CLISWELN

Climate Services for the Water-Energy-Land-Food Nexus

European Research Area for Climate Services

Joint Call for Transnational Collaborative Research

Topic A – Researching and Advancing Climate Service Development by Advanced Co-development with users

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License

Document history

Version	Date	Reason of change
1	01.09.2019	Tool ready for internal discussion
2	01.03.2020	First draft for feedback and discussion
3	01.11.2020	Final version

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Executive summary

The “Urban Drought Nexus Tool” facilitates the co-development of climate services for cities under increasing droughts. The tool integrates multiple types of information and still can be applied to other case studies with minimal adjustments on the parameters of land use, water consumption and energy use in the water sector. The tool needs hydrological projections under climate scenarios to evaluate climatic futures, and requires the co-creation of socio-economic future scenarios with local stakeholders. Thus it is possible to provide specific information about droughts taking into account future water availability and future water consumption. Ultimately, such complex system as formed by the water-energy-land nexus can be reduced to single variables of interest, e.g. the number of events with no water available in the future and their length, so that the complexities are reduced and the results can be conveyed to society in an understandable way, including the communication of uncertainties.

Contents

1. Introduction

The “Urban Drought Nexus Tool” integrates urban planning with the water sector. The tool has the purpose of providing a planning instrument to align water consumption from cities with water available under climate change at low energy costs, which translates into low economic costs and low greenhouse gas emissions. In this way, co-benefits across elements of the water-energy-land nexus can be explored under climate change and presented to context-specific decision makers aiming to achieve sustainability, especially to those dealing with droughts, but not only.

The tool can be applied with data and insights about water consumption in multiple sectors, e.g. in cities and in the agricultural sector, and with data and insights about water available at the river basin scale under climate change, and additionally with water made available by circular re-use, unconventional means like desalination, and water transfers from other basins, which are all reflected in the energy accounts.

The tool provides an entry point for urban sustainability on the basis of water scarcity and energy intensity of water use. The tool allows to use climate projections, by using data about hydrological model runs, and a matrix of urban future scenarios and climate scenarios can be produced. It is recommended that the complexity of the results is reduced to a single decision variable mimicking the decision process of the involved societal stakeholders, and that the resulting value of this variable and its uncertainties are expressed for the matrix of scenarios.

The tool is in fact an Integrated Assessment Model (IAM) for metropolitan areas and droughts, connecting the neighborhood scale with the river basin scale. We invite the reader to find all required details in the body of the deliverable (see Section 2.8). The tool is developed based on the system dynamics approach (www.systemdynamics.org). The tool is a system dynamics IAM that can be simulated using the free Vensim version, so-called Vensim PLE. For potential users who are not familiar with system dynamics modelling, it is suggested that they read first the guidelines at Section 4 below. This tool provides a free simulation model under the public license to simulate nexus elements in urban areas under climate change. This tool can be expanded according to users’ needs in specific case studies. The tools is applied to a case study in South Eastern Spain, in the Mediterranean coast, where the impacts of water scarcity have been felt in the economy and in the energy intensity of water.

2. Narrative Documentation and Description of the Main Equations

This section provides the concepts, equations and explanations behind the modelling tool. Aiming to familiarise the potential user with the software used in the tool, the equations are expressed in the language used in VENSIM©, which will be ultimately helpful to any user of the model. The interested reader can find further details on the behaviour of the main variables, a formal model documentation, and a guideline for using the tool in simulations in the next sections.

2.1. The Water Element of the Urban Nexus

For water, the model describes water into 3 separated sub-models: the surface water, the aquifer, and the urban water distribution.

Surface water

This element describes the main reservoir and surface water distribution to urban areas (see Figure 1). In this sub-model, there are two urban areas: city A and city B. The main variables are *the main reservoir*, *the main reservoir outflow to city A*, *the main reservoir outflow to city B,* and *switch aquifer and reservoir system*

The main reservoir is influenced by *the reservoir inflow*, *environmental flow*, *seepage water*, and *outflow water to cities* (city A and city B). *Environmental flow* is natural water flow to sustain life downstream the main reservoir and *seepage water* is incoming/outcoming water from/to other water sources such as small aquifer(s). Water levels in the main reservoir are also influenced by *the reservoir inflow* which is a natural inflow based on hydrological information derived from climatic data either from historical, present conditions or future projections under socio-economic scenarios like the representative concentration pathways (RCPs).

To establish a connection climate data and reservoir levels, a variable of *table of the main reservoir natural inflow_m3* should be inserted with a relationship between climate data and *the natural inflow of reservoir*.

A relationship between climate data and *the natural inflow* is defined by a lookup function so-called *table of the main reservoir natural inflow_m3* as seen in equation 1a. A format of a lookup function can be seen in equation 1b. By crossing equation 1a and 1b it is clear that the model is simulated from “0” to “119” time periods (useful to simulate 10 years at monthly time scales) and ranges of natural inflow is between “0” and “5” m^3/month in the particular example instantiated, however these values might be altered to reproduce other situations.

table of the main reservoir natural inflow_m3= WITH LOOKUP (Time/unit time of month*unit m3, ([(0,0)-(119,5)],(0,0.2885), (1,0.0264), (2,0.377), (3,0.0119), (4,0), (Yz,Xz))) ………………………………………………………………………………………… (1a)

LOOKUP NAME([(Xmin, Ymin) - (Xmax, Ymax), (Xref1, Yref1), (Xref2,Yref2),... (Xrefn,Yrefn)]……………………………………………………………………………… (1b)

Water in reservoir(s) may be discharged to fulfill water demand in each city. Discharged water from the main reservoir to city A, for example, is defined as *water input from the main reservoir for city A*. This outflow is based on water demand on each city as seen in equation 2a. Farming areas get water from the reservoir through *discharged water sustainable agriculture*. All of the discharged water flow for urban and farming areas are fulfilled based on the following equations:

water input from the main reservoir for city A = max ((total required water supply in city A - total water for city A) / adjustment time , 0) ……….…………..………..………….. (2a)

the main reservoir outflow for city A = IF THEN ELSE (the main reservoir> dead storage of the main reservoir , (min (water input from the main reservoir for city A , (the main reservoir) / TIME STEP)) , 0) ………..…………..…………..………..………..………….. (2b)

the main reservoir outflow for city B = IF THEN ELSE (the main reservoir> dead storage of the main reservoir , (min (water input from the main reservoir for city B , (the main reservoir) / TIME STEP)) , 0) ………..…………..…………..………..………..………….. (3)

discharged water sustainable agriculture = MIN (added potential potable water owing to sustainable agriculture from reservoir or river,(the main reservoir/TIME STEP)) ………… (4)

Water may seep from water surface to groundwater or vice versa in riverine areas. Urban areas may have a single water resource either a reservoir or an aquifer. To anticipate these different configurations, users should set *switch aquifer and reservoir system* to anticipate different configurations of surface water and groundwater systems. For further information, please see the next caption.

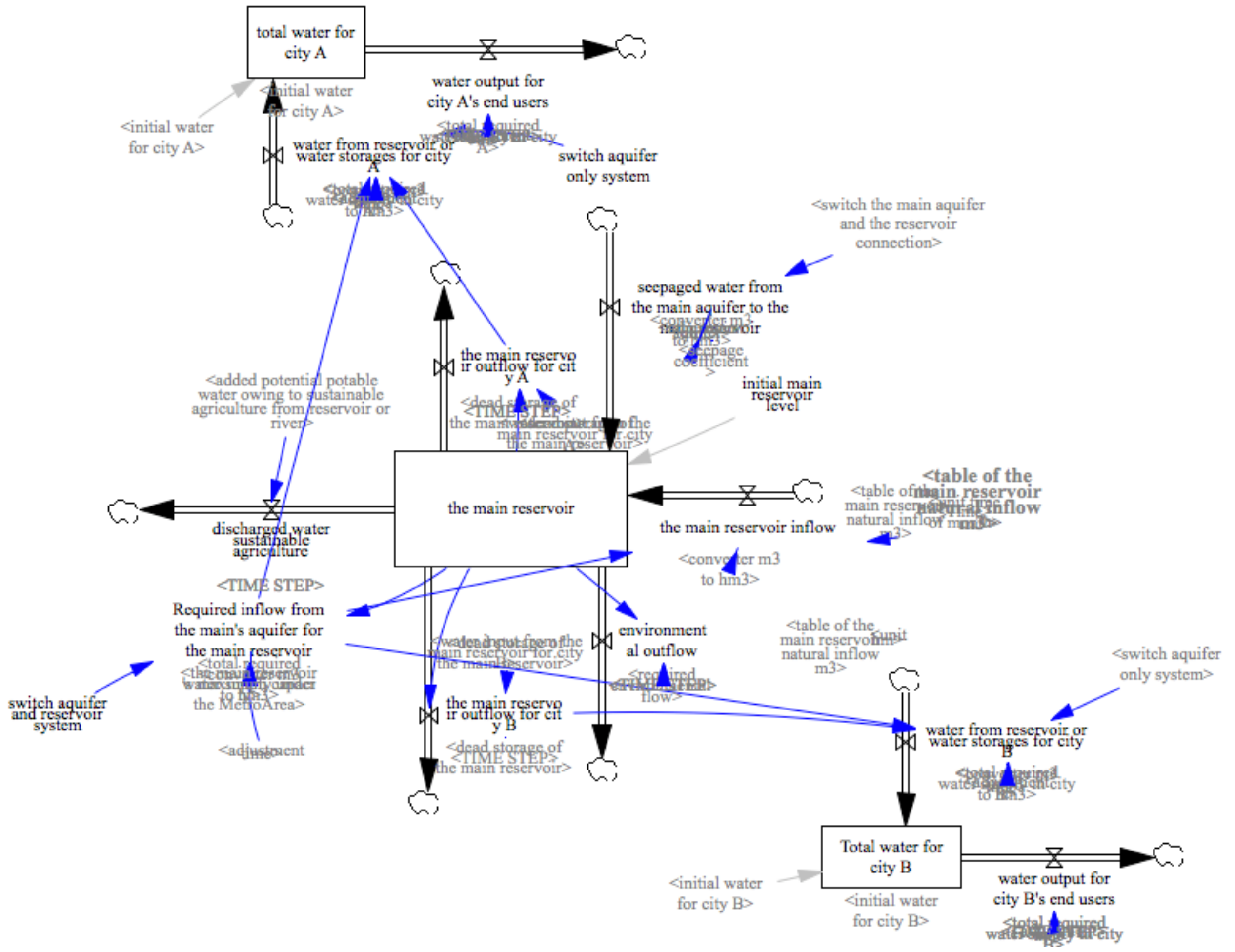

Figure 1. Surface water

Aquifer

The following text explains aquifer dynamics, which are a simplification based on water inflows and outflows surrounding the aquifer basin areas (see Figure 2). Springs or upwellings are water outflows once a water level in aquifer(s) exceeds a specific water threshold. There is aquifer recharge by infiltrated water from precipitation, and from surrounding aquifers and/or rivers.

Figure 2 is a model representation of simplified aquifer dynamics. The condition of spring water and groundwater extraction is defined by *monthly spring and upwelling flow* and *the main aquifer's extraction* respectively.

monthly spring and upwelling flow = IF THEN ELSE (the main aquifer >= threshold of spring water , ((the main aquifer - threshold of spring water) /TIME STEP) , 0) ………………. (5)

the main aquifer's extraction = IF THEN ELSE (the main aquifer >= aquifer minimum level, (min (the main aquifer / TIME STEP , Required inflow from the main's aquifer for the main reservoir+(added potential potable water owing to sustainable agriculture from the main aquifer/converter m3 to hm3))) , 0) ………………………………………………………. (6)

infiltration and percolated water to the the main aquifer = observed precipitation
* "infiltration-percolated coefficient" * the main aquifer's permeable surface areas, TIME STEP , "infiltration-percolated coefficient" * observed precipitation * the main aquifer's permeable surface areas*switch the main aquifer and the reservoir connection ……………………………………………………………….…… (7)

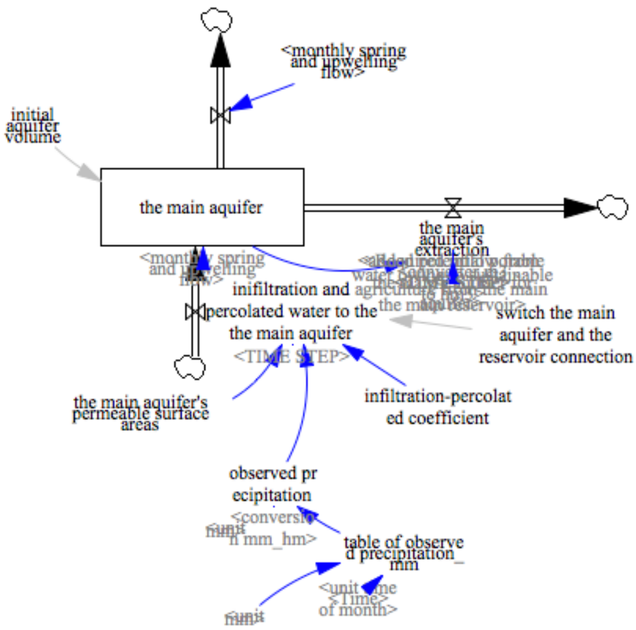

Figure 2. Aquifer model.

Urban water consumption

In the model, city A and city B is a representation of high and low-density areas respectively. Each city has accommodation such as camping sites and hotels. Each city also has urban areas for the resident population. The main difference is population density per area in each city which can be defined before model simulations. This differentiation enables to model the diverse water consumption levels that characterize different urban population densities, in relation to features such as gardens and pools in low-density areas. This is facilitated by the variable water consumption per person per day, which is differentiated for both high-density and low-density areas (see Figure 3 and 4).

The main variables in this part are as follows: *water consumption per person* (for each accommodation type and the resident population), *bed capacity of each accommodation*, and *average overnight stay* in each accommodation type.

Please note that this part should be arranged with another part: *low-high density areas*. In the part of low-high density areas, users can define *average population in low* and *high-density areas* and *the size of each area*. Main equations for this sub-model as follows:

overnight stays in camping sites (city A) = total camping sites capacity in city A*the number of day in a month*the monthly seasonality ratio ………………………………………………. (8)

total overnight stays in the MetroArea camping sites = "overnight stays in camping sites (city A)"+"overnight stays in camping sites (city B)" ……………………………………………. (9)

total water consumption of resident population in city A = ("water consumption per person per day (high-density areas)"*"resident population in high-density areas of city A"+"water consumption per person per day (low-density areas)"*"resident population in low-density areas of city A")*days in a month*"conversion liters to m^3"*the monthly seasonality ratio ……………………………………………………………………………………… (10)

Equations 8-10 are similar for other accommodation types. Total water consumption in the Metro is calculated based on equation 11.

total water consumption in the MetroArea's camping sites = total overnight stays in the MetroArea camping sites*water consumption per person in camping sites*conversion liters to m^3 ……………………………………………………………………………………….. (11)

2.2. The Land Element of the Urban Nexus: Low and High Population Density Areas

In this part, users can define some main variables such as *average people in low and high-density areas* and *sizes of low and high-density areas*. Variables of l*ow/high-density areas in city A/B* are representations of sizes of low/high-density areas in each city.

Users may want to simulate changes in area sizes in this model. To do so, users change define size changes through *fraction(s) of land-use change in urban areas* in each city and *initial size(s) of low/high density-areas*. For instance, users can define *fraction of land-use change in urban areas in city A*: 1%. This means that low/high density-areas in city will increase as much as 1% per month. Users can also change an initial size (hm^2) of urban areas in city A through *initial size(s) of low/high density-areas in city A*.

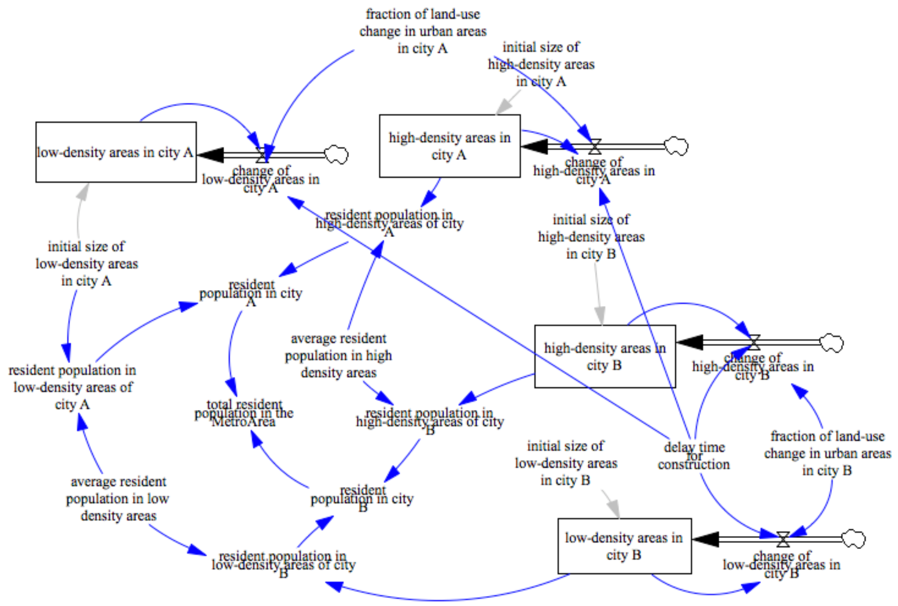

Figure 3. Low and high-density areas in the Metro (city A and B)

2.3. The Land Element of the Urban Nexus: Local Farming Areas, Water Consumption and Food Production

Farming areas usually consist of three important variables such as a size of farming areas, water demand per ha, and land-use change dynamics. The land-use change dynamics are represented by *fractions of new farming areas* and *land-use change*. The size of new farming (agricultural) areas is affected by fraction new farming area and delay time of operationalizing new farming areas (see equations 12 and 13 and figure 5). Similarly, land-use change is influenced by *delay time of converting farming areas* (for other purposes) and a *fraction of land-use change*. Equations 12-17 calculate important variables in farming areas.

new agricultural areas = DELAY3 (fraction of new agricultural areas*the total agricultural areas in the MetroArea, delay time of new agricultural areas) …………………………….. (12)

land-use change (from agricultural to urban areas) = DELAY3 ("fraction of land-use change (from agricultural to urban areas)"*the total agricultural areas in the MetroArea,"delay time of land-use change") ……………………………………………………………………….. (13)

total water demand for agricultural areas = the total agricultural areas in the MetroArea*"water demand per ha (agricultural areas)" ………………………………………………………. (14)

Blue water and reused water can be main water sources of farming areas. To capture complexities in given farming areas, this sub-model also captures wastewater treatment plants. Total used water in urban areas is defined as *inflow of used urban water*. This used water is sent to wastewater plants to generate reused water for farming areas. Another variable, *reused water for agriculture*, represents total combined water sent to farming areas.

inflow of used urban water = switch for agriculture water from reused water*(IF THEN ELSE((agricultural water storage in MetroArea/TIME STEP)<=0, ((
MIN (total water demand for agricultural areas,(total required water supply under the MetroArea/"delay processing time in the wastewater plant(s)")))) , 0)) …………….……… (15)

reused water for agriculture = "wastewater treatment plant(s) in MetroArea"/ delay time to distributed reused water to farming areas . ………………………………………………... (16)

agricultural water use = IF THEN ELSE (((agricultural water storage in MetroArea
/ TIME STEP) >= total water demand for agricultural areas), total water demand
for agricultural areas, (agricultural water storage in MetroArea / TIME STEP)) ... (17)

This tool has two variables namely *added potential blue water owing to sustainable agriculture from the main aquifer* and *added potential blue water owing to sustainable agriculture from reservoir or river*. Respectively, these variables show how much blue water should be discharged from the main aquifer and/or from the reservoir. Total of blue water from both sources is called *water from other source(s) for agriculture*, meaning other than reused.

added potential blue water owing to sustainable agriculture from the main aquifer = IF THEN ELSE(gap between total urban water supply and demand>=1, (max(0,(total water demand for agricultural areas-agricultural water use))*switch for agriculture water from aquifer), 0) … (18)

added potential blue water owing to sustainable agriculture from reservoir or river = IF THEN ELSE(gap between total urban water supply and demand>=1, (max(0,(total water demand for agricultural areas-agricultural water use))*"switch for agriculture water from river (or reservoir)"), 0) ……………………………………………………………………………… (19)

water from other source(s) for agriculture = added potential potable water owing to sustainable agriculture from the main aquifer+added potential potable water owing to sustainable agriculture from reservoir or river . ……………………………………………………… (20)

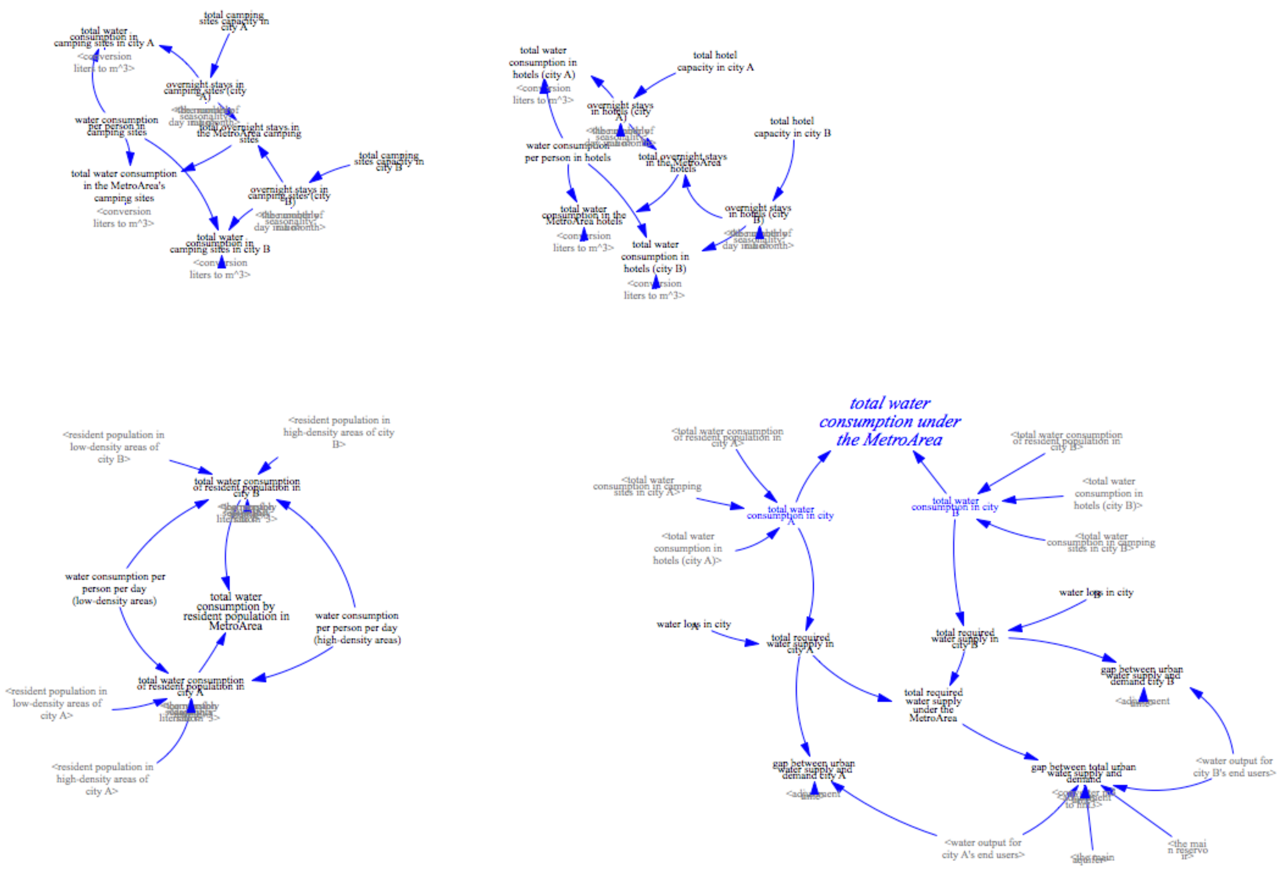

Figure 4. Water consumption.

