Summary

Rainwater harvesting (RWH) has multiple benefits in the field of the sustainable management of urban water, and several institutions have suggested this practice as a way of improving urban water management as a strategy to adapt to climate change.

One of the aspects considered in this thesis is the role of the temporal variability of rainfall. This thesis studied the impact of different temporal patterns of rainfall, based on a national scale analysis that considered more than 3400 rain gauge stations. The thesis shows the role played by the coefficient of variation of the daily rainfall depth on the RWH performance and on the design of the RWH tank capacity. This issue was never studied before for the whole Italian territory. The present work made use of the rainfall coefficient of variation and outlined how to consider it in the design stage of RWH systems.

Next, analytical expressions for three indicators of the efficiency of RWH systems have been derived, which highlight the key role of the roof area per capita parameter. These indicators were never expressed in the literature through equations but as a result of numerical simulations. The generality of these expressions (they can be used for any place) is an advantage, which points out the relationship of each indicator with the annual rainfall depth and the roof area per capita parameter. Municipalities can use these analytical expressions to plan rainwater harvesting in cities.

The analysis of RWH at the district and urban scales is rare in the scientific literature. This thesis estimated the potentiality of RWH in the city of Turin, for both domestic indoor uses and outdoor uses such as the irrigation of public green areas. Non-dimensional graphs were built for the design of RWH systems in Turin, not only for domestic use, but also for irrigation and street washing, which allow also to consider a portion of the rainwater collection area.

The effect of different sources of variability on the RWH performances and their relative importance have also been studied: i) the variability of the water demand over different time periods, ii) the variability of first flush, both regarding the effect of consecutive rainy days and the volume of first flush that is actually diverted; iii) the length and period of the rainfall series used in the simulations. This aspect is important for several reasons. First, because only one specific value for the water demand is usually considered in the analysis of RWH performance and, in addition, water demand is considered constant over time. Second, the value of first flush to be diverted is widely discussed in the literature, but its implications on the water saving potentiality have never been analysed, neither at the building scale nor at the urban one. Third, the relative importance of different sources of variability have never been compared, even if in some case is very important. In the case of the minimum length requirement of rainfall series, for instance, their importance can be lower than the impact due to the diversion of different values of first flush.

The effects of climate change on the rainwater harvesting performance is a very current topic that has been analysed in this thesis and that has never been studied in detail over the Italian territory. The research in this thesis focused on the effects of climate change regard both the future performance of existing RWH tanks and the change in the optimal tank capacity required to face with future climate conditions.

The reduction of storm water flow is another important benefit of RWH that was here analysed under two perspectives. The former considers the district and urban scales using real extreme events. Past studies were usually focused on the building scale, however the impacts at higher scales need to be studied because the urban flooding problems occur at higher scales than the building one. The second perspective evaluates the return period of the rainfall events that can be retained by RWH tanks. The return period is a widely used parameter for the design of hydraulic infrastructure and it has not included in the design of RWH systems yet.

Rainwater harvesting has important consequences also on saving electrical energy, because it reduces the requested discharge values. Energy saving in the water supply sector, however, can be obtained in different ways. This thesis considered the effects of different solutions for the pressure management in private pumping systems, highlighting the key role of the residual pressure head at the connection point between aqueduct and houses.