Abstract

Natural hazards are becoming more and more a global issue since the negative impacts that are causing on the environment and the entire biological sphere. Nowadays, these phenomena are even more exacerbated by the ongoing climate changes and environmental degradation that are affecting, although with different severity, the whole planet. Among others, one of the hardest hit areas is the Sahel, the region that embeds all arid and semi-arid countries bordering the great Sahara Desert. In these regions, climate-related extremes are increasingly threatening the basis for developing modern societies, from securing the livelihood to the economic expansion. Besides the rising frequency with which natural catastrophes occur, the relentless growth of the population makes a large share of it progressively more exposed and vulnerable to these threats. Notwithstanding these facts that are already taking place among the African communities, future projections are depicting worse scenarios in which the hydrological framework will be characterized by an intensification of precipitation, higher temperatures, and longer dry spells. Thus, impelling is the necessity of developing adaptation and mitigation strategies to face anthropic and climate-related impacts.

In this context, the main purpose of the dissertation is to provide a comprehensive analysis of suitable strategies to deal with hydrometeorological hazards affecting the Sahel, especially against floods and droughts. All addressed investigations are characterized by the twofold purpose to be: (a) contextualized, i.e. indigenous knowledge has represented the starting point of each insight and analysis; (b) advanced, i.e. enhanced numerical models have been implemented to examine and meet the goal. The goals pursued in this thesis are (i) to provide all the preliminary analyses accomplished for the implementation of the first Early Warning System for flood alertness at the service of riverine populations of the Sirba river; (ii) to assess the capabilities of indigenous rainwater harvesting techniques (RWHT) to be adopted as an effective strategy for flood mitigation; (iii) to comprehensively investigate the benefits induced by using RWHT in mitigating the plant water stress induced by rainwater shortage.

Firstly, watershed characteristics and the temporal evolution of river flow are essential data to understand the river behaviour and set up mitigation and prevention strategies against flooding. This thesis provides the recalibration of the rating curves and the updating of the discharge dataset of the Sirba River. The analysis of the updated flow time series underlines the rising trend in flood frequency and intensity. Moreover, a new changepoint into the dataset is detected in 2008, which identify the beginning of an epoch characterized by severe floods. The behavioural alterations of the river caused by land cover and climate changes are depicted through the calculation of its flow duration curves. Then, the flood hazard assessment of the Nigerien reach of the Sirba river is presented. The flood-prone areas are delineated and classified in conformity to the four alert classes currently used in Niger. The definition of the hazard thresholds exploits advanced non-stationary method able to consider the changes in the basin response to hydrometeorological extremes over time.

The second part of this dissertation offers a new concept: the use of indigenous agricultural practice for reducing runoff and mitigating flood hazard. To confirm such insight, the thesis analyses the hydraulic performances of the most used RWHT in sub-Saharan regions in terms of runoff reduction and infiltration increase. HEC-RAS and Iber are the numerical models chose to study processes occurring in the runoff formation and propagation. The simulations show that half-moons organized in staggered lines are the best configuration in reducing runoff. The right design may lead to runoff retention up to 87% and double the infiltration. Thus, the runoff collected into the field is water that does not immediately reach the river during rainstorms. The application of these techniques enhances the hydrological efficiency of the farmland bringing a noticeable reduction of the runoff coefficient.

The third part examines the capacity of RWHT in mitigating soil water stress prompted by water scarcity. A new methodology is proposed to compute the evapotranspiration rate into a two-dimensional distributed hydrological model used to simulate the water balance of typical Sahelian farmlands. This method expands the application field of such analyses in a context typically marked by data scarcity. Intercepting and storing overland flow, RWHT increase the water content in the root zone and the right design can even bring the water stress to zero. Furthermore, outcomes reveal that RWHT may lengthen the growing period up to 20 days, contributing to prevent crop failure.