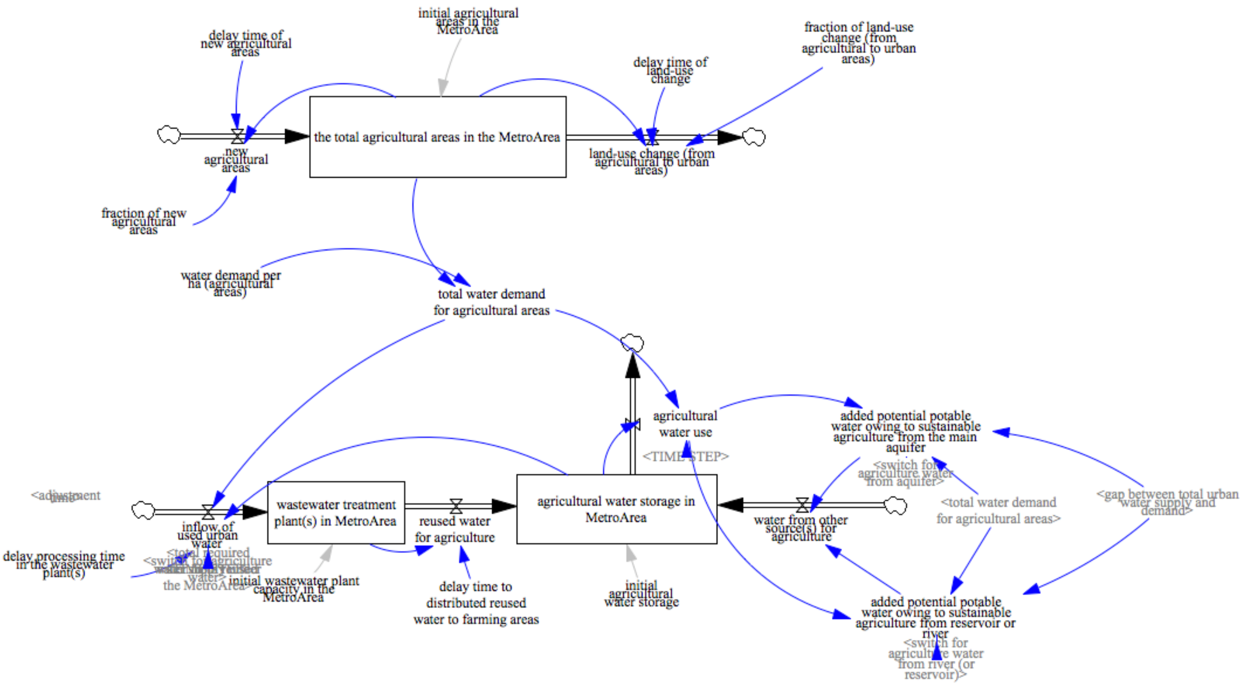

Figure 5. The farming areas.

2.4. The Energy Element of the Urban Nexus and its Greenhouse Gas Emissions

Urban development must consider energy consumption and GHG emissions to achieve sustainable development. To calculate total CO_2 emission, users firstly define in the model the *index of regional CO2 emission* (CO_2 tonnes/KwH). This model captures energy consumption based on the water cycle in the Metro (city A and city B). Total energy consumption is measured after wastewater treatment, water distribution, and groundwater extraction (see Figure 6). For each water activity, users should define in the model each *energy intensity* (KwH/m^3) such as energy for wastewater treatment and energy intensity for water distribution. Energy consumption is a multiplication of *energy intensity* and *water consumption*. Equation 21 is an example of energy consumption in terms of water distribution in the Metropolitan area.

monthly energy consumption for water distribution around urban areas in MetroArea = energy intensity for urban water distribution*total water consumption under the MetroArea ……. (21)

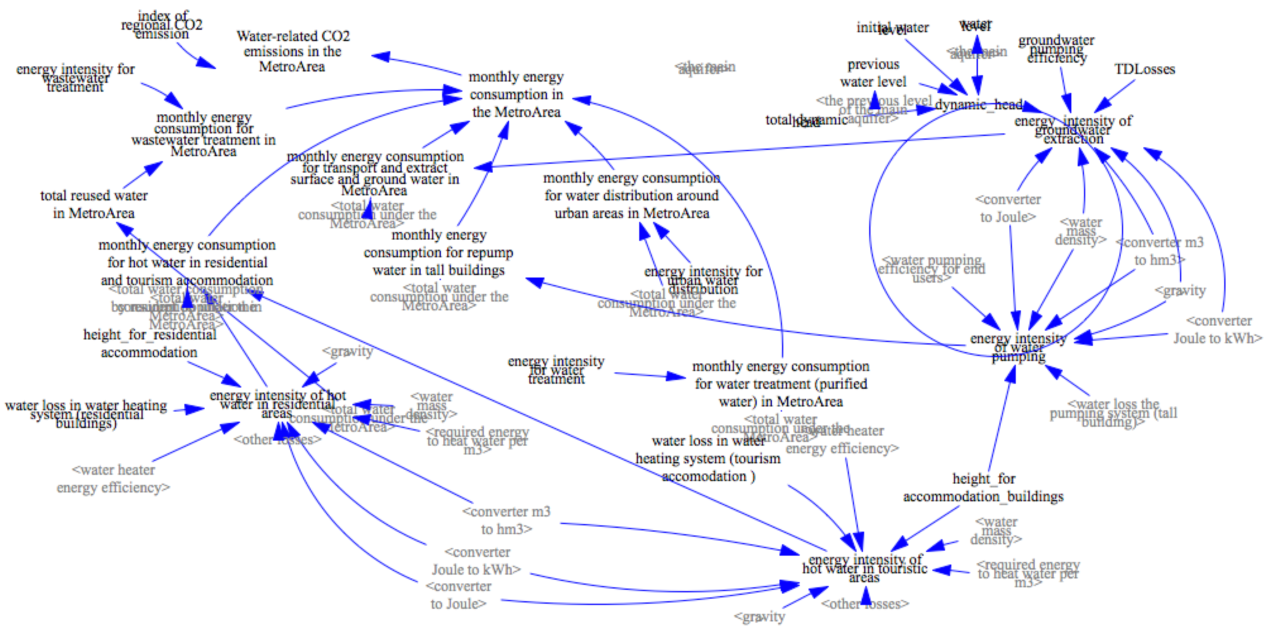

Figure 6. Energy consumption and CO_2 emissions in the Metro (city A and B)

As seen in figure 6, energy intensity of repump water and energy intensity of hot water depend on water loss, technical efficiency (hot water/pumping efficiency) and average building height. Furthermore, energy intensity of groundwater extraction is influenced by dynamic head of groundwater pump(s), groundwater pumping efficiency, and transmission and distribution losses (TDL). s

Not all the described parameters will be always available in every case study. It is possible that users or modelers may face data scarcity due to limited time or limited funding. In this case, we suggest users to use available data from existing studies. In case of energy intensity of groundwater, an existing study (King-Okumu et al., 2019) explained estimated data for groundwater extraction issues such as pumping efficiency and transmission losses. Moreover, another study (Yoon et al., 2018) provided estimated ranges of energy intensities in urban areas.

2.5. Scenario Analysis and Graphical Output

The tool is equipped with a special module to visualize graphically the output of scenario analyses in graphs. This module (see Figure 7) provides users with interactive menus to interact with the tool. As the tool captures several nexus elements, they can be analysed under different assumptions in interactive mode by switching on an off policy options and by reproducing numerically different assumptions, e.g. a reduction on water consumption per habitant will immediately display effects on the water available in the reservoir. For a complete explanation, please look at Section 4.

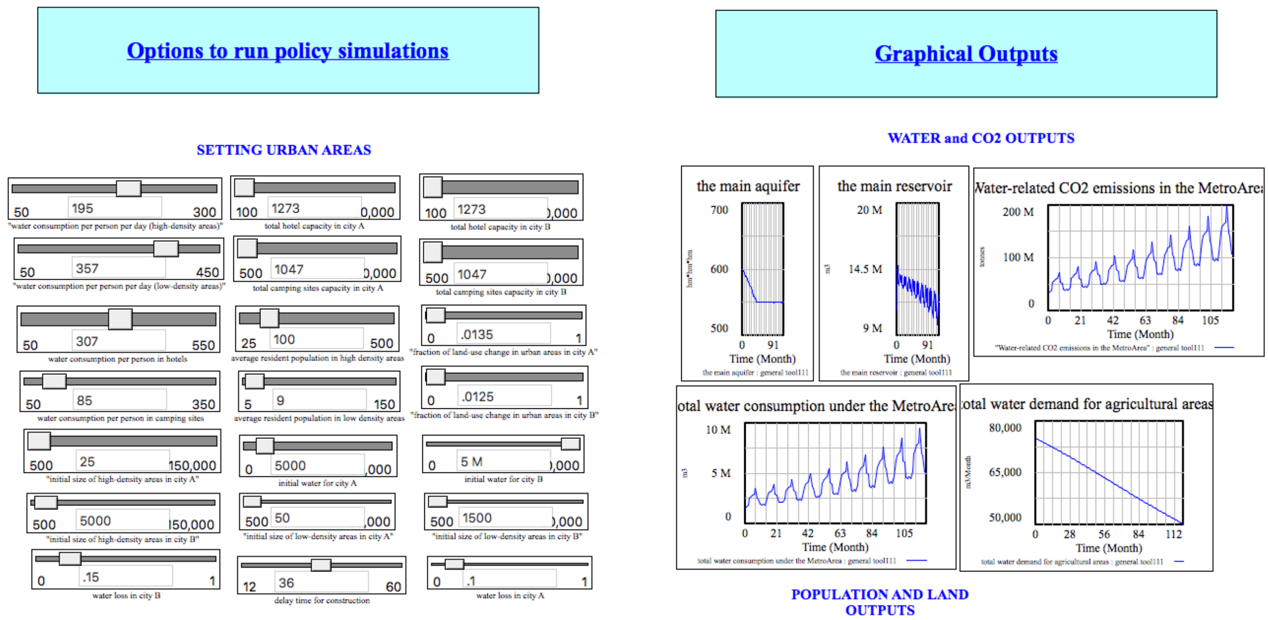

Figure 7. Part of the graphical output interface.

2.6. FAQs for Potential Users and Developers

Question 1*.* *I have little background in Vensim, where should I start ?*

Answer: In case of you have no solid background in Vensim©, please read the Section 4 on Guidelines.

Question 2*.* *I have solid background in the system dynamics and I want to re-develop similar model(s) using other tools. What is your suggestion?*

Answer: Assuming you have a solid background in the system dynamics, it is suggested to read this material and the model documentation. From the model documentation, you can develop similar model(s*) using other tools such as Stella and Powersim.*

Question 3*. I want to combine this model with python. What shall I do?*

Answer: It is possible to use this model with python. To get more info, please go to: https://pysd.readthedocs.io/en/master/ .

Question 4*. I am a modeller working with urban planners or using climate-related data, what do you think should be developed next?*

Answer: The behavioural dimension, coupling individual responses to policies with urban densities at the neighbourhood scale, and the inequality dimension of such behaviour, is a promising development. Then, a big data technique aiming at generating pre-built models to start refining the final co-produced model for specific regions would be very interesting. Despite the interest on the drought side, which requires many dynamics in the model to be frozen to observe the impact of changes in water availability, exploring dynamics on land use would be a natural next immediate step.

2.7. Coupling the Tool with the Integrated Urban Complexity Model

The "Urban Drought Nexus Tool" is technically an Integrated Assessment Model (IAM), putting together multiple linked resources to explore future socio-economic and climate scenarios. The tool has the specific purpose of analysing droughts in metropolitan areas. The tool has cross-scale properties, and is currently able to connect neighbourhood scales with related river basins. Further extensions connecting individual behaviour can be expected. The tool captures water consumption from different land use types, and for urban land use it captures different urban population density values. In this context, the outputs of the Integrated Urban Complexity model (IUCm) (Cremades and Sommer, 2019) can serve as inputs of the tool, further exploring the water consumption and the implications of low-energy urban fractal-like configurations on droughts.

3. Formal Model Documentation

This section provides a complete formal documentation of all the variables. For each variable, the documentation includes three aspects explained, as it is the standard way in the system dynamics community: the first aspect is the name of each variables and its mathematical calculation, the second is in which view of the model is the variable introduced, and the third is what other variables use the described variable. A variable may use or include more than a single other variable in its equation, that's why many variables described include variables in common, for example, environmental flow and initial main reservoir level both include the main reservoir. Additionally, in each module, there are several variables, for example, the urban water distribution module is listed in several variable descriptions. The model runs at monthly time steps and has 191 variables that are described next.

Table 1. Description of variables included in the model behind the tool.

Urban water distribution (71 variables)
Variable Name and Description
added potential potable water owing to sustainable agriculture from reservoir or river (m3/Month) = IF THEN ELSE(gap between total urban water supply and demand>=1, (MAX(0,(total water demand for agricultural areas-agricultural water use))* "switch for agriculture water from river (or reservoir)"), 0) **Description:** *this is added potable water owing to sustainable agriculture policy* **Present in 2 views:** • urban water distribution • agricultural areas **Used by:** • discharged water sustainable agriculture • "water from other source(s) for agriculture"
adjustment time (Month) = 1 **Description:** *a needed time to distribute water to a destination* **Present in 4 views:** • urban water distribution • urban water consumption • agricultural areas • energy consumption and CO2 emission **Used by:** • gap between total urban water supply and demand • gap between urban water supply and demand city A • gap between urban water supply and demand city B

- Required inflow from the main's aquifer for the main reservoir - a required volume to fulfil water consumption in the Metro.
- This should be extracted from the main aquifer
- seepaged water from the main aquifer to the main reservoir
- water from reservoir or water storages for city A - please choose 0: the reservoir system please choose 1: the river system
- water from reservoir or water storages for city B
- water input from the main reservoir for city A - the number of distributed water from Guadalest reservoir to Altea
- water input from the main reservoir for city B - the number of distributed water from Guadalest reservoir to Polop
- water output for city A's end users - a flow of available water for end users in Altea
- water output for city B's end users - a flow of available water for end users in Polop

converter m3 to hm3 (m3/(hm*hm*hm))
= 1e+06
Present in 4 views:

- urban water distribution
- the main aquifer
- urban water consumption
- energy consumption and CO2 emission

Used by:

- enegy consumption of water transportation from the main aquifer to the Guadalest reservoir
- energy intensity of hot water in residential areas
- energy intensity of hot water in touristic areas
- energy intensity of water pumping
- "energy_intensity of groundwater extraction"
- gap between total urban water supply and demand
- Required inflow from the main's aquifer for the main reservoir - a required volume to fulfil water consumption in the Metro.
- This should be extracted from the main aquifer
- seepaged water from the main aquifer to the main reservoir
- the main aquifer's extraction - extracted water from the main aquifer
- the main reservoir inflow
- water from reservoir or water storages for city A - please choose 0: the reservoir system please choose 1: the river system
- water from reservoir or water storages for city B

dead storage of the main reservoir (m3)
= 700000
Present in 1 view:

- urban water distribution

Used by:

- the main reservoir outflow for city A
- the main reservoir outflow for city B

discharged water sustainable agriculture (m3/Month)
= added potential potable water owing to sustainable agriculture from reservoir or river
Present in 1 view:

- urban water distribution

Used by:

- the main reservoir - the Guadalest reservoir's water stock

environmental outflow (m3/Month)
= MIN(required environmental flow,(the main reservoir/TIME STEP))
Present in 1 view:

• urban water distribution **Used by:** • the main reservoir - the Guadalest reservoir's water stock
initial main reservoir level (m3) = 1.1e+07 **Present in 1 view:** • urban water distribution **Used by:** • the main reservoir - the Guadalest reservoir's water stock
initial water for city A (m3) = 5000 **Present in 1 view:** • urban water distribution **Used by:** • total water for city A - a stock of total water for Altea population
initial water for city B (m3) = 5e+06 **Present in 1 view:** • urban water distribution **Used by:** • Total water for city B - a stock of total water for Polop population
required environmental flow (m3/Month) = 400 **Present in 1 view:** • urban water distribution **Used by:** • environmental outflow
Required inflow from the main's aquifer for the main reservoir ((hm*hm*hm)/Month) = (MIN((the main reservoir's maximum capacity-the main reservoir),total required water supply under the MetroArea))/adjustment time* switch aquifer and reservoir system*(1/converter m3 to hm3) **Description:** *a required volume to fulfil water consumption in the Metro. This should be extracted from the main aquifer* **Present in 2 views:** • urban water distribution • the main aquifer **Used by:** • enegy consumption of water transportation from the main aquifer to the Guadalest reservoir • the main aquifer's extraction - extracted water from the main aquifer • the main reservoir inflow • water from reservoir or water storages for city A - please choose 0: the reservoir system please choose 1: the river system • water from reservoir or water storages for city B
seepage coefficient (Dmnl) = 0.01 **Present in 1 view:** • urban water distribution **Used by:** • seepaged water from the main aquifer to the main reservoir
seepaged water from the main aquifer to the main reservoir (m3/Month) = the main aquifer/adjustment time*(1-switch the main aquifer and the reservoir

connection)*seepage coefficient*converter m3 to hm3
Present in 1 view:
- urban water distribution

Used by:
- the main reservoir - the Guadalest reservoir's water stock

switch aquifer and reservoir system (Dmnl)
= 1
Description: *please write down 1: if you consider a combination an aquifer and a reservoirplease write down 0: if NO aquifer exists but a reservoir*
Present in 2 views:
- urban water distribution
- scenarios and graphs

Used by:
- Required inflow from the main's aquifer for the main reservoir - a required volume to fulfil water consumption in the Metro.
  This should be extracted from the main aquifer

switch aquifer only system (Dmnl)
= 1
Description: *Please set this parameter 1: if you consider the second type (aquifer delivers water directly users, without reservoir(s))Otherwise, please set this parameter 0*
Present in 2 views:
- urban water distribution
- scenarios and graphs

Used by:
- water from reservoir or water storages for city A - please choose 0: the reservoir system please choose 1: the river system
- water from reservoir or water storages for city B

switch the main aquifer and the reservoir connection (Dmnl)
= 1
Description: *write "1", there is percolated water to the main aquiferwrite "0", there is seepaged water to the main reservoir*
Present in 3 views:
- urban water distribution
- the main aquifer
- scenarios and graphs

Used by:
- inifiltration and percolated water to the the main aquifer - an actual seepaged water from surface water to the main aquifer
- seepaged water from the main aquifer to the main reservoir

"table of the main reservoir natural inflow_m3" (m3/Month)
= WITH LOOKUP (Time/unit time of month*unit m3,([(0,0)-(119,5)],(0,0.2885),(1,0.0264),(2,0.377),(3,0.0119),(4,0),(5,0),(6,0),(7,0.1697),(8,0.1055),(9,0.1663),(10,1.0192),(11,0.4905),(12,0.0194),(13,0.3624),(14,0.601),(15,0.5459),(16,0.1133),(17,0.0183),(18,0.0354),(19,0.0354),(20,0.0125),(21,0.0203),(22,0.0076),(23,0.2415),(24,0.2885),(25,0.0264),(26,0.377),(27,0.0119),(28,0),(29,0),(30,0),(31,0.1697),(32,0.1055),(33,0.1663),(34,1.0192),(35,0.4905),(36,0.0194),(37,0.3624),(38,0.601),(39,0.5459),(40,0.1133),(41,0.0183),(42,0.0354),(43,0.0354),(44,0.0125),(45,0.0203),(46,0.0076),(47,0.2415),(48,0.2885),(49,0.0264),(50,0.377),(51,0.0119),(52,0),(53,0),(54,0),(55,0.1697),(56,0.1055),(57,0.1663),(58,1.0192),(59,0.4905),(60,0.0194),(61,0.3624),(62,0.601),(63,0.5459),(64,0.1133),(65,0.0183),(66,0.0354),(67,0.0354),(68,0.0125),(69,0.0203),(70,0.0076),(71,0.2415),

