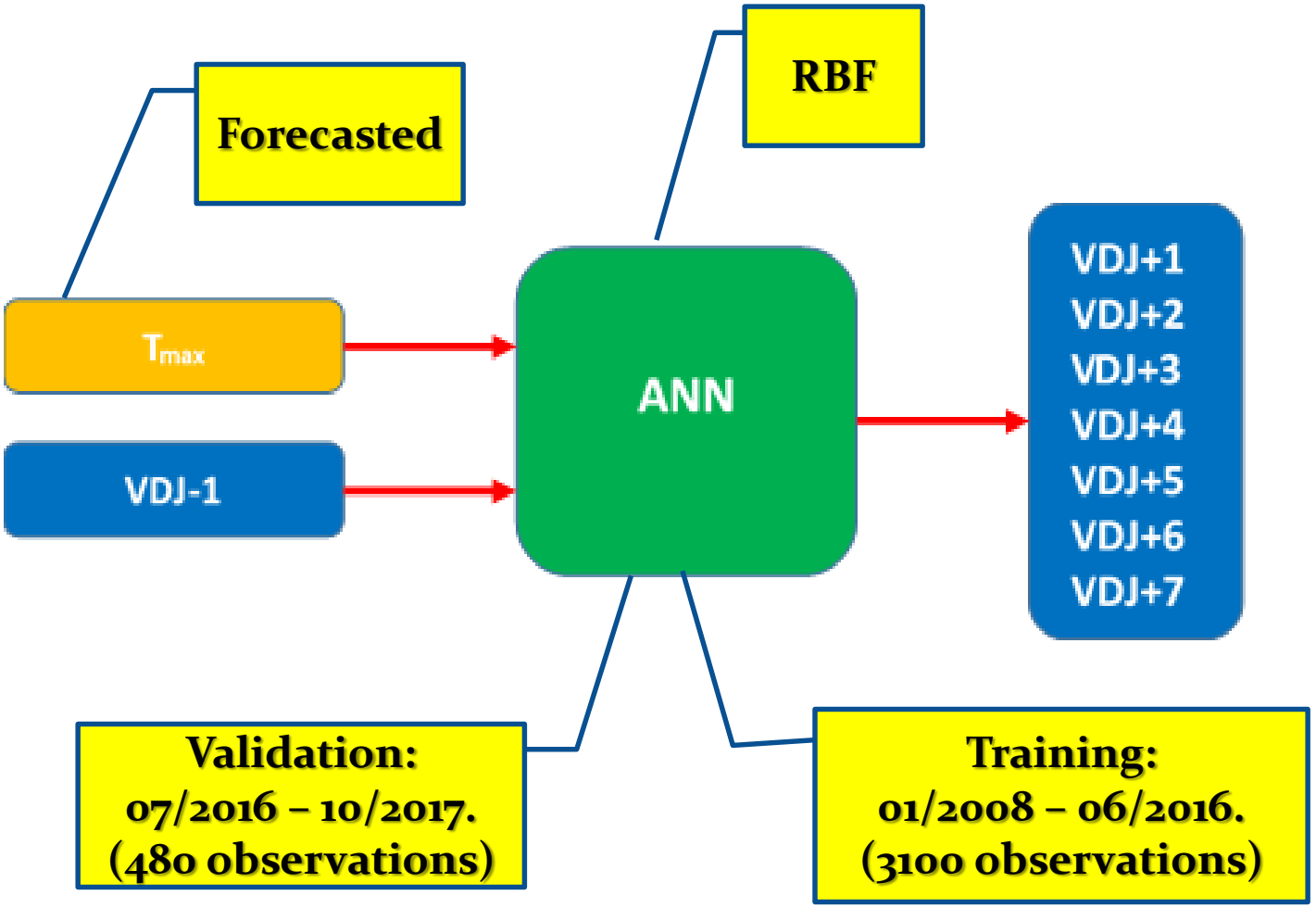
Belvedère Haut

Variables	Tmin	Tmax	VDJ	VDJ-1	VDJ-2	VDJ-3	VDJ-4	VDJ-5	VDJ-6	VDJ-7
Tmin	1									
Tmax	0.879	1								
VDJ	0.370	0.374	1							
VDJ-1	0.369	0.376	0.890	1						
VDJ-2	0.373	0.374	0.801	0.890	1					
VDJ-3		375	0.744	0.801	0.890	1				
VDJ-4		3	0.710	0.744	0.801	0.890	1			
VDJ-5		0.377	0.693	0.710	0.744	0.801	0.890	1		
VDJ-6	0.376	0.378	0.680	0.693	0.710	0.744	0.801	0.890	1	
VDJ-7	0.375	0.377	0.673	0.68	0.693	0.710	0.744	0.801	0.89	1

