COMMENTARY

Tropical mountain wetlands

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Water scarcity is an alarming problem in densely populated tropics and subtropics that are located in hydrologically sensitive zones. Mountains will play an increasingly important role in these regions, particularly in sustaining water availability in the future[1]. They are often termed as 'water towers', important for water cycling, and many major rivers of the world originate here[2]. Mountains also support a number of distinctive wetlands such as riparian areas, marshes, peatlands and wet meadows, over short distances as the hydrological characteristics change at small spatial scales. Additionally, varied landforms, biogeochemical environment, slope, elevation and climate gradient also influence mountain wetland characteristics[3,4]. These wetlands are usually small in size, and depending on the hydrology are either forested or marshy[5]. Mountain wetlands can be generally classified into three major types – (i) herbaceous wetlands with mineral soils, including marshes, wet meadows and salt flats; (ii) peatlands (fens and bogs), and (iii) riparian wetlands along streams[3].

The high elevation regions of mountains, 3000 m amsl, support wetlands located between continuous natural forest border and permanent snowline, characterized by the existence of a permafrost layer and a predominantly grassland and shrub vegetation[6]. In India, such wetlands have been described in Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh[6]. These wetlands generally occupy confined valleys widened by glaciers. The wetlands in lower elevation (<3000 m amsl) mountain ranges typically occupy streamside in narrow valleys, where alluvial soil deposits function as aquifers that store and supply water to the wetlands. Further, intermountain basins and valleys may also support large wetland complexes due to their flat topography and run-off from the surrounding mountains[3,7]. Hydrology in high-elevation areas is largely dominated by snowmelt, and glacier and permafrost meltwater, whereas it is rainfall-driven in the lower elevation mountains[8]. In India, the low elevation freshwater swamps (4C/FS1 of Champion and Seth)[9] occur mainly in the low-lying valleys of the Western Ghats and foothills of the Himalayas. These swamps remain inundated for a large part of the year and support characteristic vegetation types[10]. Whereas the Himalayan high-altitude wetlands and *Myristica* swamps of the Western Ghats have been fairly well studied, there is little comprehensive information regarding the extent, distribution and condition of wetlands located at elevation between 1000 and 3000 m amsl. This is also the case globally, where there have been a limited number of studies for such wetlands, particularly in the tropical mountain regions[11].

While the tropical montane cloud forests or shola habitats of the Western Ghats located between 1400 and 2400 m amsl have been recognized as centres of high diversity and endemism, the wetland habitats in these forests have been rarely described or designated as distinct entities[12,13]. These include the wetland ecosystems of high-elevation Western Ghats, including Anamalai, Nilgiris and Palani ranges. The western slopes of these ranges receive nearly 5000 mm of rainfall[14]. High precipitation, humidity and cool temperatures are conducive to the occurrence of a large number of wetlands in these ranges. One such type of wetland found within these ranges is peatland, characterized by accumulation of partially decayed organic matter[15]. Although most tropical peatlands are located at low altitudes (<30 m amsl), a small proportion has been reported to occur in the mountains of Africa, South America and Papua New Guinea[16]. Likewise, peat deposits have been observed in the Western Ghats, largely found in the valleys associated with small streams, where low temperature, anaerobic conditions and frequent waterlogging favour peat formation[17]. The extent of occurrence of peat occurring in concave depressions associated with streams was mapped by Thomas *et al.*[18] in the Nilgiris. Apart from peatland, 'montane swamps' have also been observed in the upper Nilgiris, restricted to flat surface valleys. Floristic studies have shown that these wetlands represent a biologically diverse assemblage of species and are dominated by endemic and endangered herbaceous species[19–21]. Barring a few isolated studies, there is an overall lack of research and the consequent absence of attention towards the conservation of these wetlands as distinct entities.

In order to bridge this paucity of information on the wetlands of the Western Ghats and to initiate a dedicated programme for the conservation of mountain wetlands in Tamil Nadu, a preliminary survey was conducted in Palani Hills, Western Ghats. Two wetlands, namely Konalar (10°09′N and 77°21′E, 2220 m amsl) and Paricombai (10°14′N and 77°22′E, 2100 m amsl) located in the recently established Kodaikanal Wildlife Sanctuary were explored. These wetlands were found to be largely dominated by sedges as well as rushes with grasses on the periphery and minimal open water habitat. Direct and indirect evidence of mammalian fauna indicated the presence of leopard, wild dog, Asian elephant, sambar deer, gaur, barking deer and wild boar within the immediate periphery of these wetlands. The area surrounding the wetlands showed extensive growth of exotic species, including pine and wattle. In addition, large-scale invasion by *Ageratina adenophora* (Spreng.) King & Robinson was noted. It was also noted that the Forest Department had in recent times embarked upon measures to conserve the wetland by phased removal of invasive and exotic tree species, undertaking shola restoration, and establishing fire breaks.

The Konalar wetland (Figure 1) lies nearly 6 km southwest of Berijam Lake near Kodaikanal. It was described by Bera and Farooqui[22] in their vegetational history study as a swampy area, approximately 1000 m long, 600 m wide and around 2 m deep. This wetland ultimately drains into River Amravathi. Such wetlands can be described as head water wetlands which are a source of streams. Headwater wetlands are critical

Figure 1. A view of the Konalar wetland.

as they determine the nutrient state and maintain water quality of downstream systems, store and regulate water flow, moderate run-off and prevent soil erosion[23]. Further, the unique high-altitude conditions of these wetlands contribute to high levels of endemism[24].

One of the major threats to such wetlands is conversion from one form to another resulting in the loss of hydrological functions, habitat and biodiversity. Evidently, the problem in such cases does not remain limited to mountains, but amplifies downstream, resulting in water and sediment pollution and reduced water supply[25]. Another major threat is of global warming and mountain wetlands have been predicted to be among the most sensitive to climate change. Montane wetlands serve as a critical habitat for a large number of species, many of which are adapted to particular hydrologic regimes and are therefore projected to shift upwards under future climate change scenarios[26].

Wetlands of Palani Hills despite being located within a protected area, where presumably anthropogenic influence is limited, are deteriorating due to the invasion of exotic woody species such as *Pinus* sp., *Acacia* sp. and *A. adenophora*. Mohandass[20] reports that in the Nilgiris montane swamps, profusion of *Pinus patula* was detrimental to the growth of indigenous species in the swamp community.

Despite their significance, research on mountain wetlands is challenging mostly because of their small size and often being difficult to map using standard wetland inventory techniques[27]. Also, being part of a large landscape, mountain wetlands are influenced by seasonal processes which operate at a variety of scales in terrestrial and aquatic environments, making their study difficult[28]. However, it is critical to study and conserve the mountain wetlands as they are one of the first places of water capture in the hydrological cycle. Our preliminary studies reiterate this, and also highlight the fact that wetlands in Palani Hills are significant for sustaining biodiversity, especially herbaceous plants, birds and mammals. Appropriate actions must therefore be undertaken for the mountain wetlands to continue to function as water towers for the surrounding areas. Further, it is important to incorporate mountain wetlands in plans for integrated watershed management and forest conservation, in addition to involving local communities for sustainable wetland use in the region[4,28,29]. As a follow-up of the initial assessments in Palani Hills, it is proposed to initiate a comprehensive action research programme in the Western Ghats of Tamil Nadu, on the distribution, characterization and understanding of the hydro-ecological dynamics of mountain wetlands, so that benchmarks can be evolved for the restoration and conservation of these critical yet least studied habitats.

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