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Sacred Groves in Peri-Urban Areas: An Opportunity for Resilient Urban Ecosystems

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Abstract: *This paper examines the significance of conserving sacred groves in maintaining the resilience of urban systems. Peri-urban areas that house natural or semi natural ecosystems provide supporting, provisioning, regulating and cultural ecosystem services. The resilience of these systems has an immense impact on the adjacent urban and rural areas. The landscape of India is dotted with sacred groves, large and small. These are remnants of the original forest vegetation that were conserved through cultural practices of ancient nature worshipping societies. Cultural homogenization and the demand for real estate have caused the disappearance of sacred groves at an alarming rate. Within the metropolises of India, these sacred groves remain only as shrines, with no forest vegetation cover whatsoever. Peri-urban areas and rural areas support the remaining sacred groves. This study examines the geographical location of sacred groves with respect to topography generated stream network patterns. The general curvature of the sanctum of sacred groves was calculated. Sacred groves are located in regions where stream flow originates, or in head water regions. The curvature values of these locations indicate surface flow accumulation characteristics. Significance of head water accumulation regions in maintaining the overall health of the watershed is well understood. Thus, sacred groves in peri-urban and rural areas present a unique opportunity in maintaining the resilience of these systems. Systematic conservation of sacred groves will result in a network of accumulation areas under forest cover in urban areas. This study highlights the urgent need to document and map sacred groves, and make this available to policy makers and planners to support informed ecological planning decision-making.*

Keywords: *peri-urban areas, head watershed, accumulation areas, ecological planning, resilience, sacred groves, urban ecosystems*

1. Introduction

More than half the world's population now lives in urban areas and cities [1]. The trend of urbanization is expected to continue. Asian cities are at the heart of this urban growth [2]. Cities are important entities in the arena of climate change. Due to their high population densities and dense built up areas, these are particularly vulnerable to climate change [3].

1.1 Significance of environmental management in peri-urban areas

Peri-urban areas are defined as areas that surround our metropolitan areas and cities - neither urban nor rural in the conventional sense[4]. They are the fastest growing regions in many countries. Peri-urban areas are neither geographically nor conceptually well defined. These areas possess urban and rural characteristics and are located somewhere between the urban core and the rural landscape. Such areas have traditionally been approached from an urban planning perspective as ground for urban sprawl and for the location of regional and trans-regional infrastructures [5]. Rapid urbanization results in physical growth and expansion of a city. This results in peri-urban areas being part of the city, with rural areas becoming the new peri-urban areas.

In India, these areas absorb tremendous environmental stress. Peri-urban areas have relatively low population densities and thus house a larger portion of semi natural or natural ecosystems that provide natural resources to the city proper [6]. Environmental management of peri-urban areas is critical to both urban and rural development, since its ecological, social and economic functions impact both [7]. Lack of long term ecological planning in the process of urbanization of peri-urban areas can result in the breaking down of the synergies between the peri-urban-urban and peri-urban-rural linkages. This could be made worse by climate change [8].

1.2 Literature review

Managing the health of the peri-urban ecosystems is crucial to developing the health of urban systems, and preventing degradation of the health of rural ecosystems. This is a process that would contribute to the 'smartness' of the city. Ecological resilience in the

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peri-urban areas ensures smooth functioning of the urban as well as rural areas. [9].

1.2.1 Resilience from forest systems

Ecosystem services are the benefits people obtain from ecosystems. These include provisioning, regulating, and cultural services that directly affect people and supporting services needed to maintain the other services[10]. Ecosystem services enhance the redundancy and flexibility of urban systems. It equips the system with the ability to recover from 'shocks'. In the ecological sense, it provides resilience, which is the capacity of an ecosystem to respond to a perturbation or disturbance by resisting damage and recovering quickly. It is a measure of how well an ecosystem can tolerate disturbance without collapsing into a different state that is controlled by a different set of processes[11].

Forest systems provide all the ecosystem services mentioned above[12]. Forests that have been little disturbed by human activity for a very long time perform these services much better[13]. Many primary forests all over the world are inhabited by or are proximal to indigenous peoples and local communities who pursue traditional lifestyles within them. Food security, livelihoods and cultural and spiritual identity of many indigenous peoples are often linked to primary forests.