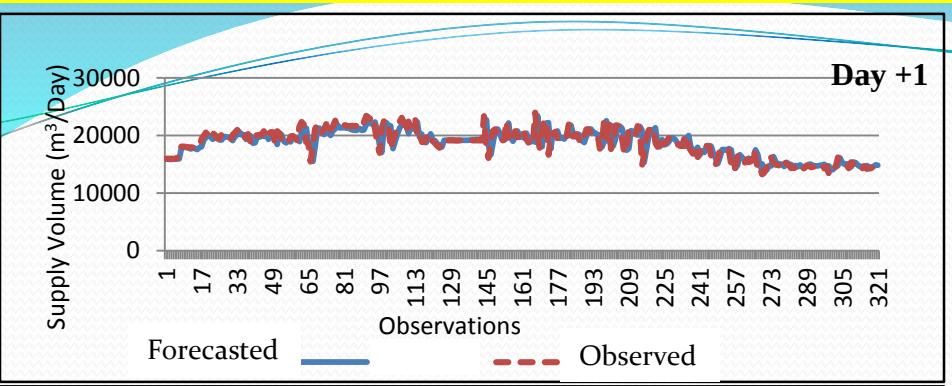
Tmax

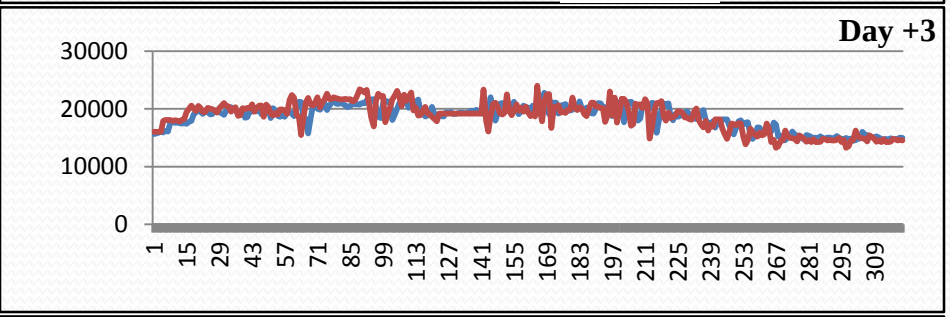
VDJ-1

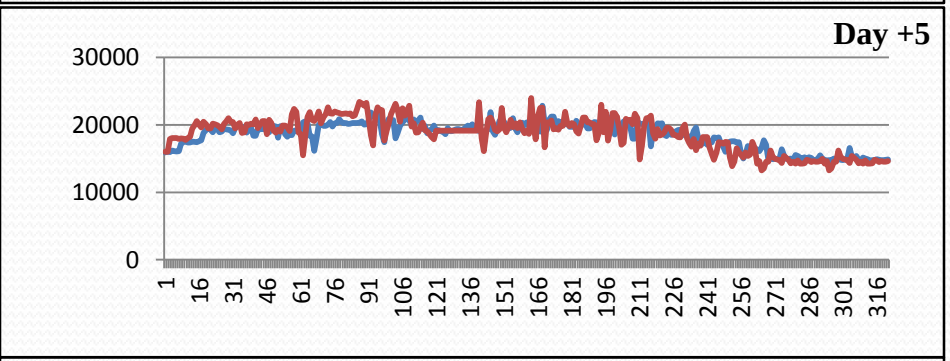
ANN design

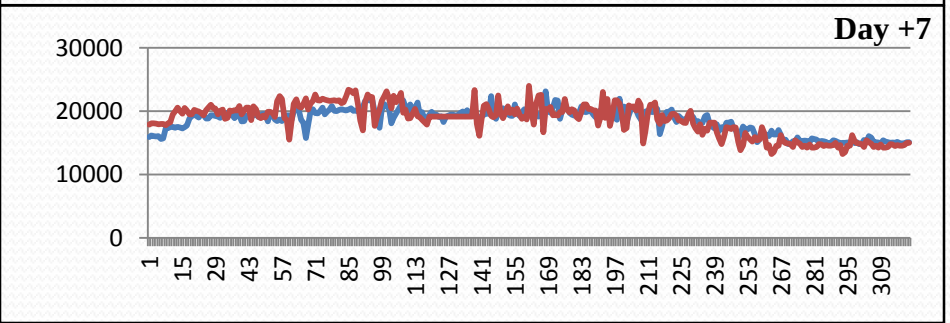

Forecasted
RBF
T_{max}
VDJ-1
ANN
VDJ+1
VDJ+2
VDJ+3
VDJ+4
VDJ+5
VDJ+6
VDJ+7
Validation:
07/2016 – 10/2017.
(480 observations)
Training:
01/2008 – 06/2016.
(3100 observations)

