



Bayesian modelling of water resource stress and drought monitoring in southeastern France

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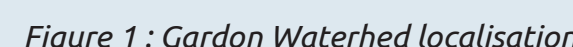
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Scientific and operational problems

The use of Bayesian networks is recent in environmental studies (Kaikkonen et al., 2021). They have mainly been used to compare the **effectiveness** of environmental management policies, **evaluate** the effects of planning on a territory, explore **alternative policies**, or determine the weight of **uncertainties on estimates**. The technical approaches differ according to the objectives (inference, classification, regression). In the case of drought, we use an influence network for the decision making approach. A **Bayesian Decision Network (BDN)** is an efficient tool for incorporating different aspects related to **decision making**, *i.e.* analyzing the expected effects of a management policy while taking into account the uncertainties of each variable.



Data and methods

The computation of conditional distributions is done with the Rjags package (<https://CRAN.R-project.org/package=rjags>). Jags is a program allowing to approximate conditional distributions (Markov Chain Monte Carlo algorithm) in the case of presence of discrete and continuous variables in the network. The Hydenet package

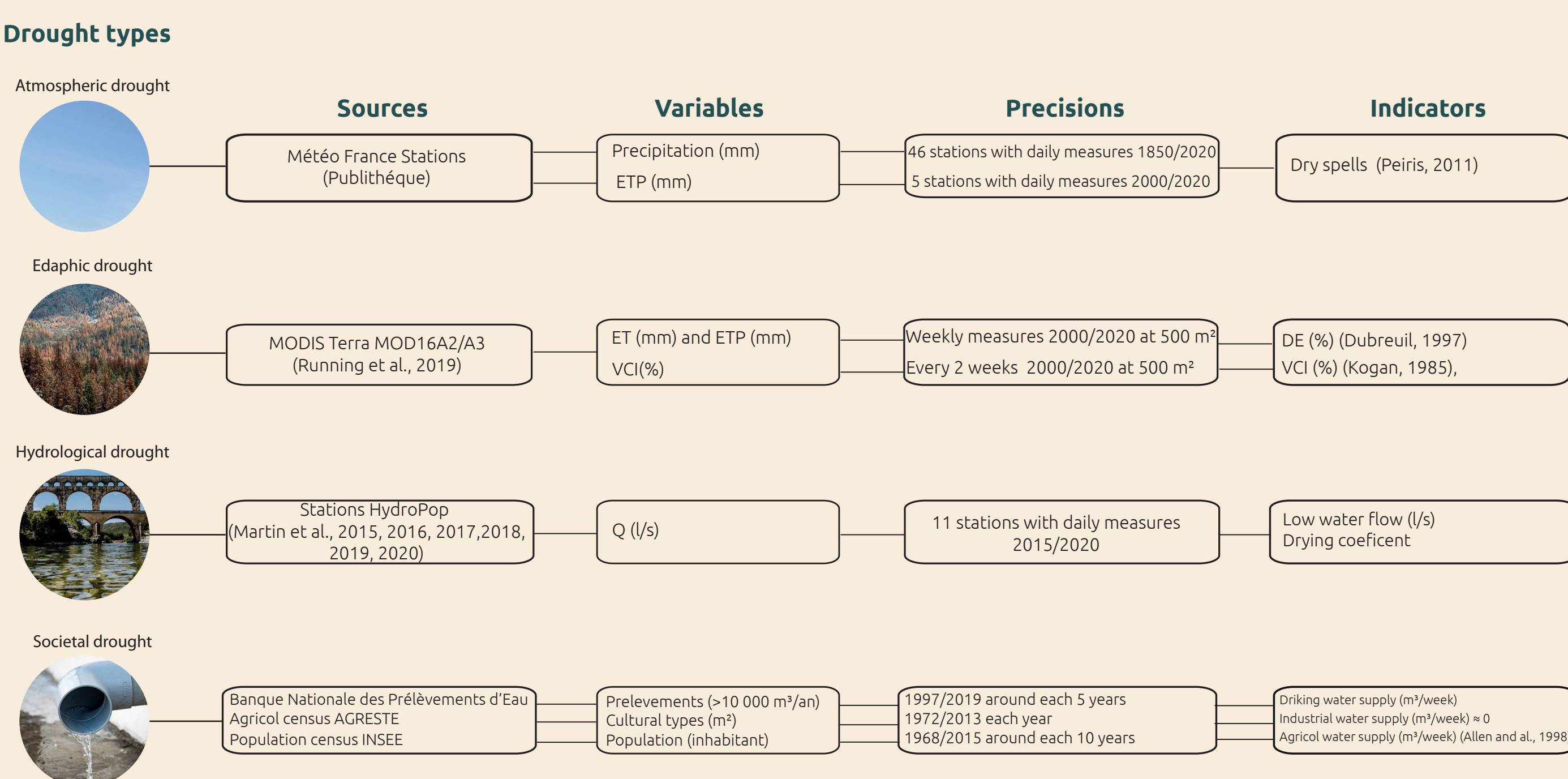


Figure 2 : data and indicators used. With Q water flow; ET Evapotranspiration; ETP Potential Evapotranspiration; VCI Vegetation Condition Index; DE Deficit Evaporation.

First résultats

Drought matrix

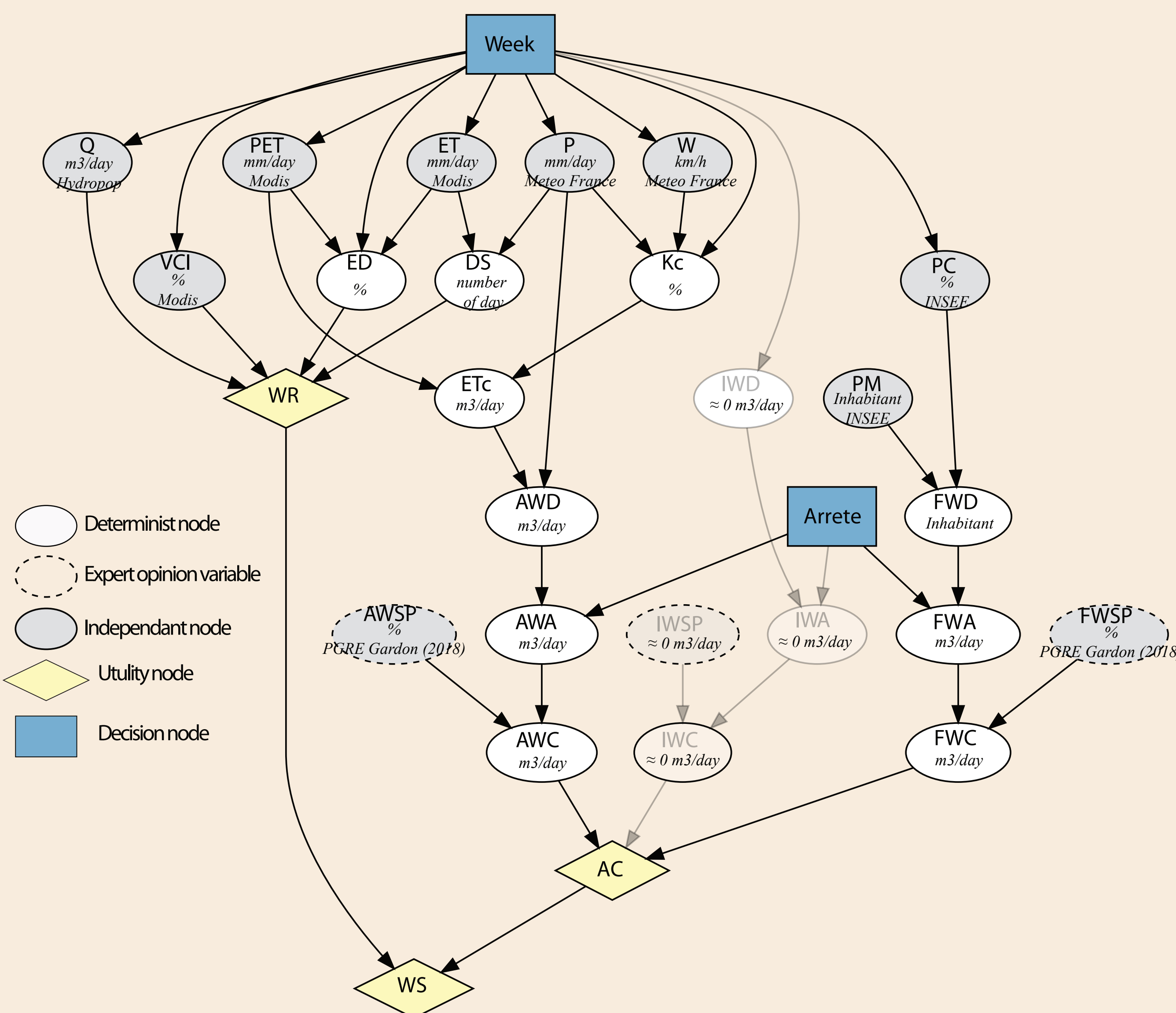
The matrix is defined by the following axes and labels:

