Human impact on river basin hydrology:

Stream flow is an essential component of water resources throughout the world, yet it has been profoundly influenced by both climate change and human activities at local, regional and global scales. Climate change, including shifts in precipitation, temperature, air humidity, and wind speed, could be the primary determinant that affects the quantity and pattern of stream flow directly or indirectly. Human activities, on the other hand, might alter stream flow indirectly via effects on climate (e.g. greenhouse gas emissions) or directly via changes in the landscape or infrastructure. While many studies have revealed that climate and human activities jointly affect the stream flow, it is highly necessary to explicitly quantify how stream flow responds respectively to the changes in climate variables and human activities. Such information provides important insights into future water resources planning and management regarding accurate prediction and effective coping with anticipated changes in stream flow suffering from climatic and human impacts.

Hydrologic patterns and flow regimes

The stream flow response to rainfall is affected by many attributes, including the area's climate, topography and geomorphology, which account for hydrological processes of precipitation, snowmelt flow, surface runoff and groundwater runoff. The complex interactions between these attributes and the natural hydrological processes induce complexity in hydrology, thus cause variability of stream flow in space and time.

River flow regimes describe the temporal patterns of flow variability. They can be described by five stream flow components: magnitude, frequency, duration, timing, and rate of changes of flows. Magnitude describes the amount of water moving past a fixed location per unit time. Frequency, also described as exceedance probability, describes how often a flow above a certain magnitude recurs over some specific time interval. The exceedance probability can be calculated by a statistical analysis based on a continuous dataset of flows and can be illustrated by the flood frequency curve. Duration is the period of time relative to a specific flow condition, which can be defined associated with a particular flow event or a composite described over a specified time period. Timing refers to the occurrence of flows within the annual hydrologic cycle. Detection of significant shifts in timing is important, especially the timing of peak and base flows, which have ecological significance. Rate of change describes how quickly flows change from one magnitude to another. The two extremes of rate of change are flashy (unstable) or stable (slow).

The flow regime has played a vital role in the hydrological, environmental and ecological aspects in understanding stream flow variability under changing climate conditions and human activities, exploring accurate environmental monitoring, and proposing effective water allocation decisions. The five hydrologic metrics describing the full range of flow regimes have been extensively used throughout the world to address hydrological, environmental and ecological questions. There exist diverse studies on flood frequency estimation and drought assessment, characterization of the spatial variation of flow regimes, hydrologic model calibration and validation, detection of flow regime alterations by human intervention and under changing climate conditions, hydrologic trend detection, environmental flow assessment, and investigation of hydrological changes on biological and ecological processes.

The stream flow characteristics can be reflected from various aspects of flow regimes, including the seasonal patterns of flows, the timing, frequency and duration of extreme flows, the flow variability at different time scales. To characterize different aspects of flow regimes, a number of hydrologic indices have been developed by researchers. In the early studies, researchers mainly focused on average flow conditions, seasonal distributions of monthly flows, flow and flood frequency duration curves, and variations of annual discharge.

Impacts of climate change and variability on flow regimes

Under the global background of climate change, the average temperature of the earth's surface in China has risen by 1.1 degrees Celsius over the past century (1908-2007) and is estimated to have annual average temperature rise by 3.5 degrees Celsius by the end of the 21st century. Climate change is a significant long-term shift or change in weather conditions identified by changes in temperature, precipitation, winds, and other indicators which usually persist for decades or even longer (IPCC, 2007). Climate variability includes all forms of fluctuations of the climate system (i.e. deviations from long-term statistics) and can be considered as a natural phenomenon and happens occasionally from time to time (e.g. a month, season or year). Climate change is the longer term change on the decades or century timescale and climate variability is variability on shorter timescales, which can arise from internal processes like ENSO or external sources like solar variability.