1.2.2Sacred groves

Sacred groves are tracts of virgin forest that were left untouched by local inhabitants. The World Conservation Union (IUCN) treats SGs as Sacred Natural Sites (SNS), defining them as 'natural areas of special spiritual significance'[14]. They harbour rich biodiversity, and are protected by local people due to their cultural and religious beliefs and taboos. These sacred virgin forests date back to thousands of years when human society was in the primitive stage[15]. They are often relics of original tropical evergreen forests that covered the region before slash and burn agriculture became prevalent[16]. The supportive role of groves in species maintenance and its ecological functions are well recognized[17].

Sacred groves in India are considered to predate the Vedic Period[15]. It is estimated that there are between 100,000–150,000 sacred groves to be found throughout the country[18]. Sacred groves are present in 19 out of the 29 states of India, distributed in all the 15 climate zones (Köppen-Geiger climate classification). They are present as patches of scrub forests in Rajasthan or as evergreen forest patches in Meghalaya. Regardless of the geographical and climatic context, they dot the landscape of rural and peri-urban India. Their exact numbers, geographical extent, biodiversity, cultural significance and socio economic importance are yet to be fully understood. In the metropolises, they have all but disappeared, giving way to urbanization. Cultural homogenization also leads to fast disappearance as faith plays a major part in the conservation of sacred groves [19]. The interesting fact is that they might not be totally eradicated even within the metropolises; rather they remain as miniscule shrines in the midst of urbanized areas with the tree cover having been lost since long or reduced ritualistically to may be single trees. Sacred groves dot the Indian landscape in the rural and peri-urban areas. Lack of awareness, coupled with poor or nonexistent documentation of geographical location and extent, has resulted in the disappearance of sacred groves at an alarming rate.

1.2.3Ecology, religion, environmentalism

The links between ecology, religion and environmentalism is being explored in the recent years [20]. Natural resource management has been in the hands of indigenous societies all over the world[21]. They were dependent on a rather limited resource catchment of a few hundred square kilometers for a wide variety of natural resources. Their ability to transform and augment their environment was limited. Thus, there was a pressing need to use the available resources in a sustainable manner. The cultural outlook of these traditional societies also necessitated respect for nature and its bounty[22]. The practice of maintaining sacred groves as protected, conserved areas for posterity is considered a way of ensuring the resilience of landscapes and their ability to recover from shocks and unexpected changes for sustained delivery of ecosystem services essential for the community[23]. This homeostatic balance is actively pursued with the goal of keeping the optimal conditions for life, even when terrestrial or external events menace them. This is the basis of landscape management today[24]. The importance of maintaining landscape heterogeneity amidst human settlements is therefore considered paramount [25], [26].

There is a distinct spatial pattern that emerges with this concern of maintaining patches of original forest - one of patches of climax vegetation in a matrix of habitation[27]. Thus delineating tracts of lands as sacred for restricting and at times completely avoiding human interference is a conscious cultural act with a distinct underlying ecological aspect. There is an urgent need to examine the possibility of integrating sacred grove conservation in the ecological planning approach for peri-urban areas for resilient urban ecosystems.

1.3 Research question: Topographical context of sacred groves

Social, anthropological and forestry aspects of sacred groves were among the first areas to be researched in sacred grove studies[28], [29]. Documentation, cultural aspects, biodiversity assessment, conservation significance and ecosystem services rendered by sacred groves have also been studied [30-37]. Although the conservation significance of sacred groves have been well researched and reviewed, quantification of ecosystem services of sacred groves are still in the nascent stage [38-40] What is more wanting is developing a spatial design perspective, primarily to see whether the locations of the groves are randomly chosen or whether there is traditional knowledge related to the location specificity. There is a need for enquiry to ascertain if there is a planning process involved in the selection of sacred grove locations. Adoption of a suitable planning process necessitates the existence of a pattern in the spatial distribution of sacred groves with respect to natural factors. Water seems to be a major criterion behind the selection of locations for the groves, as linkages between sacred groves and water are somewhat well expounded, although quantification of hydrological services is less attempted [41]. This hydrological function is attributed to the old forest or climax forests which the sacred groves are generally associated with in their original concept by the various communities concerned. In addition to such forest cover, geology, topography and soils also are decisive in drainage-recharge patterns in the landscape.

In the current study, the topographical context of sacred groves in peri-urban areas of Kerala was examined with respect to the surface water flow characteristics of the region. Traditional treatises on architecture in Kerala stress the importance of adopting sites that slope towards the North-East for building purposes [42]–[44] . Within such a North-East sloping site, the South-West corner, topographically the area of maximum altitude is reserved for the sacred grove. Topographically the lowest area, the North-Eastern corner is designated for location of the tank for ritual purposes in the classical *vastu* planning of Kerala. This spatial arrangement follows that the water percolated in the sacred grove due to its old forest vegetation cover and organic matter rich porous soil reached the tank through sub surface flows. Adherence to this guideline would expectedly result in a network of patches of old forest vegetation that encourages percolation in the monsoon months in such a way that availability of water to the tanks in the lower reaches is not compromised during the lean months. This showcases a definitive ecological planning intent in the delineation of sacred groves in the classical genre in Kerala.