(72,0.2885),(73,0.0264),(74,0.377),(75,0.0119),(76,0),(77,0),(78,0),(79,0.1697),(80,0.1055),(81,0.1663),(82,1.0192),(83,0.4905),(84,0.0194),(85,0.3624),
(86,0.601),(87,0.5459),(88,0.1133),(89,0.0183),(90,0.0354),(91,0.0354),(92,0.0125),(93,0.0203),(94,0.0076),(95,0.2415),(96,0.2885),(97,0.0264),(98,0.377),
(99,0.0119),(100,0),(101,0),(102,0),(103,0.1697),(104,0.1055),(105,0.1663),(106,1.0192),(107,0.4905),(108,0.0194),(109,0.3624),(110,0.601),(111,0.5459)
,(112,0.1133),(113,0.0183),(114,0.0354),(115,0.0354),(116,0.0125),(117,0.0203),(118,0.0076),(119,0.2415)))

Description: *a lookup table for the natural inflow of Guadalest reservoir*

Present in 1 view:

- urban water distribution

Used by:

- the main reservoir inflow

the main aquifer (hm*hm*hm)

= ∫inifiltration and percolated water to the the main aquifer-the main aquifer's extraction-monthly spring and upwelling flow *dt* + [initial aquifer volume]

Description: *a water stock in the main aquifer*

Present in 4 views:

- urban water distribution
- the main aquifer
- urban water consumption
- energy consumption and CO2 emission

Used by:

- gap between total urban water supply and demand
- monthly spring and upwelling flow - an outflow of spring water from the main aquifer
- seepaged water from the main aquifer to the main reservoir
- the main aquifer's extraction - extracted water from the main aquifer
- the previous level of the main aquifer
- water level

the main reservoir (m3)

= ∫seepaged water from the main aquifer to the main reservoir+the main reservoir inflow-environmental outflow-the main reservoir outflow for city A-the main reservoir outflow for city B-discharged water sustainable agriculture *dt* + [initial main reservoir level]

Description: *the Guadalest reservoir's water stock*

Present in 2 views:

- urban water distribution
- urban water consumption

Used by:

- environmental outflow
- gap between total urban water supply and demand
- Required inflow from the main's aquifer for the main reservoir - a required volume to fulfil water consumption in the Metro.
  This should be extracted from the main aquifer
- the main reservoir outflow for city A
- the main reservoir outflow for city B

the main reservoir inflow (m3/Month)

= ("table of the main reservoir natural inflow_m3"+ Required inflow from the main's aquifer for the main reservoir* converter m3 to hm3)

Present in 1 view:

- urban water distribution

Used by:

- the main reservoir - the Guadalest reservoir's water stock

the main reservoir outflow for city A (m3/Month)
= IF THEN ELSE (the main reservoir> dead storage of the main reservoir ,(water input from the main reservoir for city A) ,0)
Present in 1 view:
- urban water distribution

Used by:
- the main reservoir - the Guadalest reservoir's water stock
- water from reservoir or water storages for city A - please choose 0: the reservoir system please choose 1: the river system

the main reservoir outflow for city B (m3/Month)
= IF THEN ELSE (the main reservoir> dead storage of the main reservoir ,water input from the main reservoir for city B,0)
Present in 1 view:
- urban water distribution

Used by:
- the main reservoir - the Guadalest reservoir's water stock
- water from reservoir or water storages for city B

the main reservoir's maximum capacity (m3)
= 1.5e+07
Description: *the maximum capacity of the Guadalest reservoir*
Present in 1 view:
- urban water distribution

Used by:
- Required inflow from the main's aquifer for the main reservoir - a required volume to fulfil water consumption in the Metro.
  This should be extracted from the main aquifer

TIME STEP (Month [0,?])
= 0.0078125
Description: *The time step for the simulation.*
Present in 3 views:
- urban water distribution
- the main aquifer
- agricultural areas

Used by:
- agricultural water use - min(total water demand for agricultural areas,agriculture water storage/TIME STEP) total water demand for agricultural areas
- environmental outflow
- inflow of used urban water - IF THEN ELSE(ratio between agriculture water demand and supply<1, ((min(total water demand for agricultural areas,
  (initial monthly urban water in the Metro/"delay processing time in the wastewater plant(s)")))) , 0)
- inifiltration and percolated water to the the main aquifer - an actual seepaged water from surface water to the main aquifer
- monthly spring and upwelling flow - an outflow of spring water from the main aquifer

total required water supply in city A (m3)
= total water consumption in city A*water loss in city A+total water consumption in city A
Present in 2 views:
- urban water distribution
- urban water consumption

Used by:
- gap between urban water supply and demand city A

- total required water supply under the MetroArea - the total water consumption in the Metro
- water from reservoir or water storages for city A - please choose 0: the reservoir system please choose 1: the river system
- water input from the main reservoir for city A - the number of distributed water from Guadalest reservoir to Altea
- water output for city A's end users - a flow of available water for end users in Altea

total required water supply in city B (m3)
= total water consumption in city B*water loss in city B+total water consumption in city B
Present in 2 views:
- urban water distribution
- urban water consumption

Used by:
- gap between urban water supply and demand city B
- total required water supply under the MetroArea - the total water consumption in the Metro
- water from reservoir or water storages for city B
- water input from the main reservoir for city B - the number of distributed water from Guadalest reservoir to Polop
- water output for city B's end users - a flow of available water for end users in Polop

total required water supply under the MetroArea (m3)
= total required water supply in city A+total required water supply in city B
Description: *the total water consumption in the Metro*
Present in 3 views:
- urban water distribution
- urban water consumption
- agricultural areas

Used by:
- gap between total urban water supply and demand
- inflow of used urban water - IF THEN ELSE(ratio between agriculture water demand and supply<1, ((min(total water demand for agricultural areas ,(initial monthly urban water in the Metro/"delay processing time in the wastewater plant(s)")))) , 0)
- Required inflow from the main's aquifer for the main reservoir - a required volume to fulfil water consumption in the Metro.
  This should be extracted from the main aquifer

total water for city A (m3)
= ∫water from reservoir or water storages for city A-water output for city A's end users *dt* + [initial water for city A]
Description: *a stock of total water for Altea population*
Present in 1 view:
- urban water distribution

Used by:
- water input from the main reservoir for city A - the number of distributed water from Guadalest reservoir to Altea

Total water for city B (m3)
= ∫water from reservoir or water storages for city B-water output for city B's end users *dt* + [initial water for city B]
Description: *a stock of total water for Polop population*
Present in 1 view:
- urban water distribution

Used by:

- water input from the main reservoir for city B - the number of distributed water from Guadalest reservoir to Polop

unit time of month (Month)
= 1
Present in 2 views:
- urban water distribution
- the main aquifer

Used by:
- "table of observed precipitation_mm" - a lookup table of observed precipitation
- "table of the main reservoir natural inflow_m3" - a lookup table for the natural inflow of Guadalest reservoir

"unit_hm" ((hm*hm*hm)/Month)
= 1
Present in 1 view:
- urban water distribution

water from reservoir or water storages for city A (m3/Month)
= the main reservoir outflow for city A*switch aquifer only system+MIN(Required inflow from the main's aquifer for the main reservoir*
converter m3 to hm3,(total required water supply in city A/adjustment time))*switch aquifer only system
Description: *please choose 0: the reservoir system please choose 1: the river system*
Present in 1 view:
- urban water distribution

Used by:
- total water for city A - a stock of total water for Altea population

water from reservoir or water storages for city B (m3/Month)
= the main reservoir outflow for city B*switch aquifer only system+MIN(Required inflow from the main's aquifer for the main reservoir*
converter m3 to hm3,(total required water supply in city B/adjustment time))*switch aquifer only system
Present in 1 view:
- urban water distribution

Used by:
- Total water for city B - a stock of total water for Polop population

water input from the main reservoir for city A (m3/Month)
= MAX ((total required water supply in city A- total water for city A)/ adjustment time ,0)
Description: *the number of distributed water from Guadalest reservoir to Altea*
Present in 1 view:
- urban water distribution

Used by:
- the main reservoir outflow for city A

water input from the main reservoir for city B (m3/Month)
= MAX ((total required water supply in city B- Total water for city B)/ adjustment time ,0)
Description: *the number of distributed water from Guadalest reservoir to Polop*
Present in 1 view:
- urban water distribution

Used by:
- the main reservoir outflow for city B

water output for city A's end users (m3/Month)
= total required water supply in city A/adjustment time
Description: *a flow of available water for end users in Altea*
Present in 3 views:
- urban water distribution

- urban water consumption
- energy consumption and CO2 emission

Used by:

- gap between total urban water supply and demand
- gap between urban water supply and demand city A
- total water for city A - a stock of total water for Altea population

water output for city B's end users (m3/Month)
= total required water supply in city B/adjustment time
Description: *a flow of available water for end users in Polop*
Present in 2 views:

- urban water distribution
- urban water consumption

Used by:

- gap between total urban water supply and demand
- gap between urban water supply and demand city B
- Total water for city B - a stock of total water for Polop population

Main aquifer (21 variables)

Variable Name and Description

added potential potable water owing to sustainable agriculture from the main aquifer (m3/Month)
= IF THEN ELSE(gap between total urban water supply and demand>=1, (MAX(0,(total water demand for agricultural areas-agricultural water use))* switch for agriculture water from aquifer), 0)
Description: *this is added potable water owing to sustainable agriculture policy*
Present in 2 views:

- the main aquifer
- agricultural areas

Used by:

- the main aquifer's extraction - extracted water from the main aquifer
- "water from other source(s) for agriculture"

"conversion mm_hm" (mm/hm)
= 100000
Present in 1 view:

- the main aquifer

Used by:

- observed precipitation - observed precipitation in surrounding areas of the main aquifer

converter m3 to hm3 (m3/(hm*hm*hm))
= 1e+06
Present in 4 views:

- urban water distribution
- the main aquifer
- urban water consumption
- energy consumption and CO2 emission

Used by:

- enegy consumption of water transportation from the main aquifer to the Guadalest reservoir
- energy intensity of hot water in residential areas
- energy intensity of hot water in touristic areas
- energy intensity of water pumping
- "energy_intensity of groundwater extraction"
- gap between total urban water supply and demand
- Required inflow from the main's aquifer for the main reservoir - a required volume to fulfil water consumption in the Metro.

- This should be extracted from the main aquifer
- seepaged water from the main aquifer to the main reservoir
- the main aquifer's extraction - extracted water from the main aquifer
- the main reservoir inflow
- water from reservoir or water storages for city A - please choose 0: the reservoir system please choose 1: the river system
- water from reservoir or water storages for city B

"infiltration-percolated coefficient" (Dmnl)
= 0.25
Present in 1 view:
- the main aquifer

Used by:
- inifiltration and percolated water to the the main aquifer - an actual seepaged water from surface water to the main aquifer

inifiltration and percolated water to the the main aquifer (hm*hm*hm/Month)
= DELAY FIXED (observed precipitation* "infiltration-percolated coefficient"* the main aquifer's permeable surface areas ,TIME STEP ,
"infiltration-percolated coefficient"* observed precipitation* the main aquifer's permeable surface areas*switch the main aquifer and the reservoir connection)
Description: *an actual seepaged water from surface water to the main aquifer*
Present in 1 view:
- the main aquifer

Used by:
- the main aquifer - a water stock in the main aquifer

initial aquifer volume (hm*hm*hm)
= 600
Description: *an initial volume of the main aquifer*
Present in 1 view:
- the main aquifer

Used by:
- the main aquifer - a water stock in the main aquifer

monthly spring and upwelling flow (hm*hm*hm/Month)
= MAX(0,(the main aquifer-threshold of spring water)/TIME STEP)
Description: *an outflow of spring water from the main aquifer*
Present in 1 view:
- the main aquifer

Used by:
- the main aquifer - a water stock in the main aquifer

observed precipitation (hm/Month)
= ("table of observed precipitation_mm")/ "conversion mm_hm"
Description: *observed precipitation in surrounding areas of the main aquifer*
Present in 1 view:
- the main aquifer

Used by:
- inifiltration and percolated water to the the main aquifer - an actual seepaged water from surface water to the main aquifer

Required inflow from the main's aquifer for the main reservoir ((hm*hm*hm)/Month)
= (MIN((the main reservoir's maximum capacity-the main reservoir),total required water supply under the MetroArea))/adjustment time*
switch aquifer and reservoir system*(1/converter m3 to hm3)
Description: *a required volume to fulfil water consumption in the Metro. This should be extracted from the main aquifer*
Present in 2 views:

- urban water distribution
- the main aquifer

Used by:

- enegy consumption of water transportation from the main aquifer to the Guadalest reservoir
- the main aquifer's extraction - extracted water from the main aquifer
- the main reservoir inflow
- water from reservoir or water storages for city A - please choose 0: the reservoir system please choose 1: the river system
- water from reservoir or water storages for city B

switch the main aquifer and the reservoir connection (Dmnl)
= 1
Description: *write "1", there is percolated water to the main aquiferwrite "0", there is seepaged water to the main reservoir*
Present in 3 views:

- urban water distribution
- the main aquifer
- scenarios and graphs

Used by:

- inifiltration and percolated water to the the main aquifer - an actual seepaged water from surface water to the main aquifer
- seepaged water from the main aquifer to the main reservoir

"table of observed precipitation_mm" (mm/Month)
= WITH LOOKUP (Time/unit time of month*"unit_mm",([(0,0)-(119,1200)],(0,124.5),(1,10.3),(2,85.5),(3,41.6),(4,1.2),(5,1.4),(6,0),(7,11.9),(8,36.5),(9,49.5462),(10,188.3),(11,6.6),(12,8),(13,91.3),(14,136.9),(15,41.7),(16,2.1),(17,1.5),(18,63.8),(19,63.8),(20,2.2),(21,13.8),(22,46.2),(23,167.4),(24,124.5),(25,10.3),(26,85.5),(27,41.6),(28,1.2),(29,1.4),(30,0),(31,11.9),(32,36.5),(33,49.5462),(34,188.3),(35,6.6),(36,8),(37,91.3),(38,136.9),(39,41.7),(40,2.1),(41,1.5),(42,63.8),(43,63.8),(44,2.2),(45,13.8),(46,46.2),(47,167.4),(48,124.5),(49,10.3),(50,85.5),(51,41.6),(52,1.2),(53,1.4),(54,0),(55,11.9),(56,36.5),(57,49.5462),(58,188.3),(59,6.6),(60,8),(61,91.3),(62,136.9),(63,41.7),(64,2.1),(65,1.5),(66,63.8),(67,63.8),(68,2.2),(69,13.8),(70,46.2),(71,167.4),(72,124.5),(73,10.3),(74,85.5),(75,41.6),(76,1.2),(77,1.4),(78,0),(79,11.9),(80,36.5),(81,49.5462),(82,188.3),(83,6.6),(84,8),(85,91.3),(86,136.9),(87,41.7),(88,2.1),(89,1.5),(90,63.8),(91,63.8),(92,2.2),(93,13.8),(94,46.2),(95,167.4),(96,124.5),(97,10.3),(98,85.5),(99,41.6),(100,1.2),(101,1.4),(102,0),(103,11.9),(104,36.5),(105,49.5462),(106,188.3),(107,6.6),(108,8),(109,91.3),(110,136.9),(111,41.7),(112,2.1),(113,1.5),(114,63.8),(115,63.8),(116,2.2),(117,13.8),(118,46.2),(119,167.4)))
Description: *a lookup table of observed precipitation*
Present in 1 view:

- the main aquifer

Used by:

- observed precipitation - observed precipitation in surrounding areas of the main aquifer

the main aquifer (hm*hm*hm)
= ∫inifiltration and percolated water to the the main aquifer-the main aquifer's extraction-monthly spring and upwelling flow *dt* +
[initial aquifer volume]
Description: *a water stock in the main aquifer*
Present in 4 views:

• urban water distribution • the main aquifer • urban water consumption • energy consumption and CO2 emission **Used by:** • gap between total urban water supply and demand • monthly spring and upwelling flow - an outflow of spring water from the main aquifer • seepaged water from the main aquifer to the main reservoir • the main aquifer's extraction - extracted water from the main aquifer • the previous level of the main aquifer • water level
the main aquifer's extraction ((hm*hm*hm)/Month) = IF THEN ELSE (the main aquifer >= 550,(Required inflow from the main's aquifer for the main reservoir+ (added potential potable water owing to sustainable agriculture from the main aquifer/converter m3 to hm3)),0) **Description:** *extracted water from the main aquifer* **Present in 1 view:** • the main aquifer **Used by:** • the main aquifer - a water stock in the main aquifer
the main aquifer's permeable surface areas (hm*hm) = 2956 **Description:** *This is permeable surface areas around the main aquifer* **Present in 1 view:** • the main aquifer **Used by:** • inifiltration and percolated water to the the main aquifer - an actual seepaged water from surface water to the main aquifer
TIME STEP (Month [0,?]) = 0.0078125 **Description:** *The time step for the simulation.* **Present in 3 views:** • urban water distribution • the main aquifer • agricultural areas **Used by:** • agricultural water use - min(total water demand for agricultural areas,agriculture water storage/TIME STEP) total water demand for agricultural areas • environmental outflow • inflow of used urban water - IF THEN ELSE(ratio between agriculture water demand and supply<1, ((min(total water demand for agricultural areas,(initial monthly urban water in the Metro/ "delay processing time in the wastewater plant(s)")))) , 0) • inifiltration and percolated water to the the main aquifer - an actual seepaged water from surface water to the main aquifer • monthly spring and upwelling flow - an outflow of spring water from the main aquifer
unit time of month (Month) = 1 **Present in 2 views:** • urban water distribution • the main aquifer

Used by:
- "table of observed precipitation_mm" - a lookup table of observed precipitation
- "table of the main reservoir natural inflow_m3" - a lookup table for the natural inflow of Guadalest reservoir

"unit_mm" (mm/Month)
= 1
Present in 1 view:
- the main aquifer

Used by:
- "table of observed precipitation_mm" - a lookup table of observed precipitation

Urban water consumption (72 variables)

Variable Name and Description

adjustment time (Month)
= 1
Description: *a needed time to distribute water to a destination*
Present in 4 views:
- urban water distribution
- urban water consumption
- agricultural areas
- energy consumption and CO2 emission

Used by:
- gap between total urban water supply and demand
- gap between urban water supply and demand city A
- gap between urban water supply and demand city B
- Required inflow from the main's aquifer for the main reservoir - a required volume to fulfil water consumption in the Metro.
  This should be extracted from the main aquifer
- seepaged water from the main aquifer to the main reservoir
- water from reservoir or water storages for city A - please choose 0: the reservoir system please choose 1: the river system
- water from reservoir or water storages for city B
- water input from the main reservoir for city A - the number of distributed water from Guadalest reservoir to Altea
- water input from the main reservoir for city B - the number of distributed water from Guadalest reservoir to Polop
- water output for city A's end users - a flow of available water for end users in Altea
- water output for city B's end users - a flow of available water for end users in Polop

"conversion liters to m^3" (m3/liter)
= 0.001
Description: *conversion from liter to m3*
Present in 1 view:
- urban water consumption

Used by:
- total water consumption in camping sites in city A
- total water consumption in camping sites in city B
- "total water consumption in hotels (city A)"
- "total water consumption in hotels (city B)"
- total water consumption in the MetroArea hotels
- total water consumption in the MetroArea's camping sites
- total water consumption of resident population in city A - total water consumption in city A
- total water consumption of resident population in city B - total water consumption in city B

converter m3 to hm3 (m3/(hm*hm*hm))
= 1e+06
Present in 4 views:
- urban water distribution
- the main aquifer
- urban water consumption
- energy consumption and CO2 emission

Used by:
- enegy consumption of water transportation from the main aquifer to the Guadalest reservoir
- energy intensity of hot water in residential areas
- energy intensity of hot water in touristic areas
- energy intensity of water pumping
- "energy\ intensity of groundwater extraction"
- gap between total urban water supply and demand
- Required inflow from the main's aquifer for the main reservoir - a required volume to fulfil water consumption in the Metro.
  This should be extracted from the main aquifer
- seepaged water from the main aquifer to the main reservoir
- the main aquifer's extraction - extracted water from the main aquifer
- the main reservoir inflow
- water from reservoir or water storages for city A - please choose 0: the reservoir system please choose 1: the river system
- water from reservoir or water storages for city B

days in a month (day)
= 30.4
Description: *average number of days in a month*
Present in 1 view:
- urban water consumption

Used by:
- total water consumption of resident population in city A - total water consumption in city A
- total water consumption of resident population in city B - total water consumption in city B

gap between total urban water supply and demand (Dmnl)
= ((((the main aquifer*converter m3 to hm3)+the main reservoir)/adjustment time)+((water output for city A's end users+
water output for city B's end users)))/(total required water supply under the MetroArea/adjustment time)
Present in 2 views:
- urban water consumption
- agricultural areas

Used by:
- added potential potable water owing to sustainable agriculture from reservoir or river – this is added potable water owing to sustainable agriculture policy
- added potential potable water owing to sustainable agriculture from the main aquifer – this is added potable water owing to sustainable agriculture policy

gap between urban water supply and demand city A (m3/Month)
= (water output for city A's end users-total required water supply in city A/adjustment time)
Present in 1 view:
- urban water consumption

gap between urban water supply and demand city B (m3/Month)
= (water output for city B's end users-total required water supply in city B/adjustment time)
Present in 1 view:
- urban water consumption

"overnight stays in camping sites (city A)" (people*day)
= total camping sites capacity in city A* (the number of day in a month)*the monthly seasonality ratio
Present in 1 view:
- urban water consumption

