Terrain attributes of sacred grove locations point towards conscious spatial delineation

Sacred groves (SGs) are forest patches protected by indigenous communities due to their cultural beliefs and taboos[1]. It is estimated that there are between 100,000 and 150,000 SGs in India[2]. These are often relics of the original vegetation that covered the region before slash and burn agriculture became prevalent[3]. The supportive role of SGs in species maintenance and ecological functions is well recognized and reviewed[4–6].

However, studies on SGs till date are largely silent on the terrain characteristics of the land they occupy. The understanding that topography modifies water flow, material redistribution processes and the resulting ecosystem lies at the heart of this enquiry[7,8]. The relevance of natural resource management systems practised by traditional societies is well established in the literature[9,10]. Sound management of resources necessitate systematic delineation of protected areas[11]. The present study is an exploration into the terrain attributes of SG locations at watershed scale to understand if there is a possible conscious planning intent in their spatial delineation based on traditional ecological knowledge (TEK).

From a geomorphologic viewpoint, the ground surface is composed of landform elements. Topographic elements of a landscape can be computed directly from a digital elevation model (DEM)[12]. We analyse the primary topographical attributes – altitude, slope, aspect, plan curvature and profile curvature derived from 30 m resolution SRTM (shuttle radar topographic model) DEM to understand the locational significance (if any) of SGs in the ecological services they render. Altitude at a given point on the land surface is the height above mean sea level[12], which affects climate variables, vegetation and soil patterns, and material volumes[8]. Slope is a plane tangent to the terrain surface represented by DEM at any given point – the maximum rate of change of altitude and expressed in degrees or per cent[13]. Overall flow velocity is influenced by slope[14]. Aspect is the compass direction of the maximum rate of change (the orientation of the line of steepest descent expressed in degrees and converted to a compass bearing)[13]. Aspect can significantly influence the total solar irradiation received by a land parcel[15]. Profile curvature is the curvature of a normal section of the land surface; this section includes the gravity acceleration vector at a given point on the land surface[16]. Concave profile curvature results in deceleration of water and materials flow over the surface[16]. Plan curvature is perpendicular to the direction of the maximum slope[16]. Divergence or convergence of flow is controlled by horizontal (or plan) land surface curvature[16]. Concave plan curvature results in convergence of flow.

A complete inventory and documentation of SGs in India is not available at present. In the southwestern coastal State of Kerala, a large number of SGs have been recorded in Kozhikode district; 147 groves are listed here[17]. Interviews with people possessing TEK – mainly village elders, followed by fieldwork to visit the identified SGs in a 755 km^2 area comprising watersheds 5A2D1 (Ramallur River) and 5A2D2 (Korapuzha River) (latitudinal extent of 11.55 and 11.24 decimal degrees and longitudinal extent of 75.61 and 75.97 decimal degrees)[18] revealed 392 SGs (Figure 1). We employed DEM-derived terrain attributes for topographic analysis of these SG locations. For the selected area elevation data were obtained from Processed SRTM Data Version 4.1 (ref. 19). DEM-derived slope, aspect, planform curvature and profile curvature were calculated using 'Surface' toolset in 'Spatial Analyst' toolbox of ArcMap10.2 (refs 12, 19). We added the SG locations onto the map and extracted values for altitude, slope, aspect, plan curvature and profile curvature.