This pattern, however, is followed only in classical temple and domestic architecture. The vast majority of sacred groves in the region do not fall into the classical realm- they belong to the folk tradition of worship. The topographical context of these sacred groves that belong to the folk genre needs to be examined to understand if there is a conscious ecological planning intent in their spatial location.

2. Materials and methods

Literature is largely silent on the strategic locations of sacred groves [45]. For a spatial planning insight into the subject, topographical positions become imperative. For conservation and management of sacred groves, the Kerala Forest Research Institute (KFRI) located 26 sacred groves [46]. Sacred groves attached to classical temple architecture were excluded from the purview of this investiagation and six sacred groves that remained were selected; these are ones that belonged to the folk repository (Figure 1). The geographical distribution of these sacred groves along the state is rather uniform.

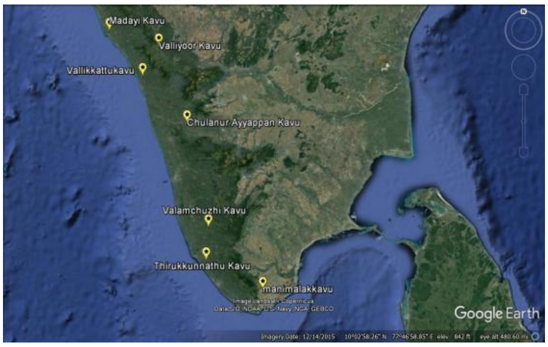

***Figure 1** Locations of six sacred grove locations in Kerala*

The geographical co-ordinates of the sacred groves[46] were identified. 30m resolution elevation data was extracted from the Shuttle Radar Topographical Mission (SRTM)[47] for the 4 sq.km area with the sacred grove approximately at the centre. 5m interval contour lines were generated using the surface analysis tool box in Arcmap [48]. The sacred grove location and the surface flow pattern are highlighted both in the plan and the view of the four sq.km area. Figures 2 to 7 illustrate the topographical context of sacred groves.