Used by:
- total overnight stays in the MetroArea camping sites
- total water consumption in camping sites in city A

"overnight stays in camping sites (city B)" (people*day)
= total camping sites capacity in city B* (the number of day in a month)*the monthly seasonality ratio
Present in 1 view:
- urban water consumption

Used by:
- total overnight stays in the MetroArea camping sites
- total water consumption in camping sites in city B

"overnight stays in hotels (city A)" (people*day)
= the monthly seasonality ratio* total hotel capacity in city A* (the number of day in a month)
Present in 1 view:
- urban water consumption

Used by:
- total overnight stays in the MetroArea hotels
- "total water consumption in hotels (city A)"

"overnight stays in hotels (city B)" (people*day)
= the monthly seasonality ratio* total hotel capacity in city B* (the number of day in a month)
Present in 1 view:
- urban water consumption

Used by:
- total overnight stays in the MetroArea hotels
- "total water consumption in hotels (city B)"

"resident population in high-density areas of city A" (people)
= average resident population in high density areas*"high-density areas in city A"
Description: *updated resident population in low-density areas*
Present in 2 views:
- urban water consumption
- low-high density urban areas

Used by:
- resident population in city A
- total water consumption of resident population in city A - total water consumption in city A

"resident population in high-density areas of city B" (people)
= average resident population in high density areas*"high-density areas in city B"
Description: *updated resident population in low-density areas*
Present in 2 views:
- urban water consumption
- low-high density urban areas

Used by:
- resident population in city B
- total water consumption of resident population in city B - total water consumption in city B

"resident population in low-density areas of city A" (people)
= average resident population in low density areas* "initial size of low-density areas in city A"
Present in 2 views:
- urban water consumption
- low-high density urban areas

Used by:

- resident population in city A
- total water consumption of resident population in city A - total water consumption in city A

"resident population in low-density areas of city B" (people)
= average resident population in low density areas *"low-density areas in city B"
Present in 2 views:

- urban water consumption
- low-high density urban areas

Used by:

- resident population in city B
- total water consumption of resident population in city B - total water consumption in city B

the main aquifer (hm*hm*hm)
= ∫inifiltration and percolated water to the the main aquifer-the main aquifer's extraction-monthly spring and upwelling flow *dt* +
[initial aquifer volume]
Description: *a water stock in the main aquifer*
Present in 4 views:

- urban water distribution
- the main aquifer
- urban water consumption
- energy consumption and CO2 emission

Used by:

- gap between total urban water supply and demand
- monthly spring and upwelling flow - an outflow of spring water from the main aquifer
- seepaged water from the main aquifer to the main reservoir
- the main aquifer's extraction - extracted water from the main aquifer
- the previous level of the main aquifer
- water level

the main reservoir (m3)
= ∫seepaged water from the main aquifer to the main reservoir+the main reservoir inflow-environmental outflow-
the main reservoir outflow for city A-the main reservoir outflow for city B-discharged water sustainable agriculture *dt* + [initial main reservoir level]
Description: *the Guadalest reservoir's water stock*
Present in 2 views:

- urban water distribution
- urban water consumption

Used by:

- environmental outflow
- gap between total urban water supply and demand
- Required inflow from the main's aquifer for the main reservoir - a required volume to fulfil water consumption in the Metro.
- This should be extracted from the main aquifer
- the main reservoir outflow for city A
- the main reservoir outflow for city B

the monthly seasonality ratio (Dmnl)
= WITH LOOKUP ("monthly_names"/time unit,([(0,0.4)-
(11,1)],(0,0.5242),(1,0.5),(2,0.57282),(3,0.75935),(4,0.81325),
(5,0.83656),(6,0.8502),(7,1),(8,0.73309),(9,0.69663),(10,0.52856),(11,0.5087)))
Description: *This is a trend of tourism*
Present in 1 view:

- urban water consumption

Used by:

- "overnight stays in camping sites (city A)"
- "overnight stays in camping sites (city B)"
- "overnight stays in hotels (city A)"
- "overnight stays in hotels (city B)"
- total water consumption of resident population in city A - total water consumption in city A
- total water consumption of resident population in city B - total water consumption in city B

the number of day in a month (day)
= WITH LOOKUP ("monthly_names"/time unit,([(0,20)-(11,40)],(0,31),(1,28),(2,31),(3,30),(4,31),(5,30),(6,31),(7,31),(8,30),(9,31),(10,30),(11,31)))
Description: *the number of day in every month*
Present in 1 view:
- urban water consumption

Used by:
- "overnight stays in camping sites (city A)"
- "overnight stays in camping sites (city B)"
- "overnight stays in hotels (city A)"
- "overnight stays in hotels (city B)"

total camping sites capacity in city A (people)
= 1047
Description: *total available beds in camping sites in city B*
Present in 1 view:
- urban water consumption

Used by:
- "overnight stays in camping sites (city A)"

total camping sites capacity in city B (people)
= 1047
Description: *total available beds in camping sites in city B*
Present in 1 view:
- urban water consumption

Used by:
- "overnight stays in camping sites (city B)"

total hotel capacity in city A (people)
= 1273
Description: *total available beds in hotels in city A*
Present in 1 view:
- urban water consumption

Used by:
- "overnight stays in hotels (city A)"

total hotel capacity in city B (people)
= 1273
Description: *total available beds in hotels in city A*
Present in 1 view:
- urban water consumption

Used by:
- "overnight stays in hotels (city B)"

total overnight stays in the MetroArea camping sites (people*day)
= "overnight stays in camping sites (city A)"+"overnight stays in camping sites (city B)"
Present in 1 view:
- urban water consumption

Used by:

• total water consumption in the MetroArea's camping sites
total overnight stays in the MetroArea hotels (people*day) = "overnight stays in hotels (city A)"+"overnight stays in hotels (city B)" **Present in 1 view:** • urban water consumption **Used by:** • total water consumption in the MetroArea hotels
total required water supply in city A (m3) = total water consumption in city A*water loss in city A+total water consumption in city A **Present in 2 views:** • urban water distribution • urban water consumption **Used by:** • gap between urban water supply and demand city A • total required water supply under the MetroArea - the total water consumption in the Metro • water from reservoir or water storages for city A - please choose 0: the reservoir system please choose 1: the river system • water input from the main reservoir for city A - the number of distributed water from Guadalest reservoir to Altea • water output for city A's end users - a flow of available water for end users in Altea
total required water supply in city B (m3) = total water consumption in city B*water loss in city B+total water consumption in city B **Present in 2 views:** • urban water distribution • urban water consumption **Used by:** • gap between urban water supply and demand city B • total required water supply under the MetroArea - the total water consumption in the Metro • water from reservoir or water storages for city B • water input from the main reservoir for city B - the number of distributed water from Guadalest reservoir to Polop • water output for city B's end users - a flow of available water for end users in Polop
total required water supply under the MetroArea (m3) = total required water supply in city A+total required water supply in city B **Description:** *the total water consumption in the Metro* **Present in 3 views:** • urban water distribution • urban water consumption • agricultural areas **Used by:** • gap between total urban water supply and demand • inflow of used urban water - IF THEN ELSE(ratio between agriculture water demand and supply<1, ((min(total water demand for agricultural areas,(initial monthly urban water in the Metro/ "delay processing time in the wastewater plant(s)")))) , 0) • Required inflow from the main's aquifer for the main reservoir - a required volume to fulfil water consumption in the Metro. • This should be extracted from the main aquifer
total water consumption by resident population in MetroArea (m3) = total water consumption of resident population in city A+ total water consumption of resident population in city B

Description: *total water consumption by resident population in the Metro* **Present in 2 views:** • urban water consumption • energy consumption and CO2 emission **Used by:** • monthly energy consumption for hot water in residential and tourism accommodation
total water consumption in camping sites in city A (m3) = "conversion liters to m^3"* "overnight stays in camping sites (city A)"* water consumption per person in camping sites **Present in 1 view:** • urban water consumption **Used by:** • total water consumption in city A - total water consumption in city A (permanent and resident population)
total water consumption in camping sites in city B (m3) = "conversion liters to m^3"* "overnight stays in camping sites (city B)"* water consumption per person in camping sites **Present in 1 view:** • urban water consumption **Used by:** • total water consumption in city B - total water consumption in city B (permanent and resident population)
total water consumption in city A (m3) = "total water consumption in hotels (city A)"+ total water consumption of resident population in city A+ total water consumption in camping sites in city A **Description:** *total water consumption in city A (permanent and resident population)* **Present in 1 view:** • urban water consumption **Used by:** • total required water supply in city A • total water consumption under the MetroArea - the total water consumption in the Metro
total water consumption in city B (m3) = total water consumption of resident population in city B+total water consumption in camping sites in city B+ "total water consumption in hotels (city B)" **Description:** *total water consumption in city B (permanent and resident population)* **Present in 1 view:** • urban water consumption **Used by:** • total required water supply in city B • total water consumption under the MetroArea - the total water consumption in the Metro
"total water consumption in hotels (city A)" (m3) = "conversion liters to m^3"* "overnight stays in hotels (city A)"* water consumption per person in hotels **Present in 1 view:** • urban water consumption **Used by:** • total water consumption in city A - total water consumption in city A (permanent and resident population)
"total water consumption in hotels (city B)" (m3) = "conversion liters to m^3"* "overnight stays in hotels (city B)"* water consumption per person in

hotels
Present in 1 view:
- urban water consumption

Used by:
- total water consumption in city B - total water consumption in city B (permanent and resident population)

total water consumption in the MetroArea hotels (m3)
= total overnight stays in the MetroArea hotels* water consumption per person in hotels* "conversion liters to m^3"
Present in 1 view:
- urban water consumption

total water consumption in the MetroArea's camping sites (m3)
= total overnight stays in the MetroArea camping sites* water consumption per person in camping sites* "conversion liters to m^3"
Present in 1 view:
- urban water consumption

total water consumption of resident population in city A (m3)
= ("water consumption per person per day (high-density areas)"*"resident population in high-density areas of city A"+
"water consumption per person per day (low-density areas)"*"resident population in low-density areas of city A")*days in a month*
"conversion liters to m^3"*the monthly seasonality ratio
Description: *total water consumption in city A*
Present in 1 view:
- urban water consumption

Used by:
- total water consumption by resident population in MetroArea - total water consumption by resident population in the Metro
- total water consumption in city A - total water consumption in city A (permanent and resident population)

total water consumption of resident population in city B (m3)
= ("resident population in high-density areas of city B"*"water consumption per person per day (high-density areas)"+
"resident population in low-density areas of city B"*"water consumption per person per day (low-density areas)")*
"conversion liters to m^3"*days in a month*the monthly seasonality ratio
Description: *total water consumption in city B*
Present in 1 view:
- urban water consumption

Used by:
- total water consumption by resident population in MetroArea - total water consumption by resident population in the Metro
- total water consumption in city B - total water consumption in city B (permanent and resident population)

total water consumption under the MetroArea (m3)
= total water consumption in city A+ total water consumption in city B
Description: *the total water consumption in the Metro*
Present in 2 views:
- urban water consumption
- energy consumption and CO2 emission

Used by:
- monthly energy consumption for hot water in residential and tourism accommodation
- monthly energy consumption for repump water in tall buildings

• monthly energy consumption for transport and extract surface and ground water in MetroArea – total energy consumption of transported water from the main aquifer to the Guadalest reservoir • monthly energy consumption for water distribution around urban areas in MetroArea – total energy consumption for water distribution to urban areas • "monthly energy consumption for water treatment (purified water) in MetroArea" – • total energy consumption for given water purification • total reused water in MetroArea
water consumption per person in camping sites (liter/(day*people)) = 85 **Present in 1 view:** • urban water consumption **Used by:** • total water consumption in camping sites in city A • total water consumption in camping sites in city B • total water consumption in the MetroArea's camping sites
water consumption per person in hotels (liter/(day*people)) = 307 **Present in 1 view:** • urban water consumption **Used by:** • "total water consumption in hotels (city A)" • "total water consumption in hotels (city B)" • total water consumption in the MetroArea hotels
"water consumption per person per day (high-density areas)" (liter/(day*people)) = 195 **Description:** *an average water consumption per resident population of high-density areas* **Present in 1 view:** • urban water consumption **Used by:** • total water consumption of resident population in city A - total water consumption in city A • total water consumption of resident population in city B - total water consumption in city B
"water consumption per person per day (low-density areas)" (liter/(day*people)) = 357 **Description:** *an average water consumption per resident population of low-density areas* **Present in 1 view:** • urban water consumption **Used by:** • total water consumption of resident population in city A - total water consumption in city A • total water consumption of resident population in city B - total water consumption in city B
water loss in city A (Dmnl) = 0.1 **Present in 1 view:** • urban water consumption **Used by:** • total required water supply in city A
water loss in city B (Dmnl) = 0.15 **Present in 1 view:** • urban water consumption **Used by:** • total required water supply in city B

water output for city A's end users (m3/Month)
= total required water supply in city A/adjustment time
Description: *a flow of available water for end users in Altea*
Present in 3 views:

- urban water distribution
- urban water consumption
- energy consumption and CO2 emission

Used by:

- gap between total urban water supply and demand
- gap between urban water supply and demand city A
- total water for city A - a stock of total water for Altea population

water output for city B's end users (m3/Month)
= total required water supply in city B/adjustment time
Description: *a flow of available water for end users in Polop*
Present in 2 views:

- urban water distribution
- urban water consumption

Used by:

- gap between total urban water supply and demand
- gap between urban water supply and demand city B
- Total water for city B - a stock of total water for Polop population

Agricultural areas (31 variables)

Variable Name and Description

added potential potable water owing to sustainable agriculture from reservoir or river (m3/Month)
= IF THEN ELSE(gap between total urban water supply and demand>=1, (MAX(0,(total water demand for agricultural areas-
agricultural water use))*"switch for agriculture water from river (or reservoir)"), 0)
Description: *this is added potable water owing to sustainable agriculture policy*
Present in 2 views:

- urban water distribution
- agricultural areas

Used by:

- discharged water sustainable agriculture
- "water from other source(s) for agriculture"

added potential potable water owing to sustainable agriculture from the main aquifer (m3/Month)
= IF THEN ELSE(gap between total urban water supply and demand>=1, (MAX(0,(total water demand for agricultural areas-
agricultural water use))*switch for agriculture water from aquifer), 0)
Description: *this is added potable water owing to sustainable agriculture policy*
Present in 2 views:

- the main aquifer
- agricultural areas

Used by:

- the main aquifer's extraction - extracted water from the main aquifer
- "water from other source(s) for agriculture"

adjustment time (Month)
= 1
Description: *a needed time to distribute water to a destination*
Present in 4 views:

- urban water distribution
- urban water consumption

- agricultural areas
- energy consumption and CO2 emission

Used by:

- gap between total urban water supply and demand
- gap between urban water supply and demand city A
- gap between urban water supply and demand city B
- Required inflow from the main's aquifer for the main reservoir - a required volume to fulfil water consumption in the Metro.
  This should be extracted from the main aquifer
- seepaged water from the main aquifer to the main reservoir
- water from reservoir or water storages for city A - please choose 0: the reservoir system please choose 1: the river system
- water from reservoir or water storages for city B
- water input from the main reservoir for city A - the number of distributed water from Guadalest reservoir to Altea
- water input from the main reservoir for city B - the number of distributed water from Guadalest reservoir to Polop
- water output for city A's end users - a flow of available water for end users in Altea
- water output for city B's end users - a flow of available water for end users in Polop

agricultural water storage in MetroArea (m3 [0,0])
= ∫"water from other source(s) for agriculture"+reused water for agriculture+agricultural water use-agricultural water use *dt* +
[initial agricultural water storage]
Present in 1 view:

- agricultural areas

Used by:

- agricultural water use - min(total water demand for agricultural areas,agriculture water storage/TIME STEP)
  total water demand for agricultural areas
- inflow of used urban water - IF THEN ELSE(ratio between agriculture water demand and supply<1,
  ((min(total water demand for agricultural areas,(initial monthly urban water in the Metro/ "delay processing time in the wastewater plant(s)")))) , 0)

agricultural water use (m3/Month)
= IF THEN ELSE (((agricultural water storage in MetroArea/ TIME STEP)>= total water demand for agricultural areas) ,
total water demand for agricultural areas ,(agricultural water storage in MetroArea/ TIME STEP)
)
Description: *min(total water demand for agricultural areas,agriculture water storage/TIME STEP) total water demand for agricultural areas*
Present in 1 view:

- agricultural areas

Used by:

- added potential potable water owing to sustainable agriculture from reservoir or river – this is added potable water owing to sustainable agriculture policy
- added potential potable water owing to sustainable agriculture from the main aquifer –
- this is added potable water owing to sustainable agriculture policy
- agricultural water storage in MetroArea

"delay processing time in the wastewater plant(s)" (Month)
= 1
Present in 1 view:

- agricultural areas

Used by:

- inflow of used urban water - IF THEN ELSE(ratio between agriculture water demand and supply<1,
((min(total water demand for agricultural areas,(initial monthly urban water in the Metro/
"delay processing time in the wastewater plant(s)")))) , 0)

"delay time of land-use change" (Month)
= 36
Present in 1 view:
- agricultural areas

Used by:
- "land-use change (from agricultural to urban areas)"

delay time of new agricultural areas (Month)
= 12
Present in 1 view:
- agricultural areas

Used by:
- new agricultural areas

delay time to distributed reused water to farming areas (Month)
= 1
Present in 1 view:
- agricultural areas

Used by:
- reused water for agriculture

"fraction of land-use change (from agricultural to urban areas)" (1/Month)
= 0.0125
Description: *0.0075*
Present in 1 view:
- agricultural areas

Used by:
- "land-use change (from agricultural to urban areas)"

fraction of new agricultural areas (1/Month)
= 0.01
Present in 1 view:
- agricultural areas

Used by:
- new agricultural areas

gap between total urban water supply and demand (Dmnl)
= ((((the main aquifer*converter m3 to hm3)+the main reservoir)/adjustment time)+((water output for city A's end users+
water output for city B's end users)))/(total required water supply under the MetroArea/adjustment time)
Present in 2 views:
- urban water consumption
- agricultural areas

Used by:
- added potential potable water owing to sustainable agriculture from reservoir or river – this is added potable water owing to sustainable agriculture policy
- added potential potable water owing to sustainable agriculture from the main aquifer – this is added potable water owing to sustainable agriculture policy

inflow of used urban water (m3/Month)
= switch for agriculture water from reused water*(IF THEN ELSE((agricultural water storage in MetroArea/TIME STEP)<=0,
((MIN(total water demand for agricultural areas,(total required water supply under the MetroArea/

"delay processing time in the wastewater plant(s)")))) , 0)) **Description:** *IF THEN ELSE(ratio between agriculture water demand and supply<1, ((min(total water demand for agricultural areas,(initial monthly urban water in the Metro/"delay processing time in the wastewater plant(s)")))) , 0)* **Present in 1 view:** • agricultural areas **Used by:** • "wastewater treatment plant(s) in MetroArea"
initial agricultural areas in the MetroArea (hm2) = 1500 **Present in 1 view:** • agricultural areas **Used by:** • the total agricultural areas in the MetroArea
initial agricultural water storage (m3) = 1e+06 **Present in 1 view:** • agricultural areas **Used by:** • agricultural water storage in MetroArea
initial wastewater plant capacity in the MetroArea (m3) = 100 **Present in 1 view:** • agricultural areas **Used by:** • "wastewater treatment plant(s) in MetroArea"
"land-use change (from agricultural to urban areas)" (hm2/Month) = DELAY3 ("fraction of land-use change (from agricultural to urban areas)"* the total agricultural areas in the MetroArea , "delay time of land-use change") **Present in 1 view:** • agricultural areas **Used by:** • the total agricultural areas in the MetroArea
new agricultural areas (hm2/Month) = DELAY3 (fraction of new agricultural areas* the total agricultural areas in the MetroArea ,delay time of new agricultural areas) **Present in 1 view:** • agricultural areas **Used by:** • the total agricultural areas in the MetroArea
reused water for agriculture (m3/Month) = "wastewater treatment plant(s) in MetroArea"/ delay time to distributed reused water to farming areas **Present in 1 view:** • agricultural areas **Used by:** • agricultural water storage in MetroArea • "wastewater treatment plant(s) in MetroArea"
switch for agriculture water from aquifer (Dmnl) = 1 **Description:** *please choose 1: water for agriculture comes from aquiferplease choose 0: water*

for agriculture comes other sources
Present in 2 views:
- agricultural areas
- scenarios and graphs

Used by:
- added potential potable water owing to sustainable agriculture from the main aquifer – this is added potable water owing to sustainable agriculture policy

switch for agriculture water from reused water (Dmnl)
= 1
Description: *please choose 1: water for agriculture comes from reused waterplease choose 0: water for agriculture comes other sources*
Present in 2 views:
- agricultural areas
- scenarios and graphs

Used by:
- inflow of used urban water - IF THEN ELSE(ratio between agriculture water demand and supply<1,
  ((min(total water demand for agricultural areas,(initial monthly urban water in the Metro/ "delay processing time in the wastewater plant(s)")))) , 0)

"switch for agriculture water from river (or reservoir)" (Dmnl)
= 1
Description: *please choose 1: water for agriculture comes from river/reservoirplease choose 0: water for agriculture comes other sources*
Present in 2 views:
- agricultural areas
- scenarios and graphs

Used by:
- added potential potable water owing to sustainable agriculture from reservoir or river – this is added potable water owing to sustainable agriculture policy

the total agricultural areas in the MetroArea (hm2)
= ∫new agricultural areas-"land-use change (from agricultural to urban areas)" *dt* + [initial agricultural areas in the MetroArea]
Present in 1 view:
- agricultural areas

Used by:
- "land-use change (from agricultural to urban areas)"
- new agricultural areas
- total water demand for agricultural areas

TIME STEP (Month [0,?])
= 0.0078125
Description: *The time step for the simulation.*
Present in 3 views:
- urban water distribution
- the main aquifer
- agricultural areas