Changes in streamflow characteristics can be influenced by climatic factors. Climate change and variability may cause hydrological changes include earlier snowmelt, change in streamflow timing, altered maximum and minimum flows, and intensified floods and droughts. According to the Intergovernmental Panel for Climate Changes (IPCC) Fifth Assessment Report, anthropogenic climate change is very likely to lead to increases in the intensity and frequency of temperature and precipitation extremes (IPCC, 2014), thus may alter hydrological processes including evapotranspiration, surface runoff, timing and magnitude of stream flow, and flood events (van Pelt and Swart, 2011, McLaughlin et al., 2014). In recent decades, the impact of climate change and variability on stream flow has been well documented, and many studies showed that the variations of precipitation, evaporation and temperature may alter stream flow. Precipitation is the main cause of variability in the water balance at temporal and spatial scales, and changes in precipitation are the most important climatic variable influencing stream flow. Changes in precipitation in terms of the intensity, duration and distribution may induce great variability in flooding, such as floods of longer duration, or floods of greater magnitude but shorter duration. It has been documented that climate change and variability, especially due to precipitation, temperature, evapotranspiration and sea level change, can attribute to the changes in the magnitude and frequency of flooding. In addition, both changes in precipitation and evaporation are strongly influenced by changes in temperature. Potential evapotranspiration (PET) indicates the amount of evaporation that would occur if a sufficient water source were available. An increase in temperature can cause an increase in the vapour pressure deficit, resulting in a decrease in relative humidity and an increase in PET. Thus, the increase in PET results in an increase in evapotranspiration (ET) rate, which indicates higher available moisture levels permit.

Impacts of human activities on flow regimes

This section reviews the facts that natural flow regime changes under human activities, and how it might be affected under different types of human activities, including urbanization, land use/cover changes, and structure interventions (such as water withdrawal, hydraulic construction and operation, et al.). Moreover, this section presented the impacts of dam constructions on natural hydrologic regimes all over the world and the consequences of flow regime alterations. Stream flow is the flow of water in streams, rivers, and other channels, which is a complex process of water cycling through the atmosphere, land cover, soils, and geologic formations, therefore, except for the changes in climate change and variability, human activities also affect the stream flow in respect to the spatial and temporal patterns. Global river systems have been experiencing significant changes under anthropogenically driven changes like water abstractions, land cover changes, and hydraulic structure constructions. In many areas of the world, stream flow is being increasingly affected to some extent by the influence of human activity. Cultivation, urbanization, and other such human activities mainly affect the hydrologic processes via land use/cover changes, therefore, have indirect effects on stream flow. It is proved that land use/land cover changes can alter the ET, groundwater discharge, and surface runoff.

Whether flow is increased or decreased depends on the type of human activity. For example, urbanization tends to result in lower infiltration capacity through expanded impermeable surfaces such as roads and buildings, and thus precipitation is re-captured by artificial structures in the form of direct runoff, which rapidly converts into stream. Usually, the stream flow, being moderated by the high infiltration rate, will increase to a certain level and then drop back to the base level. As urbanization increases the amount of impervious surface, the infiltration is limited by the expanse of impervious surfaces, thus results in lower base flow and higher peak flows and volumes. Fig. 2.1 shows that the hydrographs before and after urbanization undergoes changes in both timing and magnitude, and indicates that the rising and recession limbs of storm hydrographs become higher and steeper for urbanized streams than that for non-urbanized streams, due to faster and greater runoff and decreased infiltration.

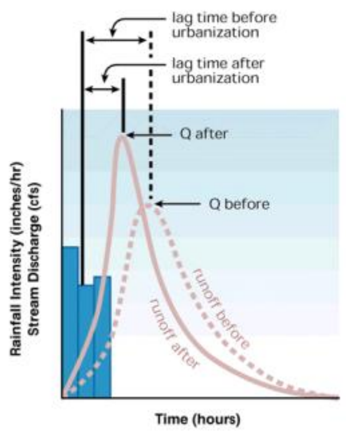

Fig. 2.1 A comparison of hydrographs before and after urbanization (blue bars indicate rainfall rate and timing).

It is evidence that in monsoonal Sri Lanka, the conversion of tea plantations to other types of land use without appropriate soil conservation measures in the upper Mahaweli catchment, can attribute to a decrease in dry season flows. It is stated that the inappropriate soil conservation measure accounts for 74% of the total reduction in mean annual stream flow in a small catchment in the Loess Plateau . In the Araguaia River in east-central Brazil, 55% of the native vegetation has been removed because of the deforestation, which has significantly modified the hydrological and morphological characteristics. The increased discharge from 1970s to 1990s was more ascribed to the deforestation than climate variability.