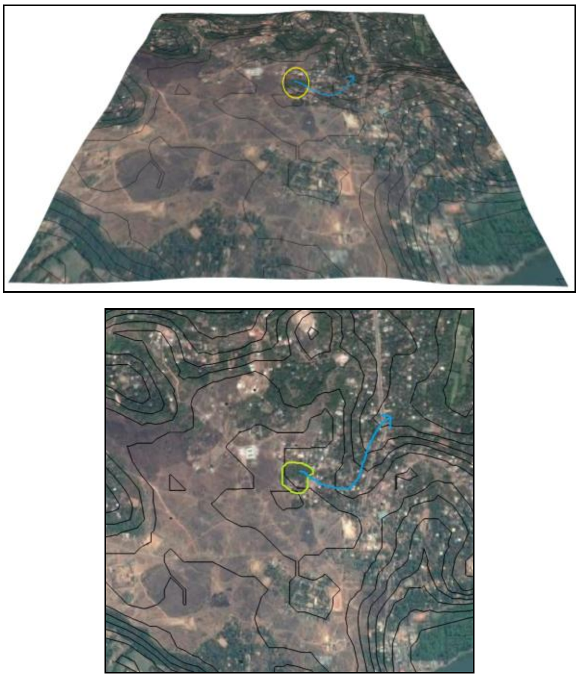

***Figure 2** Madayikkavu. +42m above MSL (12° 2'4.85"N, 75°15'40.42"E)*

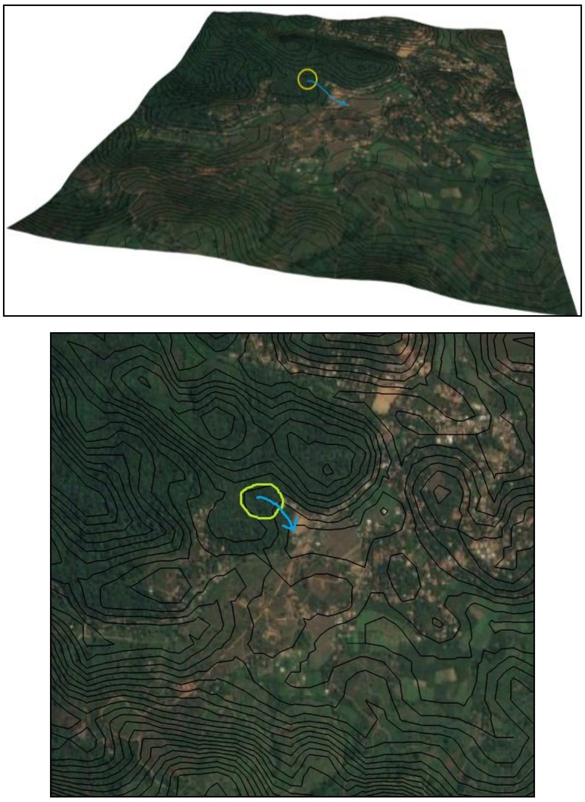

Figure 3 *Valliyurkkavu +801m above MSL (11°48'15.84"N, 76° 1'47.40"E)*

Figure 5 *Choolanurkavu +71m above MSL (10°43'12.74"N, 76°28'17.09"E)*

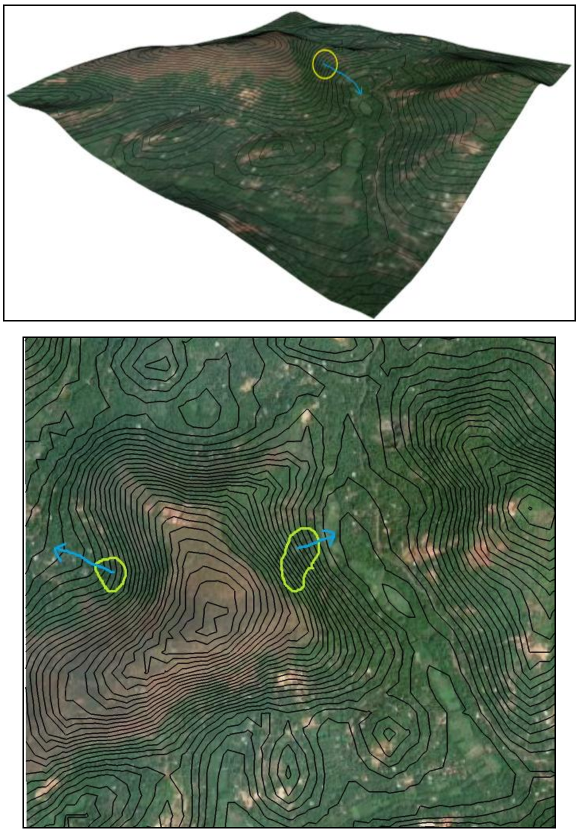

Figure 4 *Vallikkattukavu+33m above MSL (11°23'16.82"N, 75°47'10.63"E)*

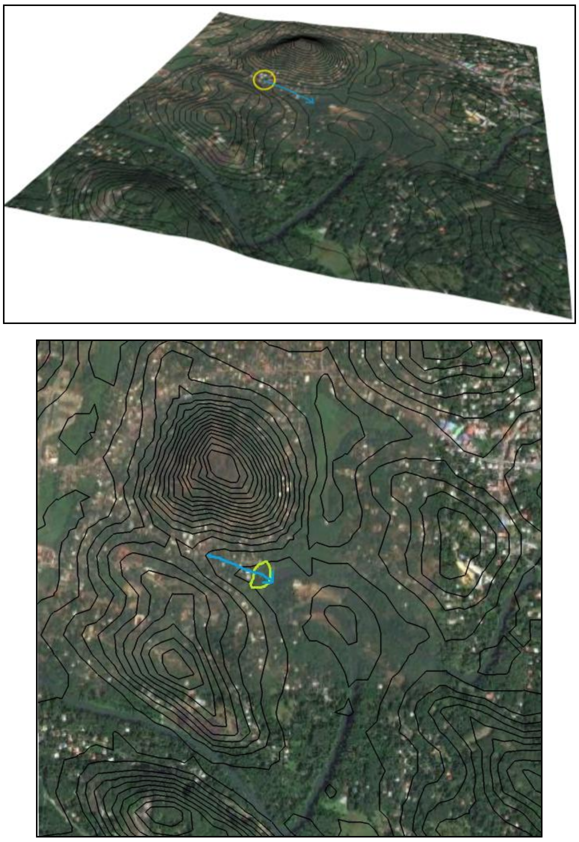

Figure 6 *Valamchizhikkavu +29m above MSL (9°15'37.69"N, 76°47'55.78"E)*

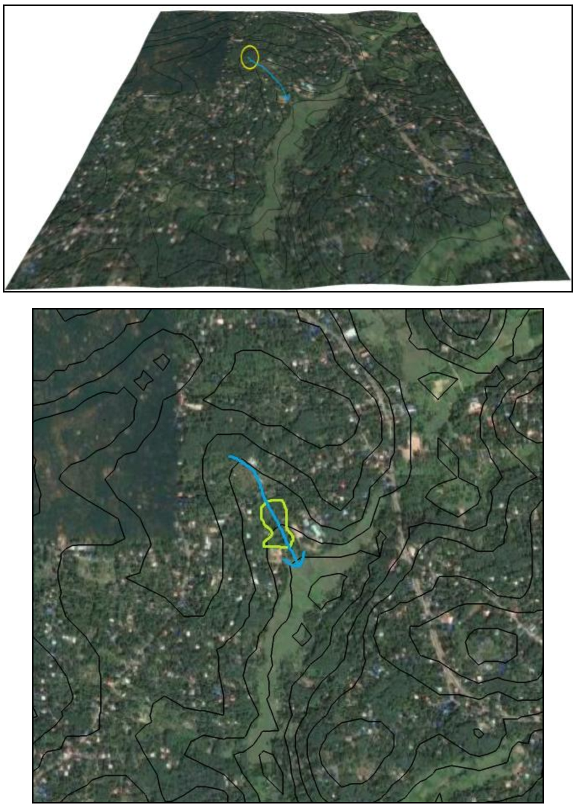

Figure 7 *Thirukunnathukavu +48m above MSL (8°47'41.51"N, 76°45'52.96"E)*

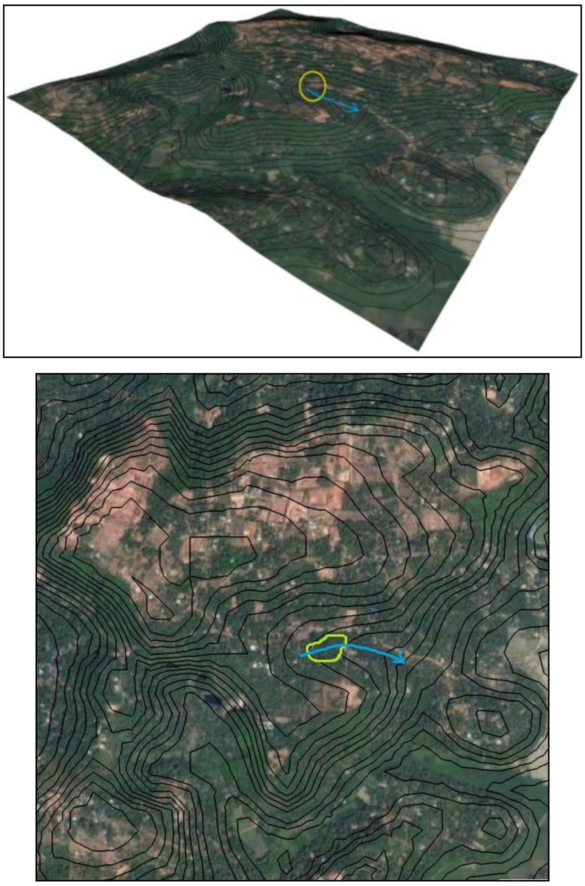

Figure 8 *Malamakkavu +72m above MSL (10°49'1.44"N, 76° 4'44.59"E)*

2.1 Curvature of sacred grove locations

Valleys determine principal routes of surface flow. Gravity-driven overland and intrasoil transport can be interpreted in terms of divergence or convergence and deceleration or acceleration of flow[49]. Flow convergence and deceleration result in the accumulation of substances at soils caused by slowing down or termination of overland and intrasoil transport[50]. Elements characterised both by convergence and by deceleration of flow are termed as zones of flow accumulation[49].

Curvature of an area influences the tendency of surface flow of water and materials to converge or diverge; and accelerate and decelerate. The general curvature of the sacred grove locations were measured with Arcmap 9.2 [48]. This is a general measure of the convexity of the landscape, where sinks and valleys are considered concave and peaks and high points are considered convex[51]. Convex surfaces have positive values and concave surfaces have negative values. A general curvature value near zero indicates either a flat area or an area where the convexity in one direction is balanced by the concavity in the perpendicular direction, such as on a saddle[51].