Used by:
- agricultural water use - min(total water demand for agricultural areas,agriculture water storage/TIME STEP)
  total water demand for agricultural areas
- environmental outflow
- inflow of used urban water - IF THEN ELSE(ratio between agriculture water demand and supply<1,
  ((min(total water demand for agricultural areas,(initial monthly urban water in the Metro/

"delay processing time in the wastewater plant(s)")))) , 0) • inifiltration and percolated water to the the main aquifer - an actual seepaged water from surface water to the main aquifer • monthly spring and upwelling flow - an outflow of spring water from the main aquifer
total required water supply under the MetroArea (m3) = total required water supply in city A+total required water supply in city B **Description:** *the total water consumption in the Metro* **Present in 3 views:** • urban water distribution • urban water consumption • agricultural areas **Used by:** • gap between total urban water supply and demand • inflow of used urban water - IF THEN ELSE(ratio between agriculture water demand and supply<1, ((min(total water demand for agricultural areas,(initial monthly urban water in the Metro/ "delay processing time in the wastewater plant(s)")))) , 0) • Required inflow from the main's aquifer for the main reservoir - a required volume to fulfil water consumption in the Metro. This should be extracted from the main aquifer
total water demand for agricultural areas (m3/Month) = the total agricultural areas in the MetroArea*"water demand per ha (agricultural areas)" **Present in 1 view:** • agricultural areas **Used by:** • added potential potable water owing to sustainable agriculture from reservoir or river – this is added potable water owing to sustainable agriculture policy • added potential potable water owing to sustainable agriculture from the main aquifer – this is added potable water owing to sustainable agriculture policy • agricultural water use - min(total water demand for agricultural areas,agriculture water storage/TIME STEP) total water demand for agricultural areas • inflow of used urban water - IF THEN ELSE(ratio between agriculture water demand and supply<1, ((min(total water demand for agricultural areas,(initial monthly urban water in the Metro/ "delay processing time in the wastewater plant(s)")))) , 0)
"wastewater treatment plant(s) in MetroArea" (m3) = ∫inflow of used urban water-reused water for agriculture *dt* + [initial wastewater plant capacity in the MetroArea] **Present in 1 view:** • agricultural areas **Used by:** • reused water for agriculture
"water demand per ha (agricultural areas)" (m3/(hm2*Month)) = 50 **Present in 1 view:** • agricultural areas **Used by:** • total water demand for agricultural areas
"water from other source(s) for agriculture" (m3/Month) = added potential potable water owing to sustainable agriculture from the main aquifer+ added potential potable water owing to sustainable agriculture from reservoir or river **Present in 1 view:**

• agricultural areas **Used by:** • agricultural water storage in MetroArea
Low-high density urban areas (24 variables)
Variable Name and Description
average resident population in high density areas (people/hm2) = 100 **Description:** *average population per ha in high-density areas* **Present in 1 view:** • low-high density urban areas **Used by:** • "resident population in high-density areas of city A" - updated resident population in low-density areas • "resident population in high-density areas of city B" - updated resident population in low-density areas
average resident population in low density areas (people/hm2) = 9 **Description:** *average population per ha in low-density areas* **Present in 1 view:** • low-high density urban areas **Used by:** • "resident population in low-density areas of city A" • "resident population in low-density areas of city B"
"change of high-density areas in city A" (hm2/Month) = DELAY3("fraction of land-use change in urban areas in city A"*"high-density areas in city A", delay time for construction) **Present in 1 view:** • low-high density urban areas **Used by:** • "high-density areas in city A"
"change of high-density areas in city B" (hm2/Month) = DELAY3("fraction of land-use change in urban areas in city B"*"high-density areas in city B", delay time for construction) **Present in 1 view:** • low-high density urban areas **Used by:** • "high-density areas in city B"
"change of low-density areas in city A" (hm2/Month) = DELAY3("fraction of land-use change in urban areas in city A"*"low-density areas in city A", delay time for construction) **Present in 1 view:** • low-high density urban areas **Used by:** • "low-density areas in city A"
"change of low-density areas in city B" (hm2/Month) = DELAY3("fraction of land-use change in urban areas in city B"*"low-density areas in city B", delay time for construction) **Present in 1 view:** • low-high density urban areas **Used by:** • "low-density areas in city B"

delay time for construction (Month) = 36 **Description:** *a needed time to construct a building in high-density areas in term of months* **Present in 1 view:** • low-high density urban areas **Used by:** • "change of high-density areas in city A" • "change of high-density areas in city B" • "change of low-density areas in city A" • "change of low-density areas in city B"
"fraction of land-use change in urban areas in city A" (1/Month) = 0.0135 **Present in 1 view:** • low-high density urban areas **Used by:** • "change of high-density areas in city A" • "change of low-density areas in city A"
"fraction of land-use change in urban areas in city B" (1/Month) = 0.0125 **Present in 1 view:** • low-high density urban areas **Used by:** • "change of high-density areas in city B" • "change of low-density areas in city B"
"high-density areas in city A" (hm2) = ∫"change of high-density areas in city A" *dt* + ["initial size of high-density areas in city A"] **Present in 1 view:** • low-high density urban areas **Used by:** • "change of high-density areas in city A" • "resident population in high-density areas of city A" - updated resident population in low-density areas
"high-density areas in city B" (hm2) = ∫"change of high-density areas in city B" *dt* + ["initial size of high-density areas in city B"] **Present in 1 view:** • low-high density urban areas **Used by:** • "change of high-density areas in city B" • "resident population in high-density areas of city B" - updated resident population in low-density areas
"initial size of high-density areas in city A" (hm2) = 25 **Present in 1 view:** • low-high density urban areas **Used by:** • "high-density areas in city A"
"initial size of high-density areas in city B" (hm2) = 5000 **Present in 1 view:** • low-high density urban areas **Used by:** • "high-density areas in city B"

"initial size of low-density areas in city A" (hm2)
= 50
Present in 1 view:
- low-high density urban areas

Used by:
- "low-density areas in city A"
- "resident population in low-density areas of city A"

"initial size of low-density areas in city B" (hm2)
= 1500
Present in 1 view:
- low-high density urban areas

Used by:
- "low-density areas in city B"

"low-density areas in city A" (hm2)
= ∫"change of low-density areas in city A" *dt* + ["initial size of low-density areas in city A"]
Present in 1 view:
- low-high density urban areas

Used by:
- "change of low-density areas in city A"

"low-density areas in city B" (hm2)
= ∫"change of low-density areas in city B" *dt* + ["initial size of low-density areas in city B"]
Present in 1 view:
- low-high density urban areas

Used by:
- "change of low-density areas in city B"
- "resident population in low-density areas of city B"

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resident population in city A (people)
= "resident population in high-density areas of city A"+"resident population in low-density areas of city A"
Present in 1 view:
- low-high density urban areas

Used by:
- total resident population in the MetroArea

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resident population in city B (people)
= "resident population in high-density areas of city B"+"resident population in low-density areas of city B"
Present in 1 view:
- low-high density urban areas

Used by:
- total resident population in the MetroArea

"resident population in high-density areas of city A" (people)
= average resident population in high density areas*"high-density areas in city A"
Description: *updated resident population in low-density areas*
Present in 2 views:
- urban water consumption
- low-high density urban areas

Used by:
- resident population in city A
- total water consumption of resident population in city A - total water consumption in city A

"resident population in high-density areas of city B" (people)
= average resident population in high density areas*"high-density areas in city B"
Description: *updated resident population in low-density areas*
Present in 2 views:

- urban water consumption
- low-high density urban areas

Used by:
- resident population in city B
- total water consumption of resident population in city B - total water consumption in city B

"resident population in low-density areas of city A" (people)
= average resident population in low density areas* "initial size of low-density areas in city A"
Present in 2 views:
- urban water consumption
- low-high density urban areas

Used by:
- resident population in city A
- total water consumption of resident population in city A - total water consumption in city A

"resident population in low-density areas of city B" (people)
= average resident population in low density areas *"low-density areas in city B"
Present in 2 views:
- urban water consumption
- low-high density urban areas

Used by:
- resident population in city B
- total water consumption of resident population in city B - total water consumption in city B

total resident population in the MetroArea (people)
= resident population in city B+ resident population in city A
Present in 1 view:
- low-high density urban areas

Energy consumption and CO2 emission (64 variables)

Variable Name and Description

adjustment time (Month)
= 1
Description: *a needed time to distribute water to a destination*
Present in 4 views:
- urban water distribution
- urban water consumption
- agricultural areas
- energy consumption and CO2 emission

Used by:
- gap between total urban water supply and demand
- gap between urban water supply and demand city A
- gap between urban water supply and demand city B
- Required inflow from the main's aquifer for the main reservoir - a required volume to fulfil water consumption in the Metro.
  This should be extracted from the main aquifer
- seepaged water from the main aquifer to the main reservoir
- water from reservoir or water storages for city A - please choose 0: the reservoir system please choose 1: the river system
- water from reservoir or water storages for city B
- water input from the main reservoir for city A - the number of distributed water from Guadalest reservoir to Altea
- water input from the main reservoir for city B - the number of distributed water from Guadalest reservoir to Polop
- water output for city A's end users - a flow of available water for end users in Altea
- water output for city B's end users - a flow of available water for end users in Polop

conversion from water volume to water mass (kg/m3) = 1000 **Present in 1 view:** • energy consumption and CO2 emission
converter Joule to kWh (Joule/KwH) = 3.6*1e+06 **Description:** *a constant to convert energy in kWh to Joule* **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • energy intensity of hot water in residential areas • energy intensity of hot water in touristic areas • energy intensity of water pumping • "energy_intensity of groundwater extraction"
converter m3 to hm3 (m3/(hm*hm*hm)) = 1e+06 **Present in 4 views:** • urban water distribution • the main aquifer • urban water consumption • energy consumption and CO2 emission **Used by:** • enegy consumption of water transportation from the main aquifer to the Guadalest reservoir • energy intensity of hot water in residential areas • energy intensity of hot water in touristic areas • energy intensity of water pumping • "energy_intensity of groundwater extraction" • gap between total urban water supply and demand • Required inflow from the main's aquifer for the main reservoir - a required volume to fulfil water consumption in the Metro. This should be extracted from the main aquifer • seepaged water from the main aquifer to the main reservoir • the main aquifer's extraction - extracted water from the main aquifer • the main reservoir inflow • water from reservoir or water storages for city A - please choose 0: the reservoir system please choose 1: the river system • water from reservoir or water storages for city B
converter to Joule (Joule/(m*m*kg/(s*s))) = 1 **Description:** *a converter from kWh to Joule for energy consumption* **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • energy intensity of hot water in residential areas • energy intensity of hot water in touristic areas • energy intensity of water pumping • "energy_intensity of groundwater extraction"
"dynamic_head" (m) = initial water level*1.2+5*(MAX(0,(water level-previous water level))+total dynamic head) **Present in 1 view:** • energy consumption and CO2 emission **Used by:**

• "energy_intensity of groundwater extraction"
energy intensity for urban water distribution (KwH/m3) = 3 **Description:** *energy consumption for each m3 water distribution to urban areas* **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • monthly energy consumption for water distribution around urban areas in MetroArea – total energy consumption for water distribution to urban areas
energy intensity for wastewater treatment (KwH/m3) = 5 **Description:** *energy consumption for each m3 transported water from the main aquifer to the Guadalest reservoir* **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • monthly energy consumption for wastewater treatment in MetroArea – energy consumption for each m3 transported water from the main aquifer to the Guadalest reservoir
energy intensity for water treatment (KwH/m3) = 2 **Description:** *energy consumption for each m3 water purification before household consumption* **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • "monthly energy consumption for water treatment (purified water) in MetroArea" - total energy consumption for given water purification
energy intensity of hot water in residential areas (KwH/m3) = (1+"water loss in water heating system (residential buildings)")*gravity*converter to Joule*required energy to heat water per m3/converter m3 to hm3*other losses*water mass density*"height_for_residential_accommodation"/(converter Joule to kWh*water heater energy efficiency) **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • monthly energy consumption for hot water in residential and tourism accommodation
energy intensity of hot water in touristic areas (KwH/m3) = (1+"water loss in water heating system (tourism accomodation)")*gravity*converter to Joule*required energy to heat water per m3/converter m3 to hm3*other losses*water mass density*"height_for_accommodation_buildings"/(water heater energy efficiency*converter Joule to kWh) **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • monthly energy consumption for hot water in residential and tourism accommodation
energy intensity of water pumping (KwH/m3) = "height_for_accommodation_buildings"*converter to Joule*gravity*water mass density*(1+"water loss the pumping system (tall building)")/(converter Joule to kWh*water pumping efficiency for end users*converter m3 to hm3) **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • monthly energy consumption for repump water in tall buildings

"energy_intensity of groundwater extraction" (KwH/(m3))
= "dynamic_head"*gravity*water mass density*converter to Joule/(groundwater pumping efficiency*
converter Joule to kWh*converter m3 to hm3*(1-TDLosses))
Present in 1 view:
- energy consumption and CO2 emission

Used by:
- monthly energy consumption for transport and extract surface and ground water in MetroArea –
- total energy consumption of transported water from the main aquifer to the Guadalest reservoir

gravity (m/(s*s))
= 9.8
Description: *a gravity constant*
Present in 1 view:
- energy consumption and CO2 emission

Used by:
- energy intensity of hot water in residential areas
- energy intensity of hot water in touristic areas
- energy intensity of water pumping
- "energy_intensity of groundwater extraction"

groundwater pumping efficiency (Dmnl)
= 0.3
Present in 1 view:
- energy consumption and CO2 emission

Used by:
- "energy_intensity of groundwater extraction"

"height_for_accommodation_buildings" (m)
= 40
Present in 1 view:
- energy consumption and CO2 emission

Used by:
- energy intensity of hot water in touristic areas
- energy intensity of water pumping

"height_for_residential_accommodation" (m)
= 40
Present in 1 view:
- energy consumption and CO2 emission

Used by:
- energy intensity of hot water in residential areas

index of regional CO2 emission (tonnes/KwH)
= 0.297
Description: *CO2 emission for each MWh energy consumption*
Present in 1 view:
- energy consumption and CO2 emission

Used by:
- "Water-related CO2 emissions in the MetroArea" - total CO2 emission for given MWh energy consumption

initial water level (m)
= 10
Present in 1 view:
- energy consumption and CO2 emission

Used by:

- "dynamic_head"

Joule converter (Joule/(m*m*kg/(s*s)))
= 1
Description: *A joule converter to convert "Joule/(m*m*kg/(Month*s*s))" to Joule*
Present in 1 view:
- energy consumption and CO2 emission

monthly energy consumption for hot water in residential and tourism accommodation (KwH)
= energy intensity of hot water in residential areas*(total water consumption by resident population in MetroArea)+
energy intensity of hot water in touristic areas*(total water consumption under the MetroArea-total water consumption by resident population in MetroArea)
Present in 1 view:
- energy consumption and CO2 emission

Used by:
- monthly energy consumption in the MetroArea - total energy consumption in the Marina Baixa

monthly energy consumption for repump water in tall buildings (KwH)
= energy intensity of water pumping*total water consumption under the MetroArea
Present in 1 view:
- energy consumption and CO2 emission

Used by:
- monthly energy consumption in the MetroArea - total energy consumption in the Marina Baixa

monthly energy consumption for transport and extract surface and ground water in MetroArea (KwH)
= "energy_intensity of groundwater extraction"*total water consumption under the MetroArea
Description: *total energy consumption of transported water from the main aquifer to the Guadalest reservoir*
Present in 1 view:
- energy consumption and CO2 emission

Used by:
- monthly energy consumption in the MetroArea - total energy consumption in the Marina Baixa

monthly energy consumption for wastewater treatment in MetroArea (KwH)
= energy intensity for wastewater treatment*total reused water in MetroArea
Description: *energy consumption for each m3 transported water from the main aquifer to the Guadalest reservoir*
Present in 1 view:
- energy consumption and CO2 emission

Used by:
- monthly energy consumption in the MetroArea - total energy consumption in the Marina Baixa

monthly energy consumption for water distribution around urban areas in MetroArea (KwH)
= energy intensity for urban water distribution*total water consumption under the MetroArea
Description: *total energy consumption for water distribution to urban areas*
Present in 1 view:
- energy consumption and CO2 emission

Used by:
- monthly energy consumption in the MetroArea - total energy consumption in the Marina Baixa

"monthly energy consumption for water treatment (purified water) in MetroArea" (KwH) = energy intensity for water treatment*total water consumption under the MetroArea **Description:** *total energy consumption for given water purification* **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • monthly energy consumption in the MetroArea - total energy consumption in the Marina Baixa
monthly energy consumption in the MetroArea (KwH) = monthly energy consumption for transport and extract surface and ground water in MetroArea+ monthly energy consumption for wastewater treatment in MetroArea+ monthly energy consumption for water distribution around urban areas in MetroArea+ "monthly energy consumption for water treatment (purified water) in MetroArea"+ monthly energy consumption for hot water in residential and tourism accommodation+ monthly energy consumption for repump water in tall buildings **Description:** *total energy consumption in the Marina Baixa* **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • "Water-related CO2 emissions in the MetroArea" - total CO2 emission for given MWh energy consumption
other losses (Dmnl) = 1.3 **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • energy intensity of hot water in residential areas • energy intensity of hot water in touristic areas
previous water level (m) = WITH LOOKUP (the previous level of the main aquifer,([(433,-400)-(455,-300)],(433.324,-394),(433.903,-393),(434.482,-392),(435.061,-391),(435.64,-390),(436.219,-389),(436.798,-388),(437.378,-387),(437.957,-386),(438.536,-385),(439.115,-384),(439.693,-383),(440.272,-382),(440.851,-381),(441.43,-380),(442.009,-379),(442.588,-378),(443.166,-377),(443.745,-376),(444.324,-375),(444.902,-374),(445.481,-373),(446.059,-372),(446.638,-371),(447.216,-370),(447.794,-369),(448.373,-368),(448.951,-367),(449.529,-366),(450.107,-365),(450.685,-364),(451.263,-363),(451.841,-362),(452.419,-361),(452.997,-360),(453.575,-359),(454.153,-358))) **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • "dynamic_head"
pump efficiency in local aquifers (Dmnl) = 0.6 **Description:** *a pump efficiency in coastal aquifers* **Present in 1 view:** • energy consumption and CO2 emission
required energy to heat water per m3 (Dmnl) = 120 **Present in 1 view:**

• energy consumption and CO2 emission **Used by:** • energy intensity of hot water in residential areas • energy intensity of hot water in touristic areas
TDLosses (Dmnl) = 0.15 **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • "energy_intensity of groundwater extraction"
the main aquifer (hm*hm*hm) = ∫inifiltration and percolated water to the the main aquifer-the main aquifer's extraction-monthly spring and upwelling flow *dt* + [initial aquifer volume] **Description:** *a water stock in the main aquifer* **Present in 4 views:** • urban water distribution • the main aquifer • urban water consumption • energy consumption and CO2 emission **Used by:** • gap between total urban water supply and demand • monthly spring and upwelling flow - an outflow of spring water from the main aquifer • seepaged water from the main aquifer to the main reservoir • the main aquifer's extraction - extracted water from the main aquifer • the previous level of the main aquifer • water level
the previous level of the main aquifer (hm*hm*hm) = DELAY FIXED(the main aquifer, 1 , the main aquifer) **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • previous water level
total dynamic head (m) = 111 **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • "dynamic_head"
total reused water in MetroArea (m3) = total water consumption under the MetroArea **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • monthly energy consumption for wastewater treatment in MetroArea – energy consumption for each m3 transported water from the main aquifer to the Guadalest reservoir
total water consumption by resident population in MetroArea (m3) = total water consumption of resident population in city A+ total water consumption of resident population in city B **Description:** *total water consumption by resident population in the Metro* **Present in 2 views:** • urban water consumption

• energy consumption and CO2 emission **Used by:** • monthly energy consumption for hot water in residential and tourism accommodation
total water consumption under the MetroArea (m3) = total water consumption in city A+ total water consumption in city B **Description:** *the total water consumption in the Metro* **Present in 2 views:** • urban water consumption • energy consumption and CO2 emission **Used by:** • monthly energy consumption for hot water in residential and tourism accommodation • monthly energy consumption for repump water in tall buildings • monthly energy consumption for transport and extract surface and ground water in MetroArea – total energy consumption of transported water from the main aquifer to the Guadalest reservoir • monthly energy consumption for water distribution around urban areas in MetroArea – total energy consumption for water distribution to urban areas • "monthly energy consumption for water treatment (purified water) in MetroArea" – total energy consumption for given water purification • total reused water in MetroArea
water heater energy efficiency (Dmnl) = 0.45 **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • energy intensity of hot water in residential areas • energy intensity of hot water in touristic areas
water level (m) = WITH LOOKUP (the main aquifer,([(433,-400)-(455,-300)],(433.324,-394),(433.903,-393),(434.482,-392),(435.061,-391), (435.64,-390),(436.219,-389),(436.798,-388),(437.378,-387),(437.957,-386),(438.536,-385),(439.115,-384),(439.693,-383), (440.272,-382),(440.851,-381),(441.43,-380),(442.009,-379),(442.588,-378),(443.166,-377),(443.745,-376),(444.324,-375), (444.902,-374),(445.481,-373),(446.059,-372),(446.638,-371),(447.216,-370),(447.794,-369),(448.373,-368),(448.951,-367), (449.529,-366),(450.107,-365),(450.685,-364),(451.263,-363),(451.841,-362),(452.419,-361),(452.997,-360),(453.575,-359), (454.153,-358))) **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • "dynamic_head"
"water loss in water heating system (residential buildings)" (Dmnl) = 0.3 **Present in 1 view:** • energy consumption and CO2 emission **Used by:** • energy intensity of hot water in residential areas

"water loss in water heating system (tourism accomodation)" (Dmnl)
= 0.535
Present in 1 view:
- energy consumption and CO2 emission