Belvédaire Haut tank

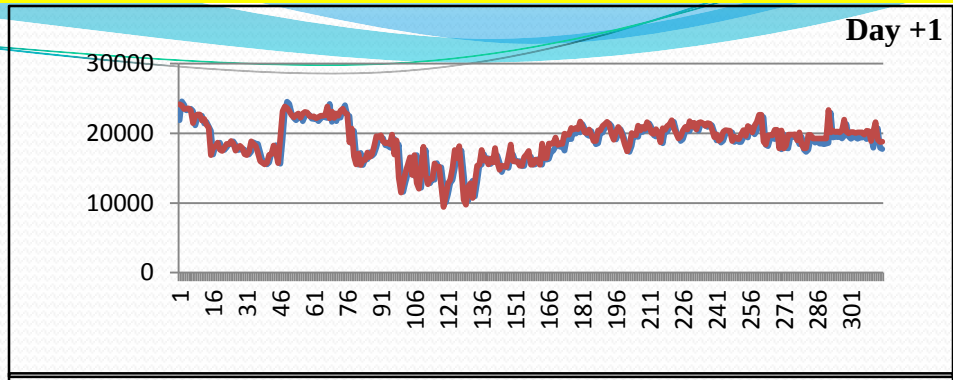


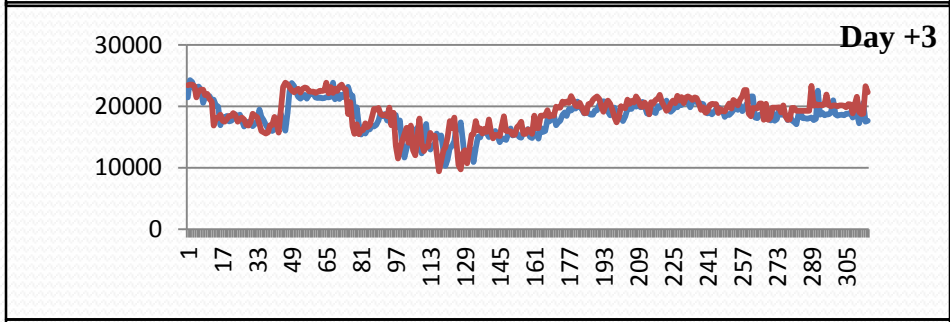


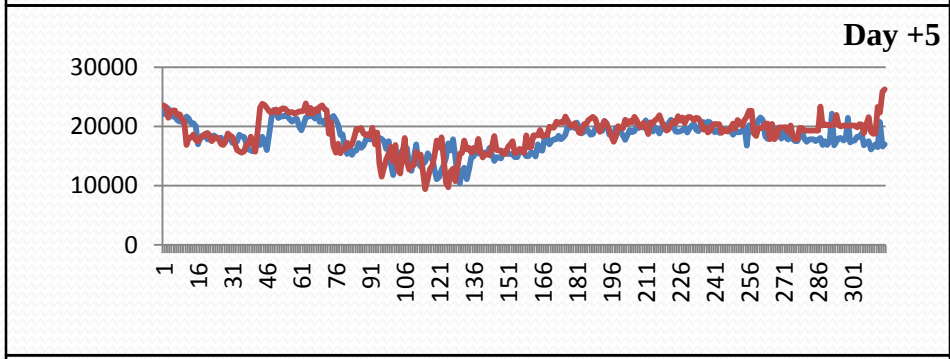




Mannouba 72 tank







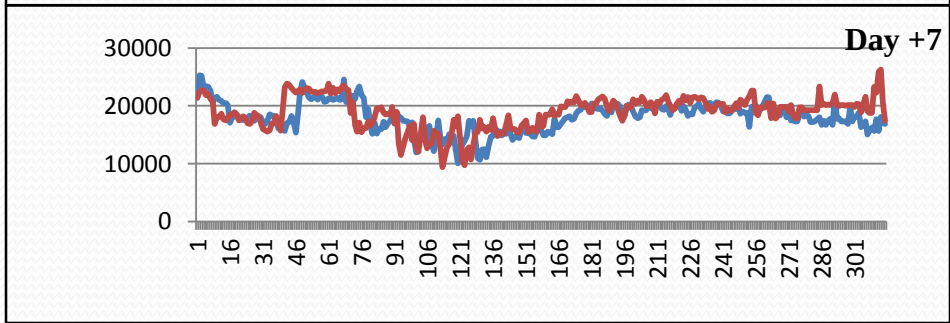


Figure. Frequency curve of forecasting errors for “Manouba 72”,

[- one week -]