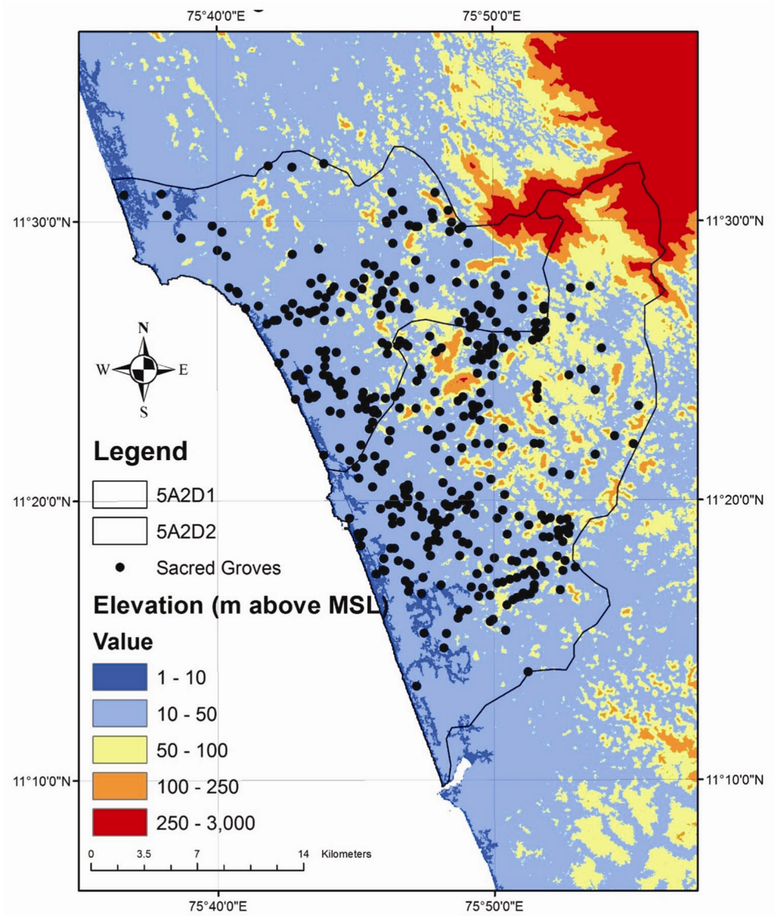

Figure 1. Sacred grove locations in watersheds 5A2D1 (Ramallur River) and 5A2D2 (Korapuzha River), Kozhikode, Kerala, India on DEM.