Used by:
- energy intensity of hot water in touristic areas

"water loss the pumping system (tall building)" (Dmnl)
= 0.3
Present in 1 view:
- energy consumption and CO2 emission

Used by:
- energy intensity of water pumping

water mass density (kg/(hm*hm*hm))
= 1e+09
Description: *a constant represents the mass of water for a hm^3 water*
Present in 1 view:
- energy consumption and CO2 emission

Used by:
- energy intensity of hot water in residential areas
- energy intensity of hot water in touristic areas
- energy intensity of water pumping
- "energy_intensity of groundwater extraction"

water output for city A's end users (m3/Month)
= total required water supply in city A/adjustment time
Description: *a flow of available water for end users in Altea*
Present in 3 views:
- urban water distribution
- urban water consumption
- energy consumption and CO2 emission

Used by:
- gap between total urban water supply and demand
- gap between urban water supply and demand city A
- total water for city A - a stock of total water for Altea population

water pumping efficiency for end users (Dmnl)
= 0.5625
Present in 1 view:
- energy consumption and CO2 emission

Used by:
- energy intensity of water pumping

"Water-related CO2 emissions in the MetroArea" (tonnes)
= index of regional CO2 emission* monthly energy consumption in the MetroArea
Description: *total CO2 emission for given MWh energy consumption*
Present in 1 view:
- energy consumption and CO2 emission

Scenarios and graphs (6 variables)

Variable Name and Description

switch aquifer and reservoir system (Dmnl)
= 1
Description: *please write down 1: if you consider a combination an aquifer and a reservoirplease write down 0:*
if NO aquifer exists but a reservoir
Present in 2 views:
- urban water distribution

- scenarios and graphs

Used by:

- Required inflow from the main's aquifer for the main reservoir – a required volume to fulfil water consumption in the Metro. This should be extracted from the main aquifer

switch aquifer only system (Dmnl)
= 1
Description: *Please set this parameter 1: if you consider the second type (aquifer delivers water directly users,*
without reservoir(s))Otherwise, please set this parameter 0
Present in 2 views:

- urban water distribution
- scenarios and graphs

Used by:

- water from reservoir or water storages for city A – please choose 0: the reservoir system please choose 1: the river system
- water from reservoir or water storages for city B

switch for agriculture water from aquifer (Dmnl)
= 1
Description: *please choose 1: water for agriculture comes from aquiferplease choose 0: water for agriculture comes other sources*
Present in 2 views:

- agricultural areas
- scenarios and graphs

Used by:

- added potential potable water owing to sustainable agriculture from the main aquifer – this is added potable water owing to sustainable agriculture policy

switch for agriculture water from reused water (Dmnl)
= 1
Description: *please choose 1: water for agriculture comes from reused waterplease choose 0: water for agriculture comes other sources*
Present in 2 views:

- agricultural areas
- scenarios and graphs

Used by:

- inflow of used urban water - IF THEN ELSE(ratio between agriculture water demand and supply<1, ((min(total water demand for agricultural areas,(initial monthly urban water in the Metro/"delay processing time in the wastewater plant(s)")))) , 0)

"switch for agriculture water from river (or reservoir)" (Dmnl)
= 1
Description: *please choose 1: water for agriculture comes from river/reservoirplease choose 0: water for agriculture comes other sources*
Present in 2 views:

- agricultural areas
- scenarios and graphs

Used by:

- added potential potable water owing to sustainable agriculture from reservoir or river - this is added potable water owing to sustainable agriculture policy

switch the main aquifer and the reservoir connection (Dmnl)
= 1
Description: *write "1", there is percolated water to the main aquiferwrite "0", there is seepaged water to the main reservoir*
Present in 3 views:

- urban water distribution
- the main aquifer
- scenarios and graphs

Used by:

- inifiltration and percolated water to the the main aquifer - an actual seepaged water from surface water to the main aquifer
- seepaged water from the main aquifer to the main reservoir

4. Guidelines for Using the Tool on Simulations

Once the reader is familiar with the nature and technical details of the model, the next step is to use it for simulations. The objective of this section is to provide a guideline for installing the “Urban Drought Nexus Tool” (from here onwards, the tool), and to understand how to simulate urban system dynamics with the tool, especially in the context of water scarcity and multiple sustainability goals relating to water, energy and land. It is important to read this guideline to avoid possible errors, mistakes, and loss of time in small but important details. This should be seen a starting document for non-specific background users, so that they can simulate their environment with the tool. Users are also free to simulate and expand this tool for their own needs. Although this tool is developed based on the system dynamics approach, this document will not cover detailed aspects such as the development of a system dynamics model, or the water-energy-land nexus (see Cremades et al., 2020). Please refer to www.vensim.com or www.systemdynamics.org to find suitable system dynamics courses. However, it is hoped that upon reading this material, users can simulate with the tool confidently.

The tool is developed in Vensim©. Vensim© is an application developed by the Ventana Systems (www.vensim.com) to build and simulate system dynamics models. In general, Vensim© versions can be categorized into two categories: free versions and commercial versions. Commercial versions are, for example, Vensim Professional and Vensim DSS while Vensim PLE is a free Vensim version. This tool can be simulated using Vensim PLE (free). Advanced Python users have Python modules available to import and use the tool in python, too, however the graphical interface provided by VENSIM is an added value that would need to be rebuilt.

Users can download Vensim PLE following following steps.

1. Please go to (https://vensim.com/download/) for downloading Vensim software (see Figure 1).
2. Please click “Free downloads” to download Vensim PLE.

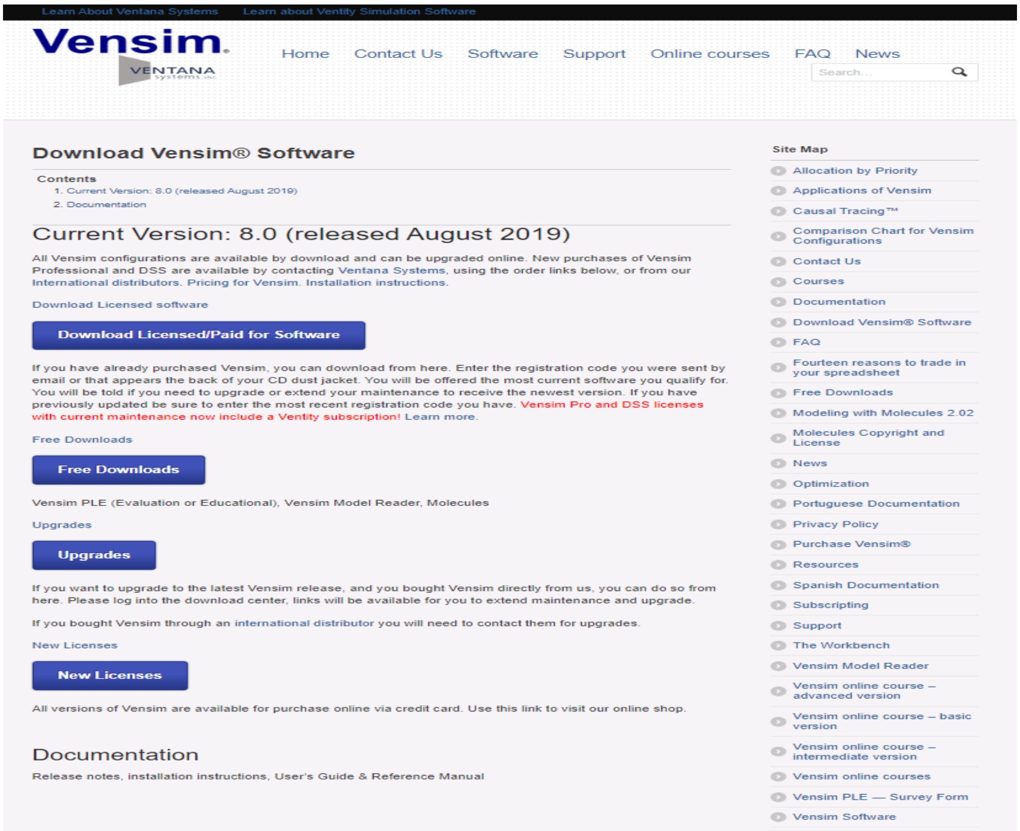
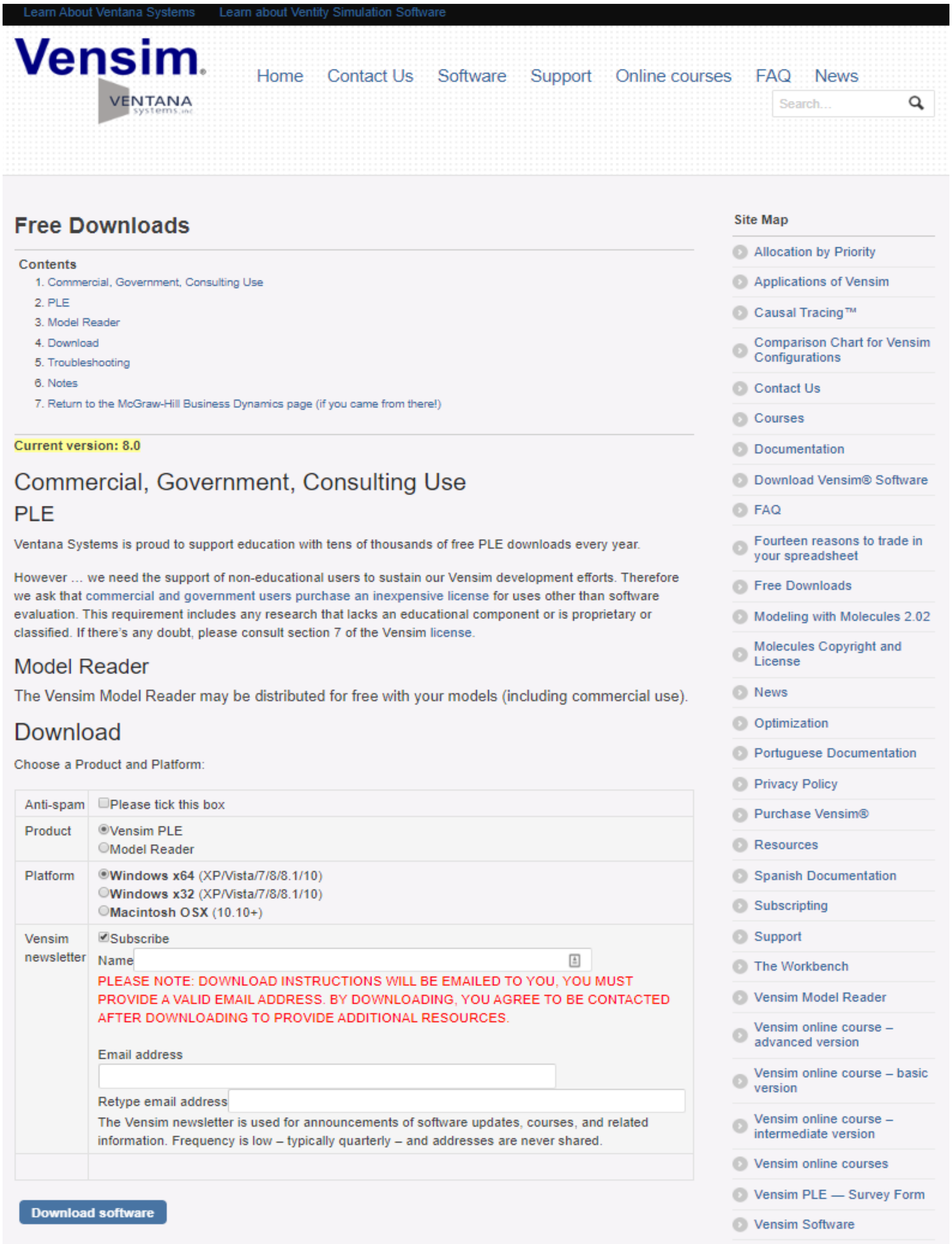


Figure 1. A download page # the first screen

3. In the next page (see Figure 2), please require fill columns and click “download software”. Afterward, please go to your email to receive a download link for your downloaded software. As you see on a download page, each Vensim version is available for Windows and Mac users.



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Contents

1. Commercial, Government, Consulting Use
2. PLE
3. Model Reader
4. Download
5. Troubleshooting
6. Notes
7. Return to the McGraw-Hill Business Dynamics page (if you came from there!)

Current version: 8.0

Commercial, Government, Consulting Use

PLE

Ventana Systems is proud to support education with tens of thousands of free PLE downloads every year.

However ... we need the support of non-educational users to sustain our Vensim development efforts. Therefore we ask that commercial and government users purchase an inexpensive license for uses other than software evaluation. This requirement includes any research that lacks an educational component or is proprietary or classified. If there's any doubt, please consult section 7 of the Vensim license.

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Figure 2. The download page.

4.1. Basic Concepts

Four types of combinations of surface water and groundwater

There are four possible combinations of water sources i.e. combinations of surface water and groundwater. The first one is a combination between an aquifer and a reservoir. The second one is a reservoir is a single water source, and the third one is an aquifer is a single water source. The last one is a river as the main water source.

This tool aims to cover all these possibilities. By default, this tool implements the first type — a combination between an aquifer and a reservoir. The following steps should be initiated prior to simulating the stool. Please note that users also can change these variables in the "scenarios and graphs" module.

1. The first type (by default)
2. The second type
   Please set "switch aquifer and reservoir system" = "0", in case you consider an observed system with a reservoir only, without aquifer(s).
3. The third type
   Please set "switch aquifer only system" = "1", in case you consider this system.
4. The fourth type
   Please, in addition to setting the switches as indicated in the table below, rename "the main reservoir" by "river reach" (https://www.usgs.gov/faqs/what-a-reach?qt-news_science_products=0#qt-news_science_products). Also, please rename all related variables with a "reservoir" word with a word with "river". For example, replace "the main reservoir inflow" to be "the main river inflow" and another instance, replace "the main reservoir outflow for city A" to be "the main river outflow for city A".

Switch variables	The first type	The second type	The third type	The fourth type
switch aquifer and reservoir system	1 (default)	0	0	0

switch aquifer only system	0 (default)	0	1	0

Table 1. Setting switch variables relate to the water source(s)

Land-use change

Before running the tool, users should co-produce narratives with societal stakeholders that take into account plausible futures, and later use them as the basis for land-use change scenarios. Users can set *fraction of land use change* in the module for *low-high density areas*. The fraction of land-use change represents a change of land based on given narratives. In this way, stakeholders can translate narratives into policy analysis through model simulations, if needed facilitated by modelers.

Reproducing the situation in a metropolitan area

1. Before running policy analyses, please make sure that you change the sub-model of *urban water consumption* accordingly. For instance, users should set each accommodation capacity such as *total camping sites capacity in city A* and *total hotel capacity in city A* to be according to the modelled area.
2. Moreover, in case of users do not consider farming areas, *initial agricultural areas in the MetroArea* in the module of *agricultural areas* should be set to 0.
3. In the sub-model or module of agricultural *areas*, there are three switch variables. The switch variables are *switch for agriculture water from reused water*, *switch for agriculture water from river (or reservoir)*, and *switch for agriculture water from aquifer*.

   Please set *switch for agriculture water from reused water* to nil, if users do not consider the application of reused water for agriculture. Otherwise, please set this variable = "1".

   The second switch variable, *switch for agriculture water from river (or reservoir),* should be nil, if agriculture gets NO water directly from river or reservoirs. Setting this switch variable = "1" meaning agriculture gets water from a river or reservoir directly.

   In case, agriculture gets water directly from an aquifer, please set *switch for agriculture water from aquifer* to "1". Otherwise, please set this variable to nil.

4.2. How to Conduct Analysis in a Vensim Environment

Instructions to start, and simulate the model are described in following paragraphs.

1. Please open Vensim PLE (free version) and open the tool (for it, you may double-click the .mdl file "Urban_Drought_Nexus_Tool_v0.mdl" to open the model in Vensim PLE).

2. Checking available modules

Upon opening the Vensim model or the tool, you can click a menu as seen in figure 3a to see all modules. The model consists of seven modules (with an overview module), such as the main aquifer and agricultural areas. A screenshot of different modules is displayed in figure 3b. You can click any module to see variables in each module or sub-model.

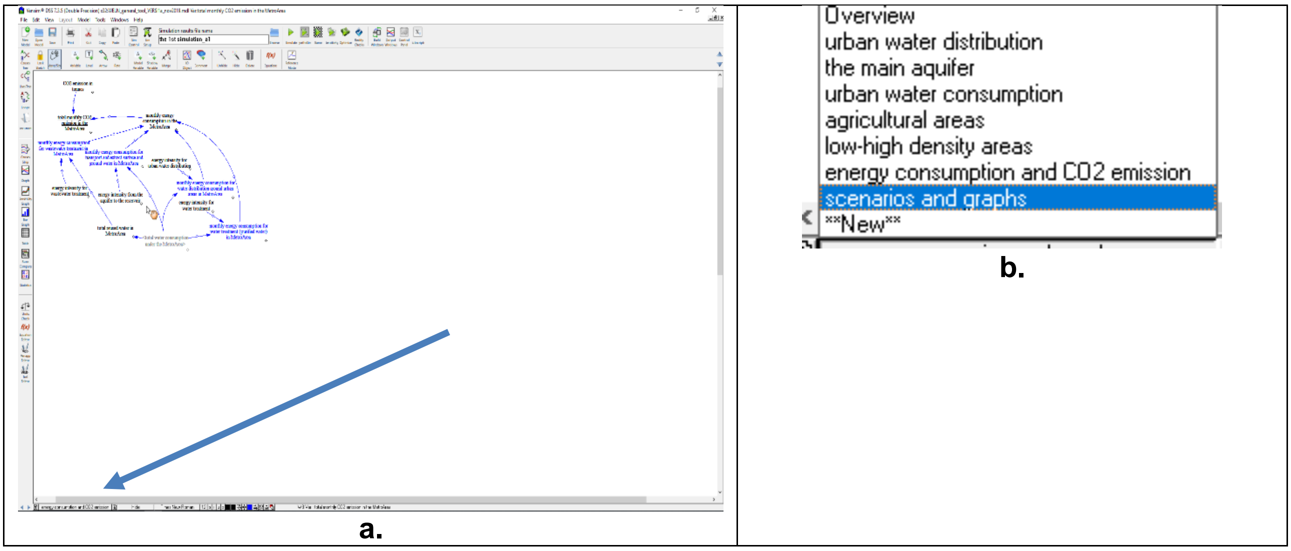


Figure 3. Overview of modules

Running the tool for the first time

There are three consecutive steps to conduct policy analysis in the Vensim environment. The first step is to open and run the model that constitutes the tool. The second one is setting policy levers and the last one is to save outputs (graphs or tables). Beware of warnings, because they might appear first thing after running a simulation and the non-expert user might not be able to interpret every possible warning, however warnings are not errors, so there is no inherent problem with a log showing warnings, e.g. about end of simulation issues.

Now, how to run the models is explained. Please go to module *scenarios and graphs* as explained section *C2. checking available modules*. You will get a screen as seen in figure 4.

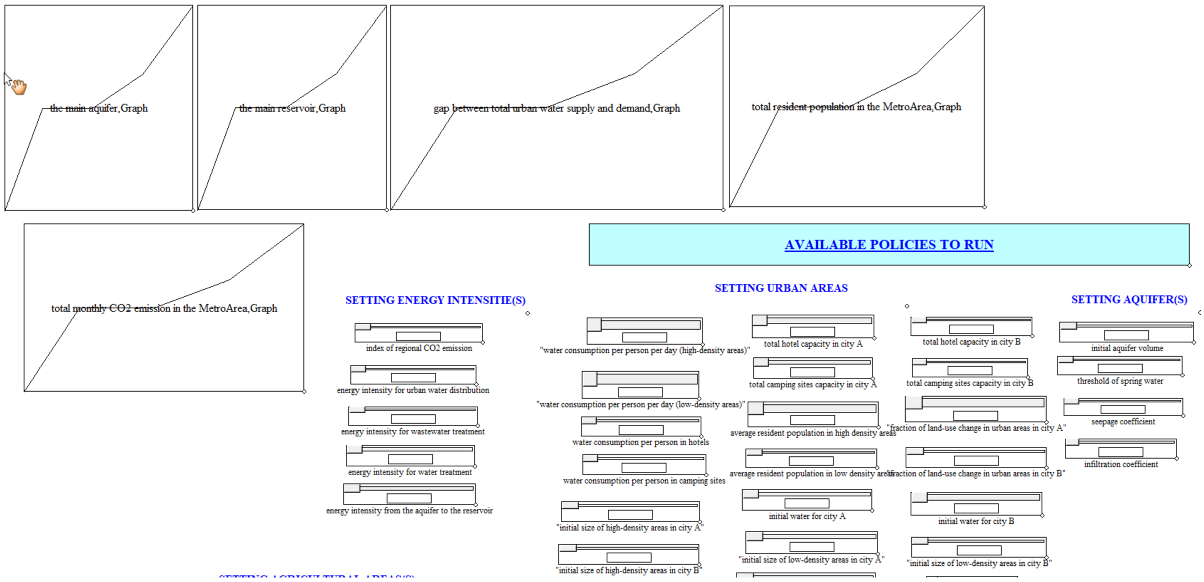


Figure 4. A module “scenarios and graphs”

Please set switch variables (see switches for model options with letters in red color) as explained above. Before running simulation, please naming your scenarios. In the module *graphs and scenarios*, switch variables are displayed in the right bottom of this screen.

Please do a double click to change the value of these switch variables. A new pop-up screen will be displayed as seen in figure 5. Please click “equation” and a new screen as seen in figure 6 will be displayed. Users can change the values as shown in the arrow (figure 6).

