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Resilience of Watershed Systems to Climate Change

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Climate change can have significant impact on watershed systems. These impacts are expressed in the form of impairment in water supplies, increase in natural disasters, increased exposure to waterborne contaminants, water quality issues, species extinction, biodiversity loss, economic losses, and rapid resource exploitation. The intensification of the hydrologic cycle resulting from climate change result in increased storm flows, intensity of droughts and floods, and changes to the Eco hydrologic processes of watershed systems. Impacts vary depending on the geographic location and state of the watershed system. For example, some watersheds in dry regions of sub-Saharan Africa face threats of severe droughts and desertification, while other watersheds with high moisture regime like northeast India face increased intensity in precipitation and higher flood regime. These impacts result in changes to the Social and Ecological Systems (SES) [1] of watershed and create transitory or permanent changes in watershed systems. The magnitude of impacts varies depending on the resilience [2] of the SES [3] of the watershed system. Resilience of watersheds reflects the ability of the SES to absorb climatic disturbances and to reorganize itself to maintain itself within the current domain or transform to another new stable domains in both ecological and social dimensions [4]. This is specified resilience as this reorganizational ability is specific to climate change and not to other stressors that watersheds face.

Climate change can alter the socio-ecological structure and processes in watersheds depending on the magnitude, duration, and frequency of the impact. The state of a watershed that is in a stable domain can remain within the basin of attraction or transform to another stable basin depending on the degree and nature of impacts. For example, cropping system within a watershed can recover from short-term changes in precipitation depending on existing social and ecological mechanisms to adapt to these changes. Thus the watershed structure and function remains in the stable domain (basin of attraction) after the impact. If the watershed experiences larger and sustained impacts, the system can transform to a new basin of attraction with altered social and ecological structure that emerged from the impact. Natural disasters like typhoons, tsunamis, biological invasions, major droughts, and heavy floods that are severe in intensity have a high damage potential that can alter the basic structure and function of SES in watershed systems that are vulnerable and low in resilience.

Adaptability of SES systems to climate change reflects the capacity to learn, combined experience and knowledge, adjust responses, and continue developing within a stability domain. In watersheds, the capacity to learn is the ability of ecosystems to adapt to new environmental conditions and capability of governance mechanisms to use and adapt to emerging changes and information. Adaptability of watersheds also reflects potential adjustments and changes to structure and functions in order to stay in the stability domain of the watershed SES. Changes in cropping practices to suite prolonged dry conditions, changes in watershed land use, and improvement of governance mechanisms are examples of adaptability of watersheds to water deficit conditions. Transformability of watershed SES refers to the capacity to create a fundamentally new stable domain [5]. For example, River geomorphology, Riparian land use, and Floodplain governance rules can change to stabilize systems exposed to major floods in a floodplain.

There is a need for renewed understanding of resiliency, adaptability, and transformability of watersheds through social and ecological research and assessment that spans multiple time periods and at multiple scales. Management of watersheds to climate change requires a thorough understanding of state and dynamics of the SES in response of climatic change. Watershed components that increase resilience often correlate with practices that improve the ecosystem health of a watershed. For example, green infrastructure in watersheds is a critical factor in defining resilience of a watershed to climate change. With better functioning green infrastructure in urban watersheds, hydrologic intensification can be mitigated. In watersheds, extent and distribution of open space can influence vulnerability of the watershed to climatic impacts and this is an important factor to consider in enhancing resiliency. On the socio-economic side, institutions that adapt to new and emerging conditions of climate influence are capable of handling the impacts. Stakeholder involvement in resource decisions is another factor influencing watershed resilience. Trans-disciplinary research and strategic approaches that involve innovative worldviews [6] could be used to integrate efforts toward sustainability of watershed systems. Information dissemination and decision support systems related to a watershed can enhance resilience to handle adverse impacts of climate change.

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