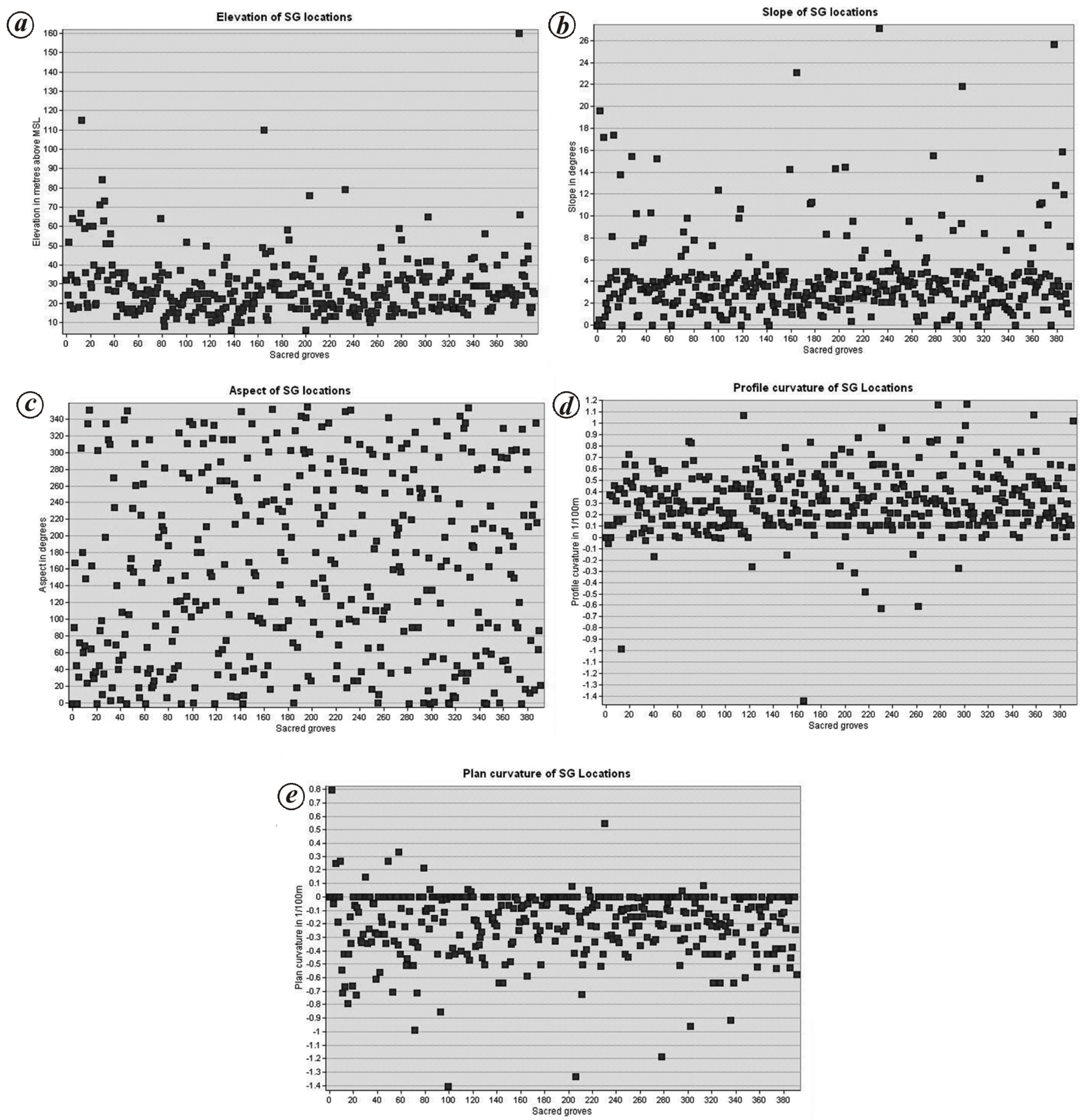

Figure 2. Scatter plots of terrain attributes: (***a***) altitude; (***b***) slope; (***c***) aspect; (***d***) profile curvature and (***e***) plan curvature of 392 sacred grove locations in the study area.

The elevation in the study region ranged from 0 to 900 m. Figure 2 *a* shows the elevation of the 392 SGs, ranging from 6 to 160 m amsl. The mean of the elevation is 27.7 m, with a SD of 15.6 m. Ninety-one per cent of SGs have elevation less than 50 m. The slope of the region ranges from 0° to 63°. Figure 2 *b* shows the slope of the SG locations. The minimum slope is 0° and the maximum is 27°. The mean is 4.1° with a SD of 3.7. Eighty-four per cent of SG locations have slope less than 5°. Aspect of SGs shows no tendencies, with minimum being 0 and maximum 354. The mean is 160 with a SD of 110 (Figure 2 *c*). Profile curvature ranges from –2.4 and 2.1 1/100 m. Figure 2 *d* shows the profile curvature values of SG locations. The minimum is –1.4 and maximum 1.2 1/100 m. The mean is 0.3, with an SD of 0.27. Ninety-three per cent of SG locations have positive profile curvature, or are concave. Planform curvature in the study region ranges from –1.2 to 2.12 1/100 m. Plan curvatures of SG locations ranges from –1.4 to 0.79 1/100 m, with a mean of –0.18 and SD of 0.23 (Figure 2 *e*). Sixty-five per cent of SGs have negative plan curvature values, or are concave.

In summary, we find evidence, at a watershed scale, for location of SGs to not be at random with respect to all terrain attributes examined, with the exception of aspect. There appears to be a discernible pattern in the terrain attributes of SG locations: they are characterized by low altitude, low slope, concave plan curvature and concave profile curvature. SGs are found proximal to historical settlements that were, in turn, located in the lower reaches of the region. The low slope, concave plan curvature and concave profile curvature of SG locations ensure that the old forest vegetation cover characteristic of SGs can encourage percolation of water in land parcels that result in low velocity, convergence and deceleration of flow. This observation hints at a conscious effort in the delineation of SGs with respect to terrain attributes of the land they occupy. However, the aspect of SG land parcels appears to follow no discernible pattern. While SGs attached to ancestral homes that are built based on traditional architectural treatises face north, east or northeast, those that house folk deities are found to be distributed equally with respect to compass directions. It is recommended that the terrain attributes of SGs in the country as well as the globe be investigated with respect to regional ecological planning objectives and a local focus.