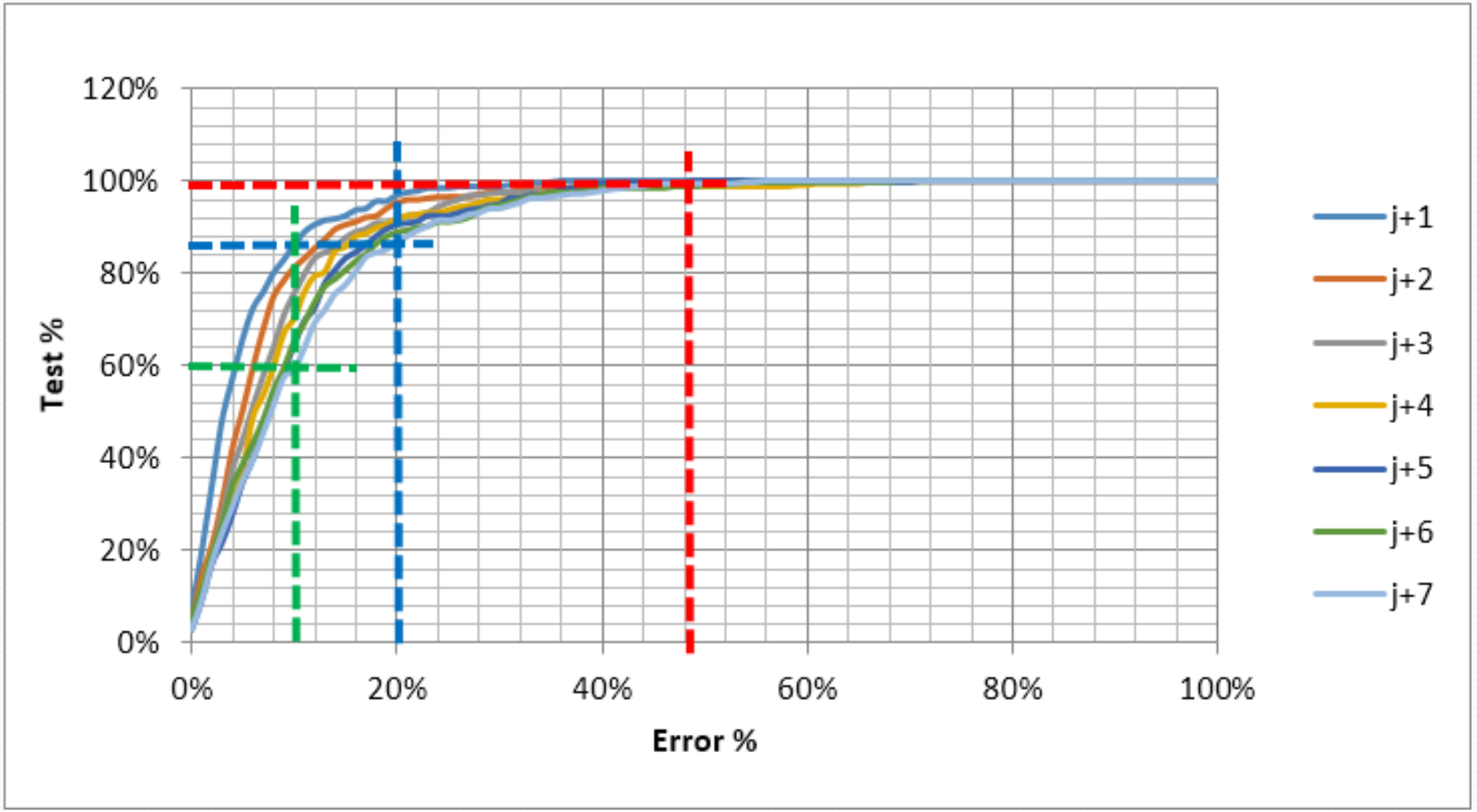
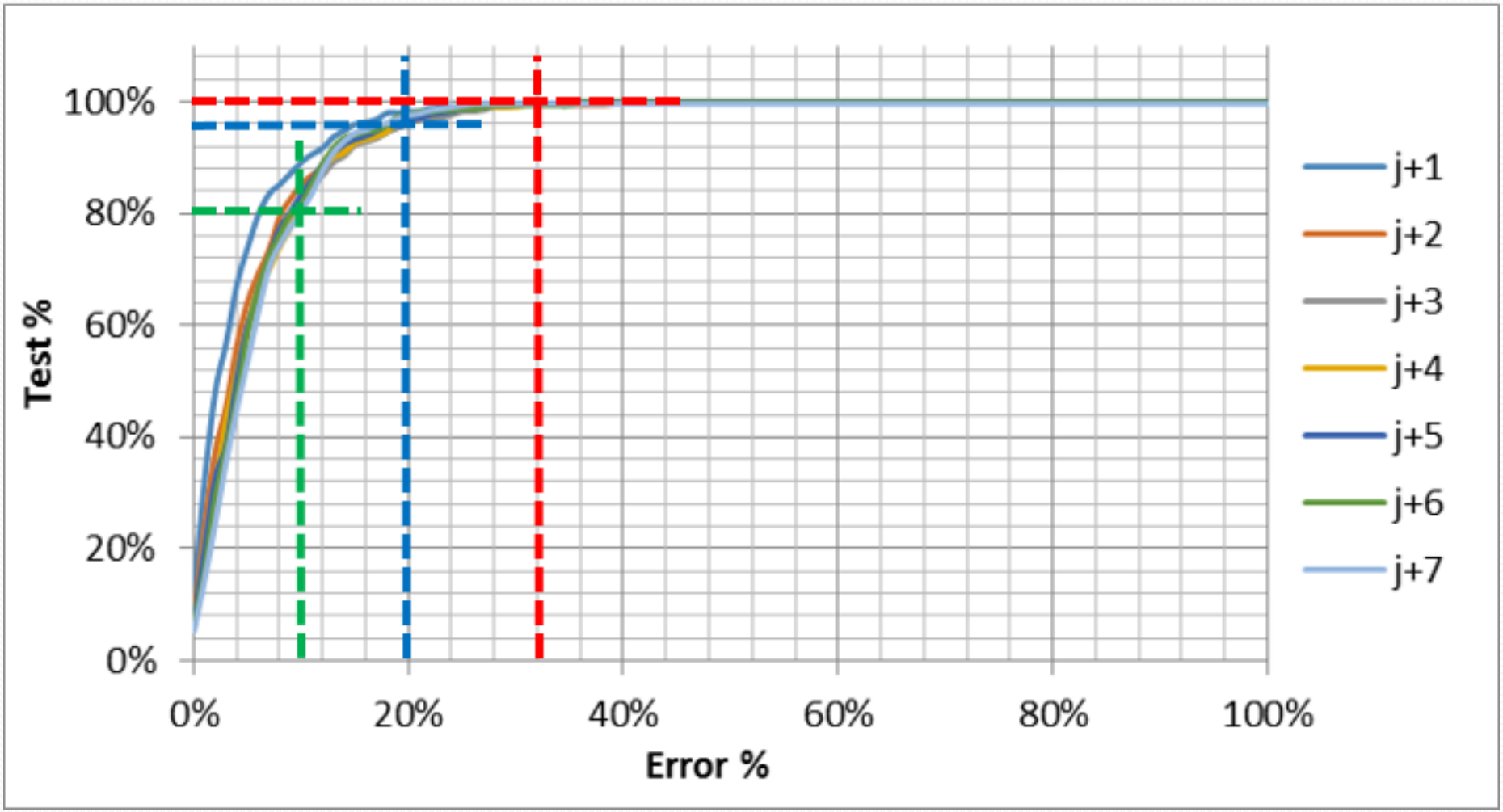