- Y-axis (Water resource):** Wet (top), Dry (bottom). Ticks at 3σ , 2σ , σ , \bar{x} , $-\sigma$, -2σ , -3σ .
- X-axis (Anthropogenic Consumption):** High (left), Weak (right). Ticks at 3σ , 2σ , σ , \bar{x} , $-\sigma$, -2σ , -3σ .

The matrix is divided into six regions:

- Normal:** Top-left region (Wet, High consumption).
- Abundance:** Top-right region (Wet, Weak consumption).
- Vigilance:** Middle-right region (Wet/Dry boundary, Weak consumption).
- High stress:** Middle-left region (Wet/Dry boundary, High consumption).
- Drought:** Bottom-left region (Dry, High consumption).
- Normal:** Bottom-right region (Dry, Weak consumption).

Figure 4: First DBN conceptual proposition of water stress in up-stream Gargara Watershed. In order for each node: variable code, unit and source. With Q is water flow, PET is potential evapotranspiration, ET is evapotranspiration, P is cummul precipitation, W is the median wind speed, VCI is Vegetation Condition Index, ED is evaporation deficit, DS is dry spell, Kc is cultural coefficient, WR is water resource, Etc agricultural plant transpiration, PC week variation coefficient of population, PM population of municipalities, AWD is agricultural water demand, IWD is industrial water demand, FWD is fresh water demand, AWPSP is agricultural water system performance, IWPSP is industrial water system performance, FWPSP is fresh water system performance, AWA is agricultural water abstraction, IWA is industrial water abstraction, FWPSP is fresh water abstraction, AWC is agricultural water consumption, FWC is fresh water consumption, IWC is industrial water consumption, AC is Anthropogenic consumption and WS is water stress.



First conclusions, some limitation and perspectives

water deficit monitoring need to be further explored to improve the inference of the environmental branch of the DBN. The temporal hindsight on hydrometric data limits the quality of water deficit estimation for surface rivers at the moment. An estimate of groundwater hydrologic drought is absent. No piezometers representative of the area and measuring over the long term are available. In Cevenne context ("natural rivers"), we have exclu in the model big hydraulic aménagement impact, industrial impact and water quality. Agricol water need estimated by FAO method over-estimate probably the demand and calcul repose on larges simplification hypotheses of plant developpement and on a approximate surface of cultures types. In case the robustness of the model is validated, **environmental scenarios** (effect of climate change on the mode and dispersion of the distribution laws of the indicators) and **social evolution** (increase in population, tourist attractiveness...) will be engaged.