The Curvature tool of Arcmap 9.2 calculates the second derivative value of the input surface on a cell-by-cell basis. For getting the curvature in one point, the methodology relies on the altitudinal values from the neighboring cells of the targeted point.

For each cell, a fourth-order polynomial of the form: $Z = Ax^2y^2 + Bx^2y + Cxy^2 + Dx^2 + Ey^2 + Fxy + Gx + Hy + I$ is fit to a surface composed of a 3x3 window. The coefficients a, b, c, and so on, are calculated from this surface[48].

Z_1	Z_2	Z_3
Z_4	Z_5	Z_6
Z_7	Z_8	Z_9

Figure 3. *Sliding 3 x 3 window in raster (Source: adaptation after Jenness, 2013[51])*

3. Results

It is found that sacred groves of the folk tradition are located where the contour lines signify formation of valleys. Thus they occur where surface water converges to initiate stream flow. This ensures that the canopy cover, leaf litter and root system of the old forest vegetation, characteristic of sacred groves, intercept surface flow at convergence areas. At a local scale, head watershed regions are delineated as sacred groves.

Table 1 summarises the sacred grove locations' curvature values that indicate whether the zones have accumulative or dispersive characteristics with regard to surface flow. All curvature values of sacred grove locations are less than zero. This signifies surface flow convergence and deceleration. These accumulation areas are considered the wettest parts of the landscape [52].

Table 1: *Curvature values and geographical coordinates of sacred grove locations*

Sacred grove	Latitude	Longitude	Curvature
Madayi	12° 2'4.85"N	75°15'40.42"E	-1.066319942
Valliyur	11°48'15.84"N	76° 1'47.40"E	-1.172960043
Vallikkattu	11°23'16.82"N	75°47'10.63"E	-1.279590011
Choolanur	10°43'12.74"N	76°28'17.09"E	-0.746425986
Valamchizhi	9°15'37.69"N	76°47'55.78"E	-1.066319942
Thirukunnath	8°47'41.51"N	76°45'52.96"E	-0.959690988
Malama	10°49'1.44"N	76° 4'44.59"E	-1.279590011

4. Conclusions

The significance of head watershed regions in watershed management has been receiving attention in the recent years[53–55]. Headwater streams are the smallest parts of river and stream networks, but make up the majority of the stream network[56]. They are the part of rivers farthest from its endpoint or confluence with another stream. Many headwater streams have been lost or altered due to human activities such as urbanization and agriculture, and this can impact species and water quality in the downstream areas[57].

The presence of sacred groves in head water accumulation zones regions is a conscious cultural phenomenon rooted in a need for ecological planning. Old forest cover in head water regions results in maximizing percolation for sustaining groundwater flows in the lean periods in the downstream areas[58]. It can be seen that agricultural fields are located downstream of sacred groves. This spatial pattern ensures that water that percolates the sacred grove, due to its topographical position as well as due to the old forest vegetative cover, ensures water supply for the downstream areas through the lean months as sub surface flows. Though sacred groves of folk tradition are not physically proximal to water bodies, its location together with the vegetative cover is significant to surface water attenuation. This spatial pattern in sacred grove locations reveals an ecological planning intent for maximizing surface water potential towards better watershed management.

Thus sacred groves may have been deliberately located in a conscious pre-determined manner. Such regional planning responds to specific objectives that result in overall ecological resilience of the system. These groves are the result of a dynamic interaction between humans and ecosystems: changing human conditions drive changes both directly and indirectly in ecosystems[10]. At present, what is needed in Indian regional planning is an ecosystem based approach to address urban climate change adaptation and resilience[59], [60]. This need is ever more in the case of peri-urban areas due to the state of flux they are in[4].

Peri-urban areas present an urgent need for ecological planning. Existence of sacred groves in peri-urban areas that respond to regional ecological planning objectives is a case of rare serendipity. These areas are facing rapid, unplanned urbanization processes and present a unique opportunity where areas critical to maintaining resilience of the system are delineated as sacred groves. With efforts in place for systematic documentation and conservation of these relic forest patches, ecosystem services provided by them will be invaluable as population densities increase further. These sacred groves can function as urban forests in peri-urban areas: urban forests with primary forest vegetation instead of secondary plantations.

Systematic conservation of these sacred groves will result in a network of old forest vegetation patches in the matrix of urbanization and may even serve as green relief spaces with recreational potential. This study presents an urgent need to map and document these groves, to be made available to planners and policy makers to make informed decisions on ecological planning for resilient urban systems.

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