Figure. Frequency curve of forecasting errors for “Belvédère”, for one week



Tests percentage with error ≤ 15% - 19 supply networks

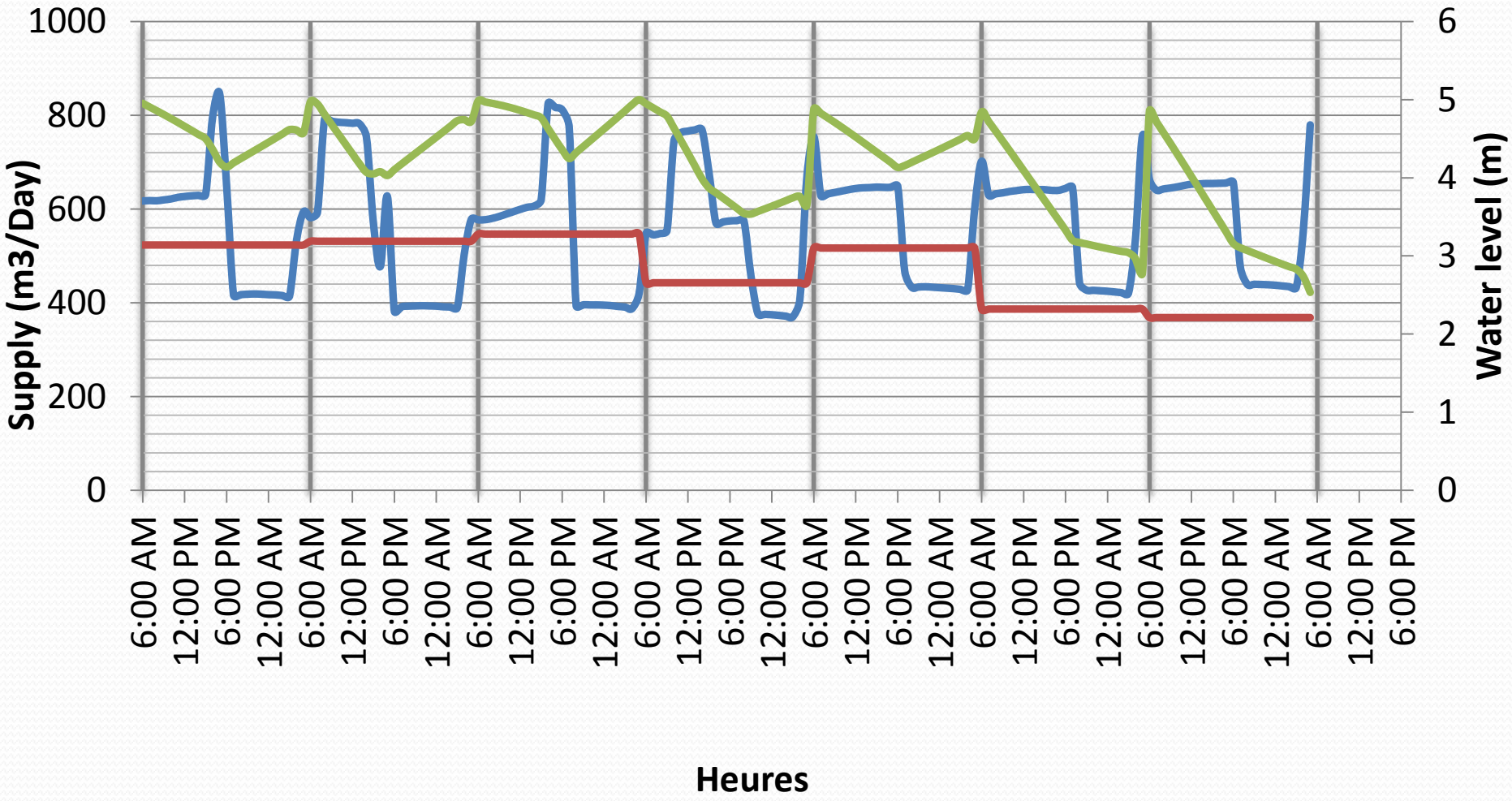
Day	FC	BC	HL	LB	SR	AML	AR	CART	BEL45	MB	GEG45	MA109	UN109	MATH	MAN72	GEG72	BH72	MA72	BK72
J1	92%	90%	94%	90%	99%	95%	100%	92%	95%	97%	100%	99%	100%	100%	100%	100%	100%	96%	100%
J2	89%	91%	89%	83%	99%	94%	100%	93%	88%	97%	98%	97%	93%	100%	100%	100%	100%	91%	100%
J3	83%	84%	79%	85%	97%	93%	100%	89%	84%	97%	90%	93%	92%	100%	100%	100%	100%	88%	99%
J4	88%	83%	79%	78%	97%	89%	99%	89%	83%	97%	83%	92%	96%	100%	100%	100%	100%	72%	86%
J5	83%	71%	74%	77%	96%	88%	99%	87%	81%	97%	78%	91%	100%	100%	100%	100%	100%	72%	85%
J6	72%	83%	73%	74%	96%	87%	98%	88%	78%	97%	79%	88%	99%	100%	100%	100%	100%	72%	77%
J7	75%	85%	69%	68%	96%	91%	97%	85%	81%	97%	80%	88%	98%	100%	100%	100%	99%	63%	69%