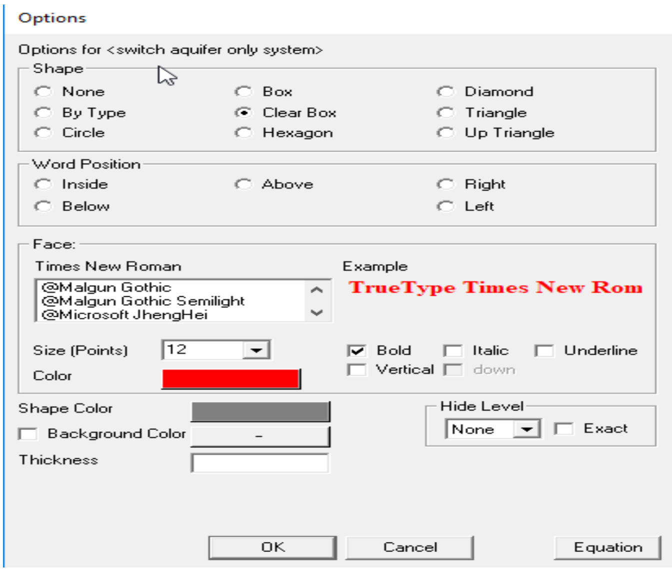


Figure 5. Changing variable values – step 1

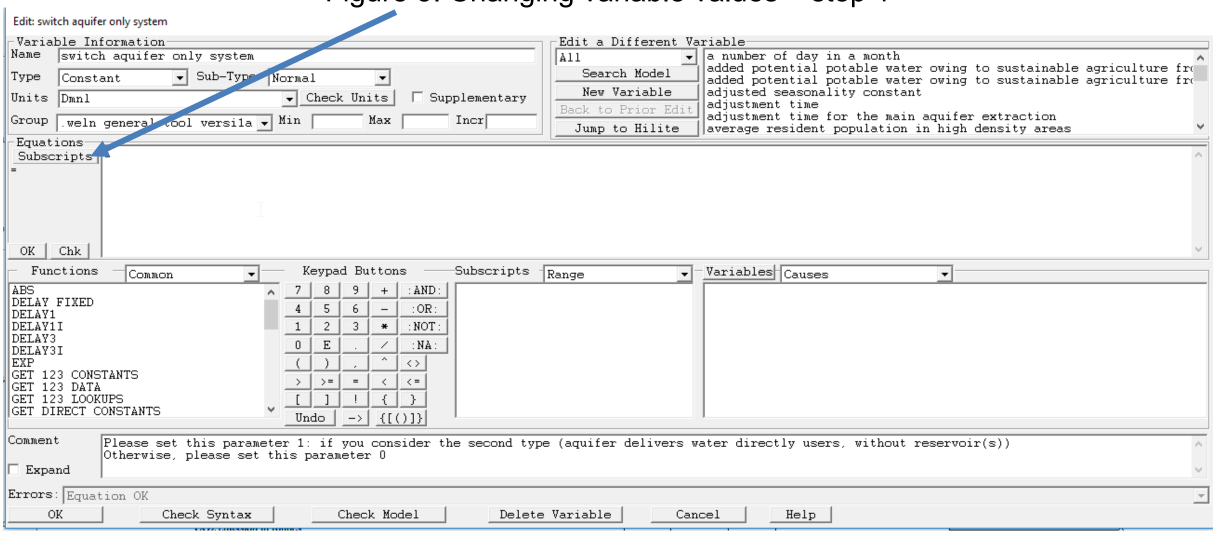


Figure 6. Changing variable values – step 2

Naming scenarios

It is useful to name each run (each simulation) with meaningful names. This aims to ease readers in compare different simulation outputs. Figure 7 displays a text box for naming your runs. Referring to figure 7, you replace "the 1st simulation" to rename your runs with meaningful names. An icon "browse" is used to reload existing scenarios or existing runs.

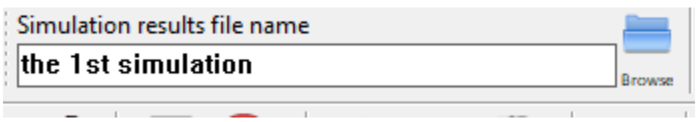


Figure 7. Naming each run / simulation

After naming your scenarios, please click an icon “Simulate” as seen in figure 8.

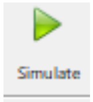


Figure 8. An icon “Simulate”

To see simulation outputs, please click the icon “Lock Sketch” (figure 9). A screen will be displayed as seen in figure 10.

Figure 9. An icon “Simulate”

Please note, clicking an icon “Move/Size”, means you want to move a variable or enlarge outputs (graphs, tables).

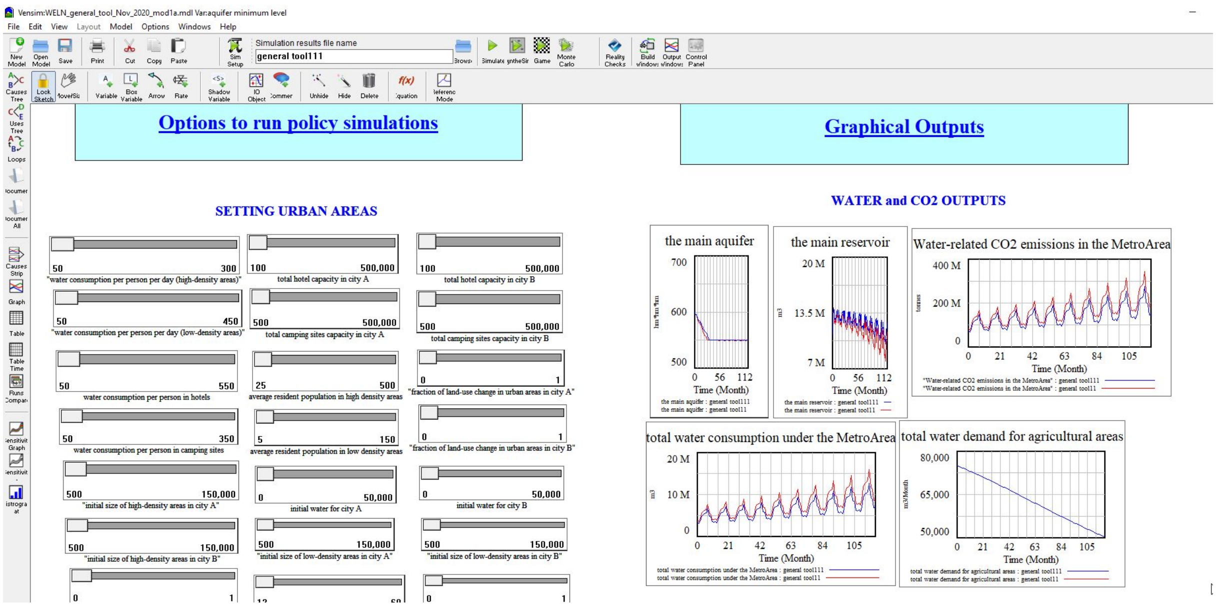


Figure 10. Output after running a simulation

Policy Analysis: Setting Policy Levers

As previously mentioned, once users click a simulate icon, users can only see outputs of the models without controlling or changing parameters during the simulation. For setting policy levers, users should click a Sim Setup icon, so users can change parameters prior to model simulation.

1. For setting policy levers, users should click “Sim Setup” as seen in figure 11. Upon clicking “Sim Setup”, a screen will be displayed as seen in figure 12.

Figure 11. Sim Setup Icon

There is an icon “stop setup” which will halt simulation while “model constants” will save the latest parameter setup. These icons are important in case users want to save constants or want to restart a new simulation with new parameters.

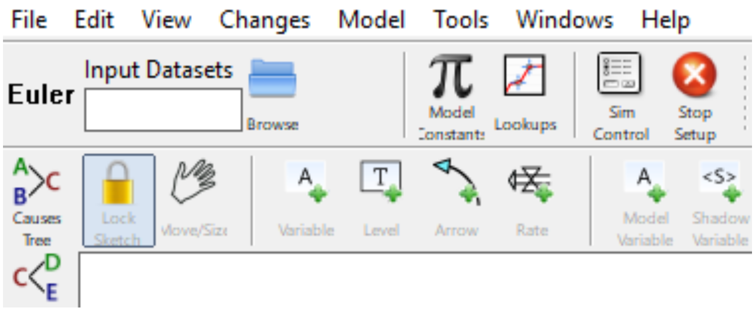


Figure 12. An icon of “**Stop Setup”** occurs after clicking Sim Setup

2. In the “Sim Setup,” users can setup parameters (available in the module of scenarios and graphs) before running simulation. Figure 13 displays some parameters, so-called sliders that can be manipulated before running simulation.

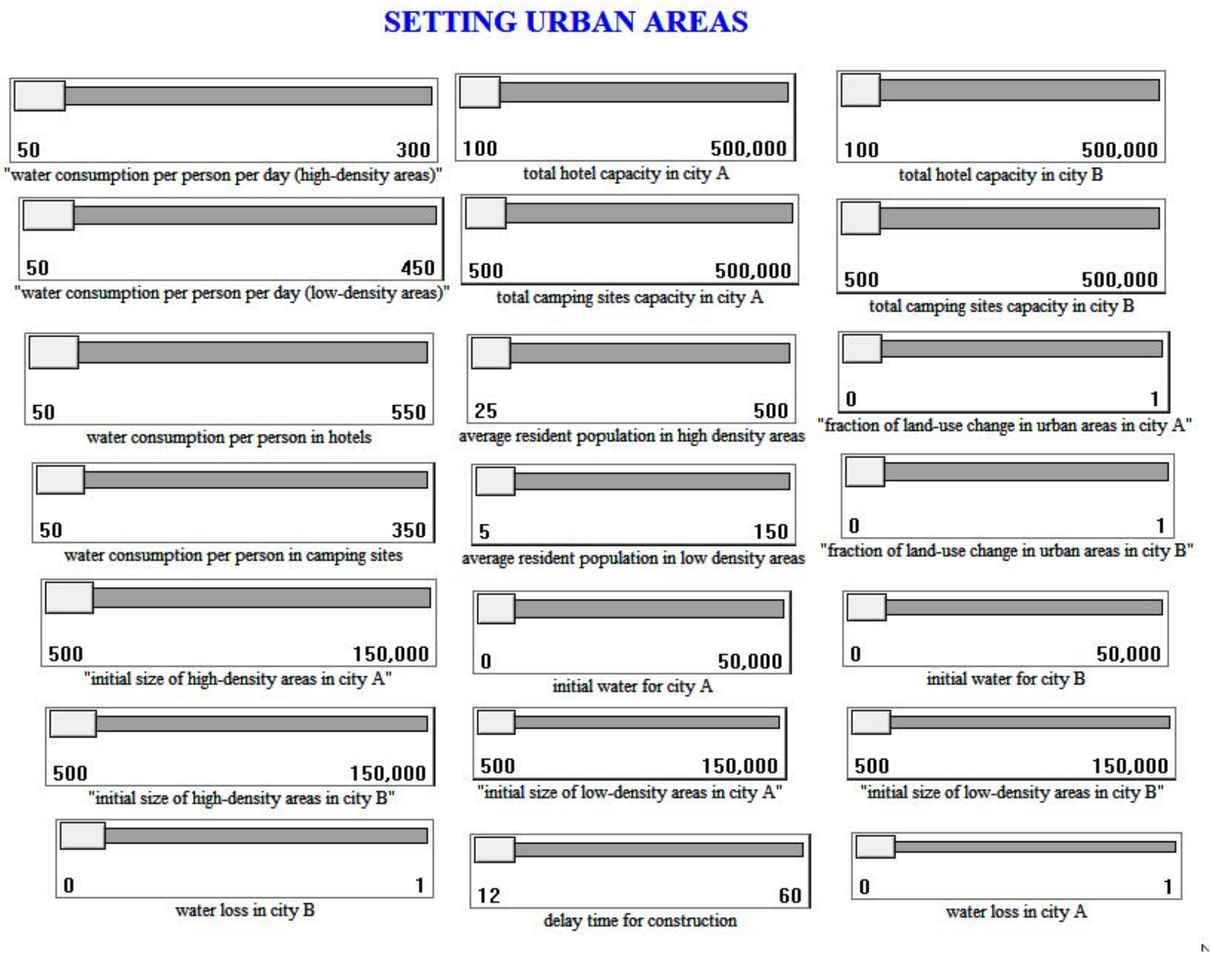


Figure 13. A sample of sliders to set policy analysis

To change a parameter named *water consumption per person per day (high-density areas)* (see figure 14), users move a slider to right/left or simply write down a number in a middle-center box. This principle applies for all sliders in the *scenario and graphs* module.

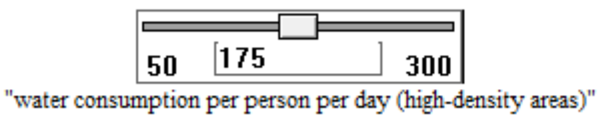


Figure 14. A slider “"water consumption per person per day (high-density areas)"”

3. After changing the values of parameters using sliders, please do not forget to name your scenario. Afterward, please click “Simulate”, and users can see a screen displaying some graphs with 2 different scenarios.

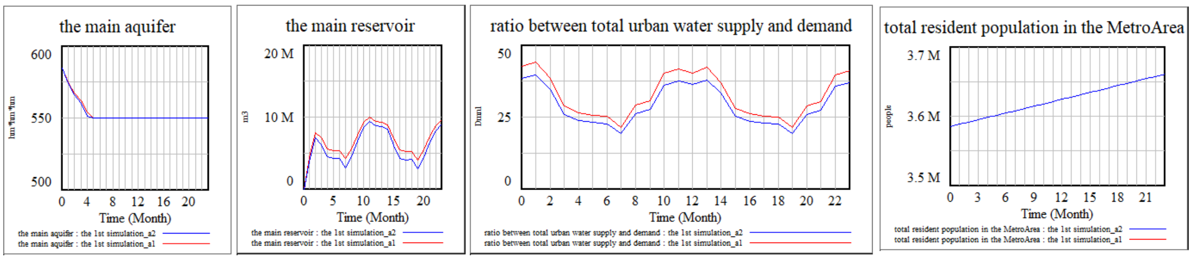


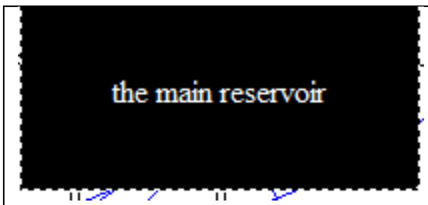
Figure 15. A screen after clicking "simulate"

4. Users may simulate the model dynamically through the "synthesim" mode. To activate this option, press the "synthesim" button in the menu. During the "synthesim" mode, users can change a slider value and dynamically see the outputs.
5. If users want save a simulation under the "synthesim" mode, users can click "save this run".

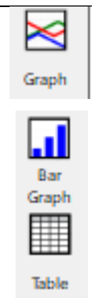
4.3. Visualizing and saving outputs

There are three possible ways to display and/or saving the values of any variables. They are "graph", "bar graph", and "table" as seen in figure 16. These icons are located in the left of the Vensim environment.

1. To see an output display, users can simply a variable (a chosen variable will be seen as figure 16a) and then click a preferred display (bar or graph or bar graph as seen in figure 16b). Afterward, a preferred display (a graph or a table) will occur in the Vensim environment. Please note for each preferred display, users can save a given display as seen in figure 18.



(a) A chosen variable will be shadowed



(b) Three display/saving types

Figure 16. Displaying/Saving Variable Outputs

2. After clicking an icon table, a display as seen in figure 17 will be appeared.

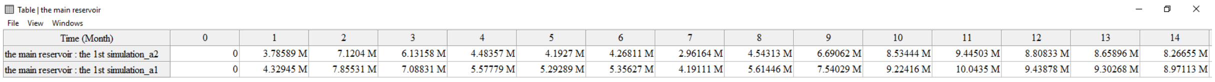


Table | the main reservoir

File View Windows

Time (Month)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
the main reservoir : the 1st simulation_a2	0	3.78589 M	7.1204 M	6.13158 M	4.48357 M	4.1927 M	4.26811 M	2.96164 M	4.54313 M	6.69062 M	8.53444 M	9.44503 M	8.80833 M	8.65896 M	8.26655 M
the main reservoir : the 1st simulation_a1	0	4.32945 M	7.85531 M	7.08831 M	5.57779 M	5.29289 M	5.35627 M	4.19111 M	5.61446 M	7.54029 M	9.22416 M	10.0435 M	9.43878 M	9.30268 M	8.97113 M

Figure 17. A display of “the main reservoir”

3. To save the output, please click “file” and then click “save” as seen in figure 18.

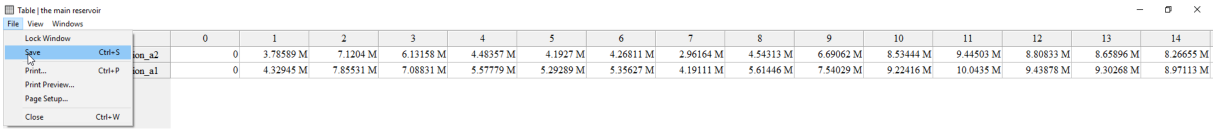


Table | the main reservoir

File View Windows

Lock Window

Save Ctrl+S

Print... Ctrl+P

Print Preview...

Page Setup...

Close Ctrl+W

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ion_a2	0	3.78589 M	7.1204 M	6.13158 M	4.48357 M	4.1927 M	4.26811 M	2.96164 M	4.54313 M	6.69062 M	8.53444 M	9.44503 M	8.80833 M	8.65896 M	8.26655 M
ion_a1	0	4.32945 M	7.85531 M	7.08831 M	5.57779 M	5.29289 M	5.35627 M	4.19111 M	5.61446 M	7.54029 M	9.22416 M	10.0435 M	9.43878 M	9.30268 M	8.97113 M

Figure 18. Saving an output

5. Examples of the Behaviour of the Main Variables

As the population in a metropolitan area with two cities (city A and city B) increases (figure 1), water demand also increases in both cities. Consequently, water available in the main aquifer and the main reservoir tends to decrease (figures 2 and 3).

This model also has features to assess whether city A, city B, and farming areas get sufficient water. Figures 4 displays potential imbalances between water supply and water demand. Figure 5 displays the CO_2 emissions in the metropolitan area.

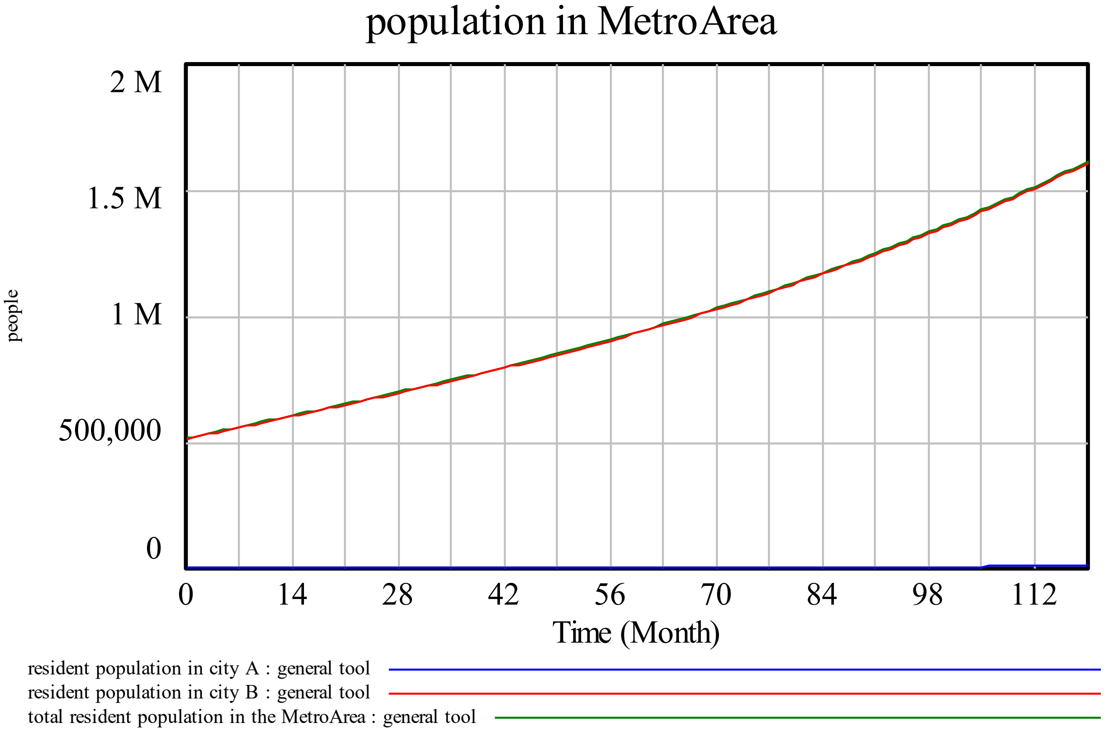


Figure 1. Population trend in metropolitan area.