References

- Allen, R.G., Pereira, L.S., Raes, D., Smith, M. (1998) Crop evapotranspiration—guidelines for computing crop water requirements. FAO Irrigation and drainage paper 56. Food and Agriculture Organization, Rome.
- Charré, J. A propos de sécheresse. *geocar* 52, 215–226 (1977).
- Chen, S. H. & Pollino, C. A. Good practice in Bayesian network modelling. *Environmental Modelling & Software* 37, 134–145 (2012).
- Dubruel, V. La sécheresse dans la France de l'Ouest : une contrainte climatique trop souvent oubliée. *Sécheresse* 8, 47–55 (1997).
- Herring, S. C., Hoerling, M. P., Kossin, J. P., Peterson, T. C. & Stott, P. A. Extreme fall 2014 precipitation in cevennes mountains. 12.
- Martin, P. et al. L'étiage 2016 dans les Gardons amont (Cévennes). 55 (2015).
- Martin, P., Didon-Lescot, J.-F., Ayrat, P.-A., Domezguez, J.-M. & Grand, N. L'étiage 2016 dans le Gardon amont (Cévennes). 63 (2016).
- Martin, P., Didon-Lescot, J.-F., Ayrat, P.-A., Domezguez, J.-M. & Grand, N. L'étiage 2017 dans les Gardons amont (Cévennes). *Projet pilote de suivi des débits d'étiage. 3eme rapport sur huit stations temporaires d'étiage et deux stations pérennes*. 59 (2017).
- Martin, P. et al. L'étiage 2018 dans les Gardons amont (Cévennes). *Projet pilote de suivi des débits d'étiage. Premier rapport sur huit stations temporaires d'étiage et deux stations pérennes*. 71 (2018).
- Martin, P. et al. L'étiage 2019 dans les Gardons amont (Cévennes). *Projet pilote de suivi des débits d'étiage. Rapport sur huit stations temporaires d'étiage et deux stations pérennes*. 52 (2019).
- Milano, M. et al. Current state of Mediterranean water resources and future trends under climatic and anthropogenic changes. *Hydrological Sciences Journal* 58, 498–518 (2013).
- Norrant, C. & Douedroit, A. Monthly and daily precipitation trends in the Mediterranean (1950–2000). *Theor. Appl. Climatol.* 83, 89–106 (2006).
- Kaikonen, L., Parviainen, T., Rahikainen, M., Uusitalo, L. & Lehtikoinen, A. Bayesian Networks in Environmental Risk Assessment: A Review. *Integr Environ Assess Manag* 17, 62–78 (2021).
- Yagan, F. N. Drought in the 1980s in the United States as Derived from NOAA Polar-Orbiting Satellite Data. *Bulletin of the American Meteorological Society* 76, 14 (1995).
- Pearls, J. Probabilistic reasoning in intelligent systems: networks of plausible inference. (Kaufmann, 2008).
- Peiris, T. Critical Evaluation of Dry Spell Research. 11, 8 (2011).
- Phan, D. T., Smart, J. R. C., Capon, S. J., Hadwen, W. L. & S. H. 2010. Applications of Bayesian belief networks in water resource management: A systematic review. *Environmental Modelling & Software* 85, 98–111 (2016).
- Running, S. W., Mu, Q., Zhao, M. & Moreno, A. User's Guide MODIS Global Terrestrial Vegetation Analysis (ET) Product (MOD16A2/3A and Year-end Gap-filled MOD16A2G/3AGF). (2019).
- Running, S. W., Mielke, T. L., Torresan, S., Abdo, A. & Marcomini, A. Reviewing Bayesian Networks potentials for climate change impacts assessment and management: A multi-risk perspective. *Journal of Environmental Management* 102, 320–331 (2017).
- Stagge, J. H., Kingston, D. C., Takkelsen, L. M. & Hannah, D. M. Observed drought indices show increasing divergence across Europe. *Scientific Reports* 7, (2017).