Tests percentage with error ≤ 20% - 19 supply networks

Day	FC	BC	HL	LB	SR	AML	AR	CART	BEL45	MB	GEG45	MA109	UN109	MATH	MAN72	GEG72	BH72	MA72	BK72
J1	100%	97%	96%	99%	100%	99%	100%	98%	97%	98%	100%	100%	100%	100%	100%	100%	100%	100%	100%
J2	100%	97%	93%	86%	100%	96%	100%	97%	93%	99%	100%	99%	98%	100%	100%	100%	100%	97%	100%
J3	86%	94%	83%	90%	100%	97%	100%	95%	87%	99%	96%	97%	98%	100%	100%	100%	100%	91%	100%
J4	97%	93%	83%	88%	100%	94%	100%	95%	94%	98%	91%	96%	100%	100%	100%	100%	100%	81%	90%
J5	94%	83%	83%	88%	100%	94%	100%	95%	90%	98%	90%	98%	100%	100%	100%	100%	100%	84%	95%
J6	88%	90%	81%	84%	100%	93%	100%	97%	87%	98%	89%	97%	100%	100%	100%	100%	100%	84%	88%
J7	80%	90%	81%	80%	100%	97%	100%	97%	91%	97%	93%	95%	100%	100%	100%	100%	100%	81%	81%

Figure. Optimal management of “Manouba 72” supply network

(April 30 – May 06, 2018)