1. Gadgil, M. and Chandran, M. D. S., *India Int. Cent. Q*., 1992, **19**, 183–187.
2. Gokhale, Y., Malhotra, K.., Chatterjee, S. and Srivastava, S., *Cultural and Ecological Dimensions of Sacred Groves in India*, Indian National Science Academy, New Delhi and Indira Gandhi Rashtriya Manav Sangrahalaya, Bhopal, 2001.
3. Chandran, M. D. S. and Hughes, J. D., *Compass*, 1997, **44**, 413–427.
4. Ray, R., Chandran, M. D. S. and Ramachandra, T. V., *J. For. Res*., 2014, **25**(1); doi:10.1007/s11676-014-0429-2.
5. Khan, M. L., Khumbongmayum, A. D. and Tripathi, R. S., *Int. J. Ecol. Environ. Sci*., 2008, **34**(3), 277–291.
6. Bhagwat, S. A. and Rutte, C., *Front Ecol. Environ*., 2006, **4**, 519–524.
7. Florinsky, I., Eilers, R., Manning, G. and Fuller, L., *Environ. Model. Software*, 2002, **17**(3), 295–311; doi:10.1016/S1364-8152(01)00067-6.
8. Florinsky, I. V. and Kuryakova, G. A., *Catena*, 1996, **27**(2), 123–141.
9. Berkes, F., *Sacred Ecology, Traditional Ecological Knowledge and Resources Management*, Routledge, New York, 2008.
10. Gadgil, M., Berkes, F. and Folke, C., *Ambio*, 1993, **22**(2), 151–156.
11. Margules, C. R. and Pressey, R. L., *Nature*, 2000, **405**(6783), 243–253; doi:10.1038/35012251.
12. Moore, I. D., Grayson, R. B. and Ladson, A. R., *Hydrol. Process*., 1991, **5**(1), 3–30.
13. Wilson, J. P. and Gallant, J. C. (eds), *Terrain Analysis: Principles and Applications*, John Wiley, 2000.
14. Zeverbergen, L. W. and Thorne, C. R., *Earth Surf. Process. Landforms*, 1987, **12**, 47–56.
15. Zakharov, S. A., *J. Bot. l'URSS*, 1940, **25**(4–5), 378–405.
16. Hugget, R. J., *Fundamentals of Geomorphology*, Routledge, London, 2007.
17. Nambeesan, U., *Islands of Biodiversity in Kozhikode District*, Society for Protection of Environment, Kozhikode, 1999.
18. Government of India, *Watershed Atlas of India*, Soil and Landuse Survey of India, 2012.
19. Jarvis, A., Reuter, H. I., Nelson, A. and Guevara, E., CGIAR-CSI SRTM 90 m database, 2008; http://srtm.csi.cgiar.org

ACKNOWLEDGEMENTS. We thank Prof. Madhav Gadgil (founder, Centre for Ecological Sciences) for valuable insights from his vast experience that enriched this study. Prof. Unnikrishnan Nambeesan (author, *Islands of Biodiversity in Kozhikode District*) and Prof. Balagopal T. S. Prabhu (former head of Department of Architecture and Planning, NITC) extended invaluable support in locating the groves.

Received 21 December 2016; revised accepted 22 December 2017

ANJANA BHAGYANATHAN[1,*]
A. K. KASTHURBA[1]
SANTOSH G. THAMPI[2]
DEEPAK DHAYANITHY[3]

[1]Department of Architecture, and
[2]Department of Civil Engineering,
National Institute of Technology,
Calicut 673 601, India
[3]Indian Institute of Management,
Kozhikode,
Calicut 673 570, India
**For correspondence.*
e-mail: anjana.bhagyanathan@gmail.com

Similarity in Ph D thesis in state universities is less than 10%

Plagiarism is the most common form of academic dishonesty which includes, exploiting works or ideas of others without citation and acknowledgement. The common types of plagiarism are direct, self and accidental plagiarism[1]. Good scientific measures in research ethics can control these fraudulent practices. There are software-based services such as URKUND, Turnitin, Plagtracker, etc. available for detecting plagiarism in manuscripts[2]. These tools are designed to support students and researchers to self-analyse the percentage of similarity, thereby alerting possibilities of plagiarism. Such software, if enforced, can drastically bring down cases of major plagiarism. However, there are no scientifically derived measures of normal level of overlap with other sources, to the best of our knowledge. Institutions or organizations which prescribe permissible limits, do not have any rationale for their choice. Most world class Universities or Institutes (Harvard, Cambridge, IIT Delhi, IISc, etc.) recommend ways of avoiding plagiarism rather than prescribe limits of overlap with other sources[3–5]. There is increasing focus on management of plagiarism in scholarly works in higher education institutions all over India. However, no major scientific study of existing patterns of similarity in scholarly writing has been reported. This communication reports an attempt in this direction based on 487 thesis from Shodhganga INFLIBNET website. We present the existing levels of overlap with other sources in Ph D thesis, from a state university, University of Kerala, based on the Ph D thesis uploaded from this University in Sodhganga INFLIBNET