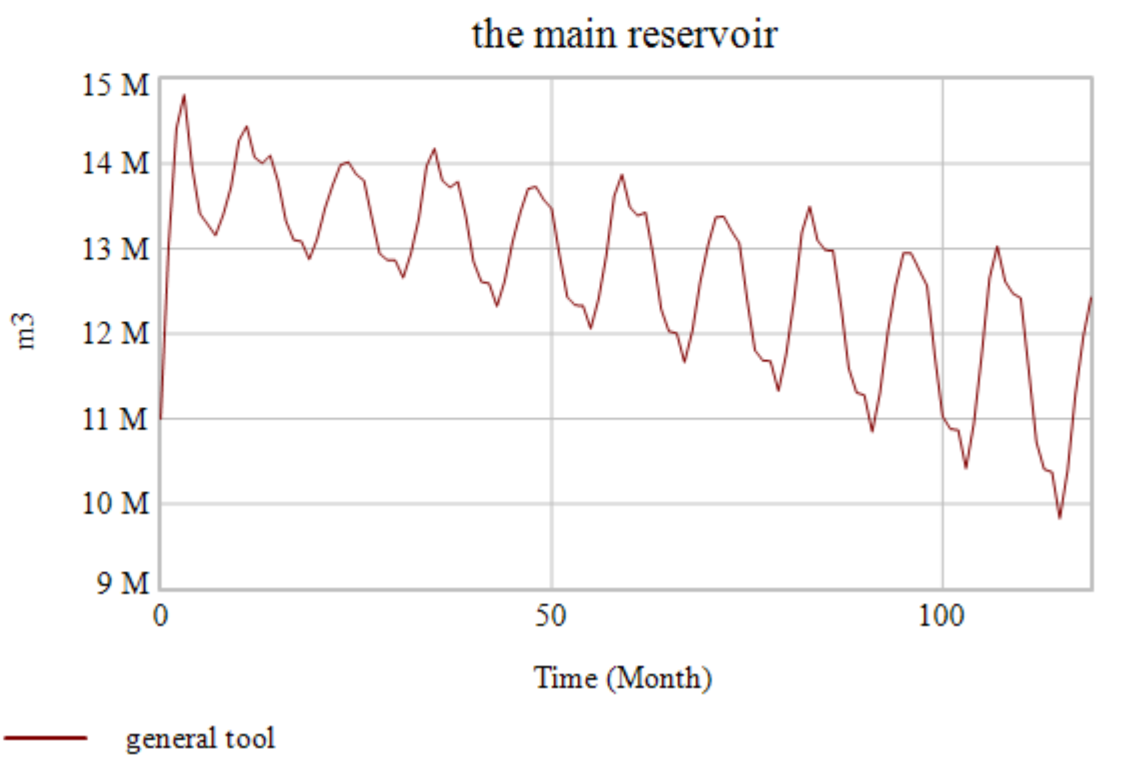


Figure 2. The main reservoir.

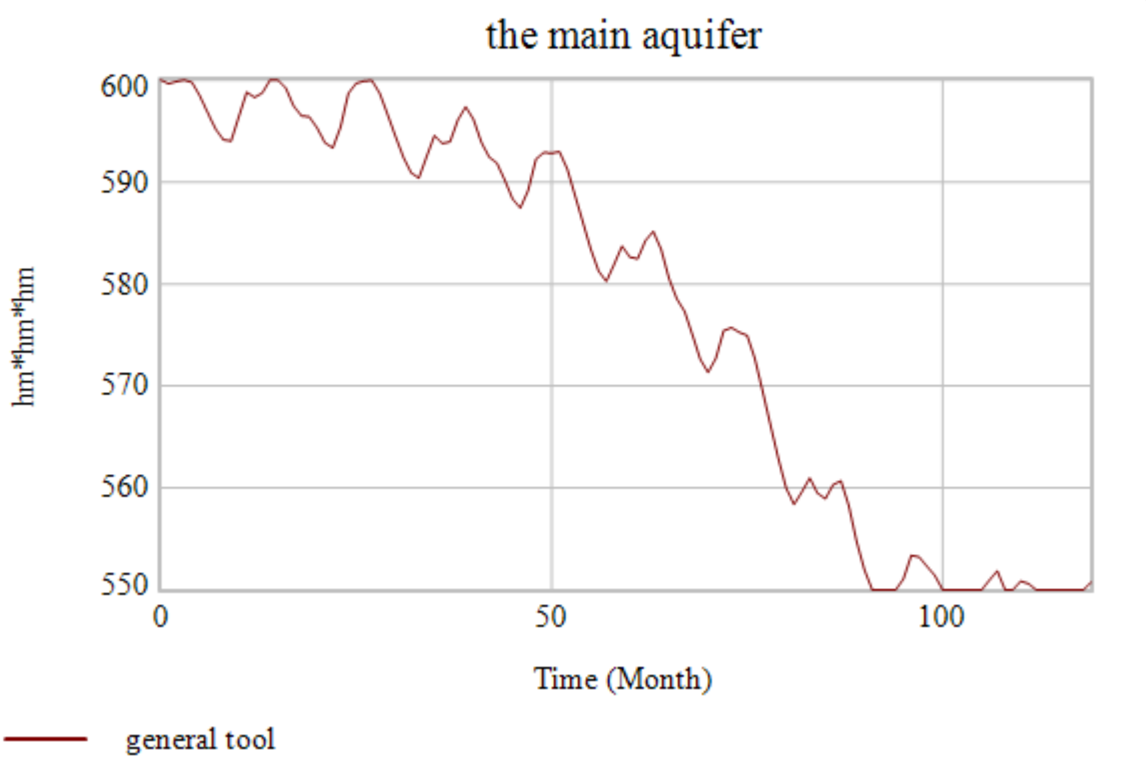


Figure 3. The main aquifer.

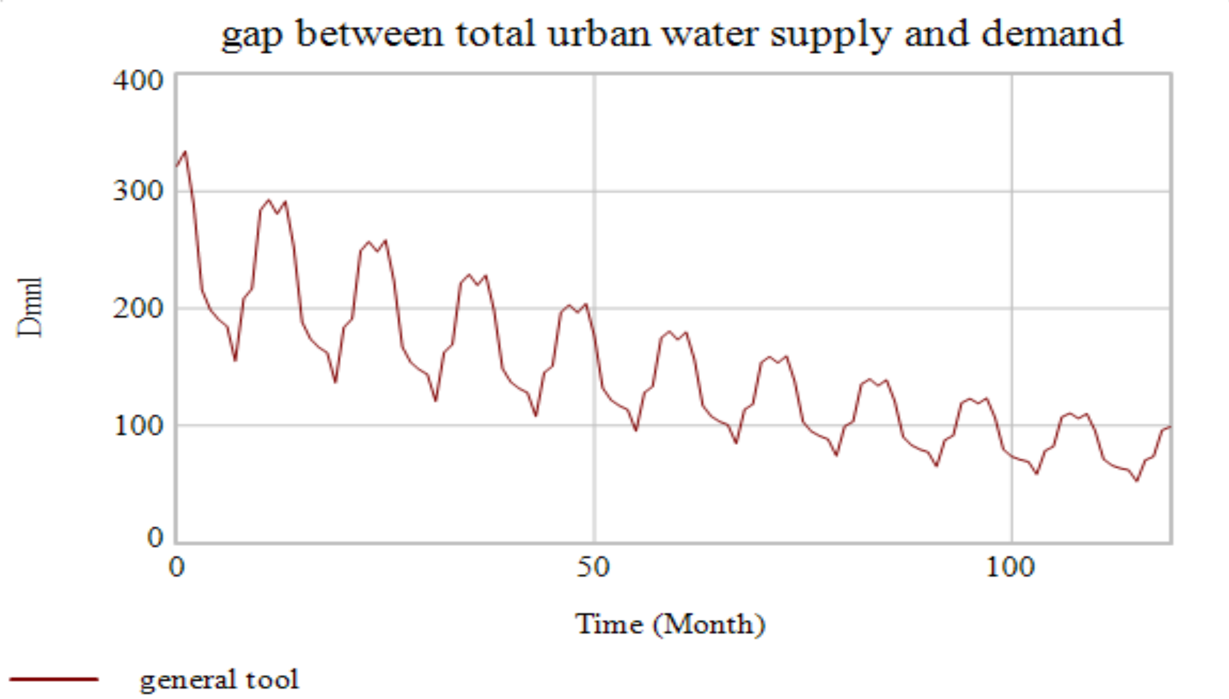


Figure 4. Total balance between water supply and water demand in the metropolitan area.

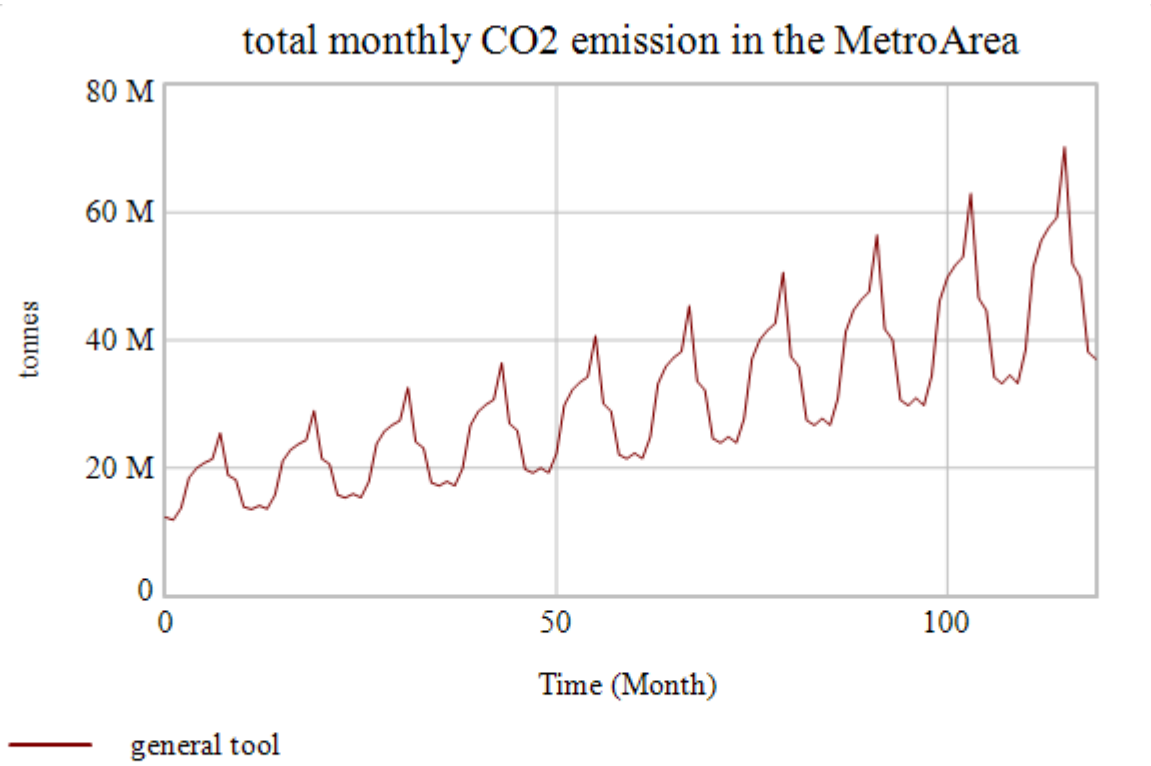


Figure 5. Total CO2 emission in Metropolitan area.

6. An example of application of the tool

6.1. Case study

To provide an example of an application, we showcase the use of the tool in a case study around Benidorm, in Spain. A complete description about the case study area is available on earlier deliverables of the project CLISWELN (Bahri et al., 2018), and on publications emerging from the project (Cremades et al., *in preparation*). As a brief summary, the case study where the model has been applied with showcasing purposes is located in a drought-prone area in Alicante (South Eastern Spain), in one of the most arid places in Europe. Specifically, the area modelled is formed by the touristic hub formed by the coastal municipalities of the Marina Baixa county: Benidorm, L'Alfàs del Pi, Altea, Benidorm, Finestrat, La Nucia, Polop, and La Vila Joiosa. These municipalities share water resources from an aquifer and two relatively small rivers with a dam on each of them.

6.2. Model calibration

Details about the calibration and validation of the data used are already available on other previous deliverables of the project CLISWELN (Bahri et al., 2018). In addition to that content, we elaborate here on specific values where the calibration has been improved. To increase the model confidence, this study shows similar patterns between simulated outputs and observed outputs. There are four main types of outputs such as water transfer, total water demand (urban and agriculture), and energy intensities (kWh/m^3). Similar patterns in the agricultural water demand and urban water demand are also described in this section.

Furthermore, energy intensities described in this study such as energy intensity of groundwater extraction and energy intensity of hot water are comparable to those described in another study (Yoon et al., 2018). For instance, this study finds that energy intensity of repump water and energy intensity of groundwater extraction are about 0.2517 kWh/m^3 and 0.5791 kWh/m^3 while that study (Yoon et al., 2020) found similar values are about 0.2519 kWh/m^3 and 0.531 kWh/m^3 for respective energy intensities.

This study also finds that energy intensity of hot water in touristic and residential areas are about 49 kWh/m^3 and 58 kWh/m^3 respectively. For comparison, another study (Yoon et al., 2018) described energy intensity of hot water in touristic and residential areas are about 53.7 kWh/m^3 (49.8-64) and 54.9 kWh/m^3 (47-66). This means that this study has similar ranges of energy intensity of hot water as described in that study (Yoons et al., 2018).

The Algar aquifer has the significant roles in providing water supply for the Marina Baixa county. This aquifer is especially useful or play important roles during droughts. In our model simulation, it is found that the contribution of the Algar aquifer is about 18% of the total required water supply for Marina Baixa. These findings are similar to data in policy documents detailing the contribution of this aquifer in a 20% (CHJ, 2015).

Based on the system dynamics simulation, the total agricultural demand and urban water demand are about 21.7 hm^3/year and 26.9 hm^3/year respectively. The referred policy document projects demands for 2015-2021 between 21.9 and 24.6 for total urban water demand, while for total agricultural water demand it projects 20.2 and 27 (CHJ, 2015). To sum up, this study can reproduce similar patterns of nexus elements, like water and energy. In this way, the model used in this study is a representation of the observed nexus system in the Marina Baixa, Spain. Owing to this point, the system dynamics model can be used to estimate the impacts of climate change on the nexus in the Marina Baixa.

6.3. Defining scenarios, modelling and communicating results in a complex system

Policy scenarios have been co-produced with stakeholders, during the co-production phase, interviews were carried out as described in Cremades et al. (in prep.) to understand the future scenarios considered by the stakeholders. It is important to understand that complicated scenarios mixing several or multiple policies and other aspects included do not clarify the understanding of the outcome of policy actions, thus, while modelling a complex system like this, it is advisable to explore single changes one by one, and to focus on specific variables of interest linked to the decisions of stakeholders for presenting the results. In this way, a simplified set of results can be explored meaningfully and the implications of single policies can be understood by non-scientific audiences. The focus in these scenarios is on approaching the variables of interest of the land use and water planners when considering droughts, hence the variable of interest is the number of months without water in the system, requiring an external transfer.

Table1. Policy scenarios considered by stakeholders across their visions of the future in the Marina Baixa coastal hub.

Name of scenario	% Change in Urban Land Use	% Change in Irrigated Agricultural Land Use 2100 [2], (Baseline data in ha) [3]	% Change in Agricultural Water Use Per Agricultural Area Unit	Increased Storage Capacity (m3)	Increase in Circular Water Reuse by Agriculture and Cities (exchanged m3/year)
Urban growth	50	0	0	0	0
Irrigation efficiency	0	0	-30	0	0
Agricultural decline	0	-30	0	0	0
Water storage	0	0	0	3.500.000	0
Circular water	0	0	0	0	2.000.000
Baseline reference	0	0	0	0	0

The policy scenarios are explored under plausible climatic futures represented by hydrologic data from diverse models obtained from the sectoral water tool of the e Copernicus Climate Change Service (C3S). In particular, while the C3S Climate Data Store was fully developed, we could use data from the pilot available at SWICCA.EU. In total, data from 10 regional climate model (RCM) and general circulation model (GCM) were used, covering a variety of representative concentration pathway (RCP) scenarios (8.5, 4.5 and 2.6). This is the list of models with the nomenclature RCM_GCM_RCP:

REMO2009_MPI-ESM-LR_rcp85, SMHIRCA4_EC-EARTH_rcp85, SMHIRCA4_HadGEM2-ES_rcp85, KNMIRACMO22E_EC-EARTH, KNMIRACMO22E_EC-EARTH_rcp45, RCA4_EC-EARTH_rcp45, IPSL_CM5AMR_rcp45, SMHIRCA4_HadGEM2-ES_rcp45, REMO2009_MPI-ESM-

LR_rcp26, SMHIRCA4_EC-EARTH_rcp26. This diversity of RCMs, GCMs and RCPs allowed to express the results in the light of the existing uncertainty in the climate signal.

6.4. Results

The sets of results in Figure 1 below exemplify the use of the tool for the scenarios above. Results can be observed one by one as indicated in the guidelines, or can be produced massively in an automatic way by advanced users and then analysed to express the uncertainty across climate and policy scenarios for a key variable in a single plot.

The results in Figure 1 showcase the potential of the tool for exploring climate futures, e.g. in time windows of 20 years, expressed in each column of panels in the figure, and across policy scenarios, expressed in each row of panels in the figure.

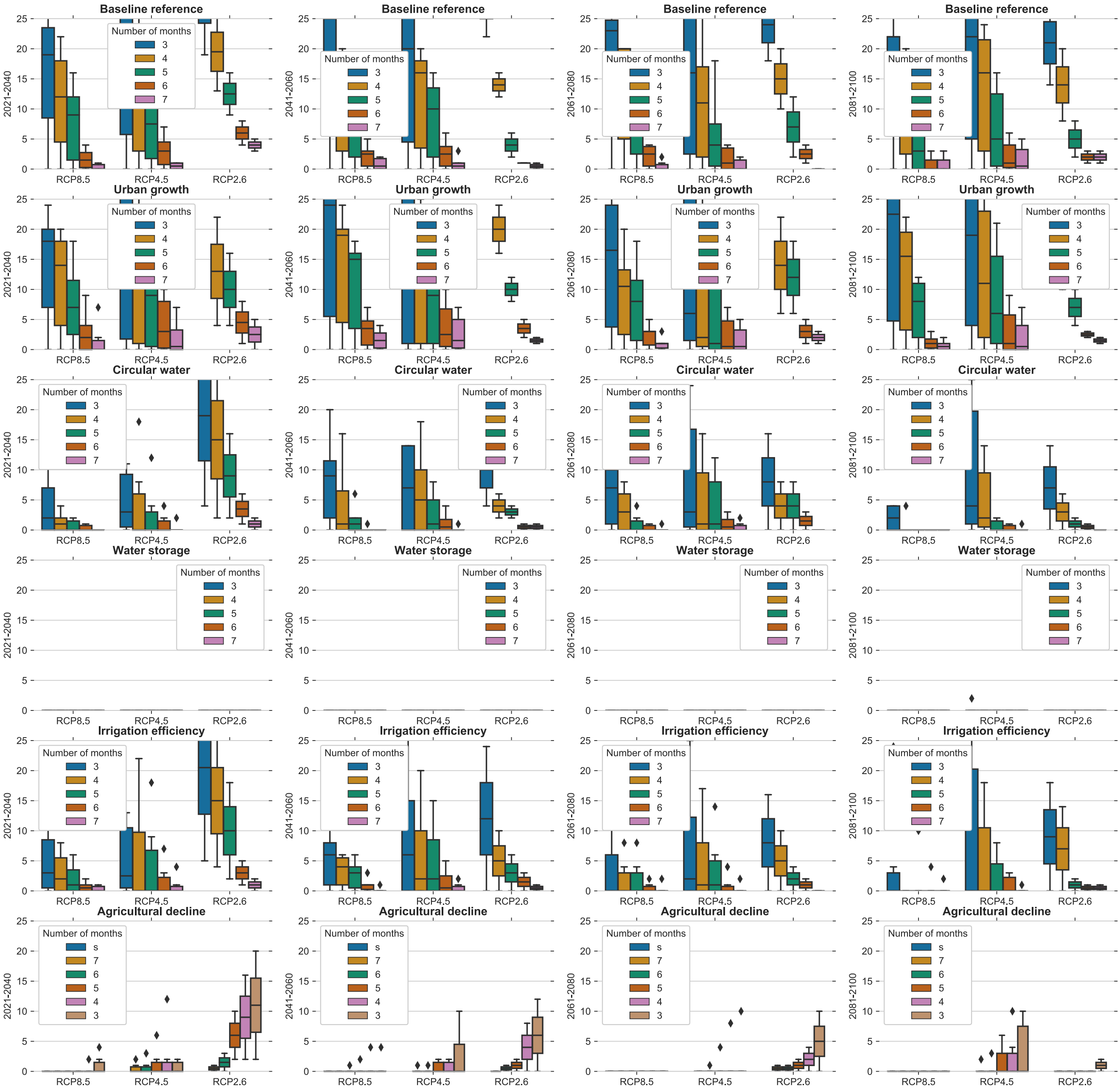


Figure 1: Number of drought (defined as no water supply available) events and their duration in months across policy scenarios (rows) and time windows of 20 years (columns), expressed as box-and-whisker plots for 3 representative concentration pathways (RCPs), each with ensemble members as indicated above.

7. Conclusions

The present deliverable represents a complete detailed explanation of a new tool for the provision of climate services for cities facing droughts. This tool incorporates all elements required to explore cities and their context as a complex system, on the basis of the lens of the water-energy-land nexus. This tool enables climate-related service provision on the basis of its very detailed water component, which includes differentiated water consumption by urban land use densities and by touristic establishments, in accordance with the focus of the case study where the tool has been exemplified.

It is strongly recommended to use the energy intensity of water as an entry point for urban sustainability, because when urban water demands or demands coming from other sectors become too big, or the limitations of water available under climate change become significant, the energy intensity of water increases its values beyond what is economically viable considering the costs of energy. With this cost-based rationale it is possible to find an entry point for sustainable planning of cities under climate change, even in those locations where the short-term agenda is more prominent than long-term climate impacts.

System dynamics as a tool for modelling and interacting with stakeholders have the advantage of a graphical output with sliders that can be modified while the changes in the graphs are observed. This provides an opportunity for creating systems understanding amongst stakeholders, so that they can see themselves the impact of their envisioned scenarios under climate change on their variables of interest.

Tool availability and license

The "Urban Drought Nexus Tool" is an open access software piece and is stored in ZENODO, where future releases would be also announced, the DOI link provided below is also the address of the tool in the ZENODO repository. The tool has a CC-BY 4.0 license, and according to this license you can share and adapt the tool, and only need to give credit, e.g. by including the following citation with a DOI:

Bahri, M., & Cremades, R. (2021). The Urban Drought Nexus Tool (Version 0.1). Zenodo. http://doi.org/10.5281/zenodo.4587632

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