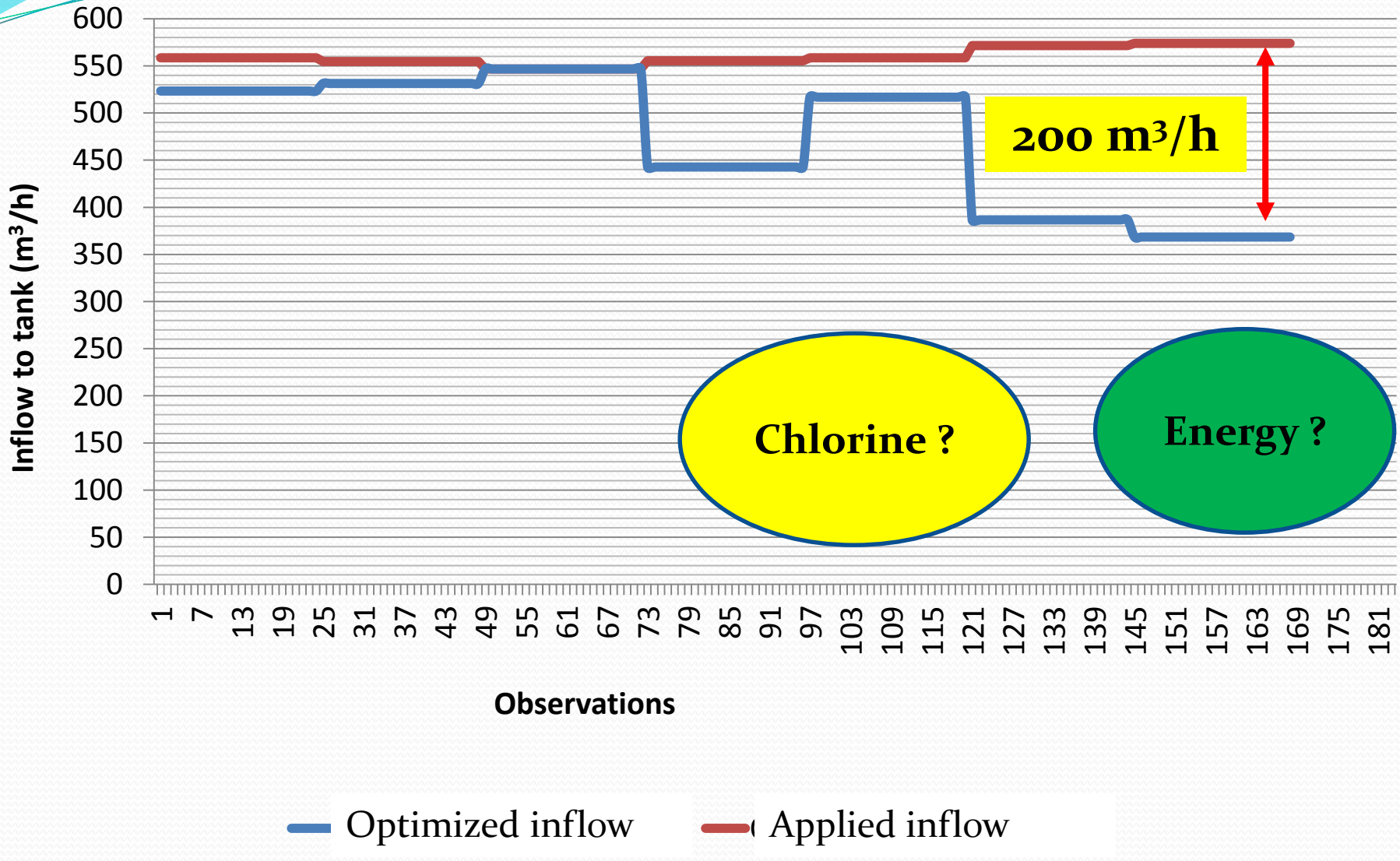

Inflow to tank (m³/h)
600
550
500
450
400
350
300
250
200
150
100
50
0
1
7
13
19
25
31
37
43
49
55
61
67
73
79
85
91
97
103
109
115
121
127
133
139
145
151
157
163
169
175
181
Observations
200 m³/h
Chlorine ?
Energy ?
Optimized inflow
Applied inflow

Figure. Frequency curve of forecasting errors for “Manouba 72”,

[- one month -]

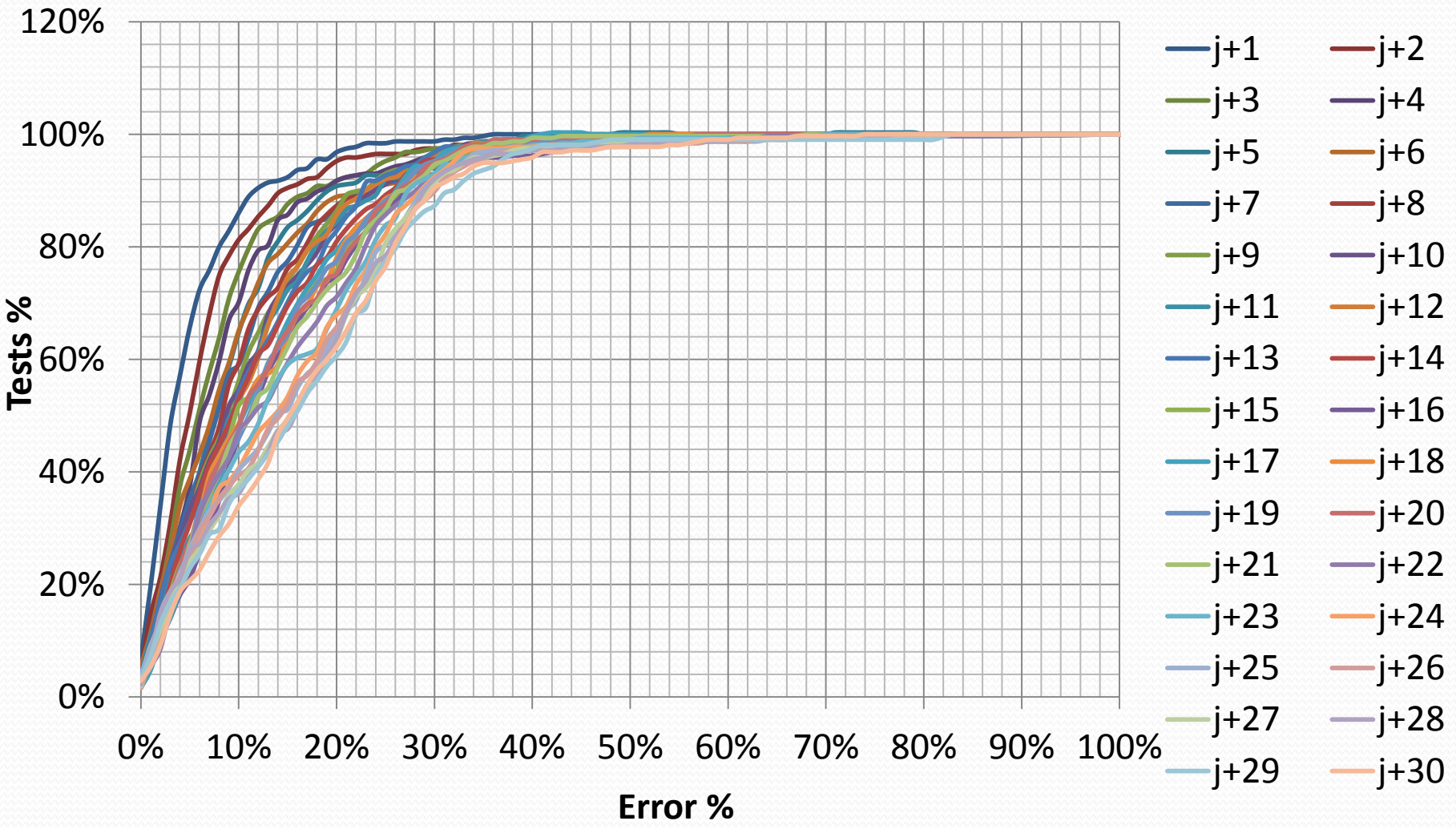
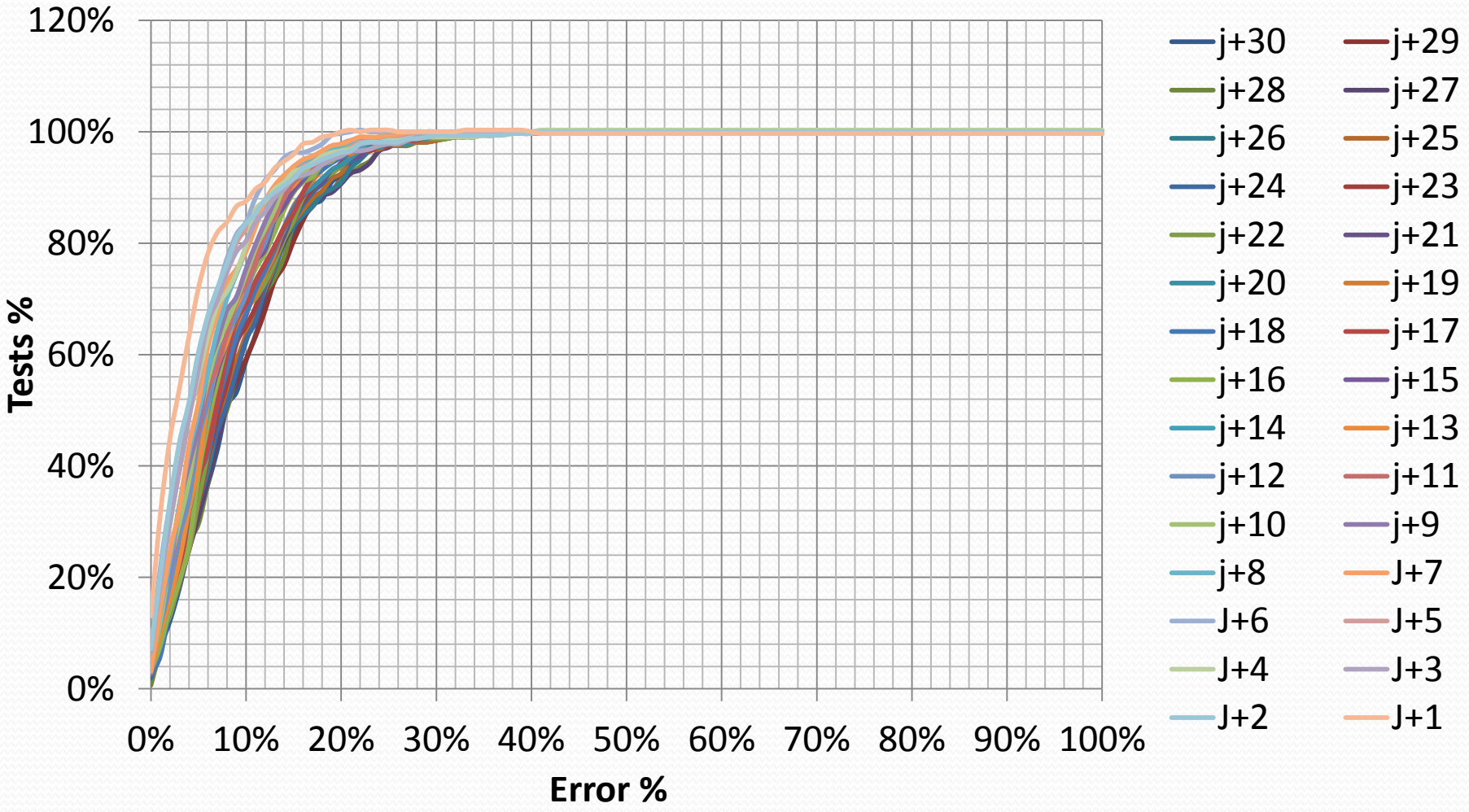


Figure. Frequency curve of forecasting errors for “Belvédère”, [- one month -]



Conclusions

- **Forecasting daily DWD for one week** using **ANN is possible, accurate and robust**, while the case study was complex (large socio-economic heterogeneity):
  - Input 1: **Maximal forecasted temperature**
  - Input 2**: One previous daily supply**.

- **Relative errors** were less than **15%** for more than **70%** of the tests. Forecasting daily DWD for longer period (month) is possible with decrease of accuracy.

- **More explorations** are **required** for supply networks in **different climatic and socio-economic contexts**, to improve forecasting performances.

- Managers of Drinking water networks can profit from these findings to **improve performances** by optimizing **pumping**, **treatment, disinfection and networks operation.**

Acknowledgements

- Tunisian company of Drinking Water Supply (SONEDE)
- WSTA
- KISR

شكرا

Merci

Gracias

Obrigado

Thank You

Dank u wel

Danke schön

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