Potentiality of wall flora in characterization of urban ecology

Sandeep Pandey[1], Neetesh Kumar[2] and Satyendra Kumar Singh[2]

[1]*Faculty, School of Environmental Biology, A.P.S University Rewa, Madhya Pradesh*

[2]*M.Phil (Botany) Students, School of Environmental Biology, A.P.S University Rewa, Madhya Pradesh*

ABSTRACT

City walls are considered secondary habitat of urban biota and communities serving as a knowledge center of floral heterogeneity. The old and ruined city walls containing favorable growth factors like temperature, humidity, nutrients, houses unique plant assemblages and thus can be managed for evaluating floral diversity. The wall vegetation mainly depends on physical characteristics of wall material, vertices plant types and composition. Special technology in wall engineering enhancing the quality and favoring species composition should be given special emphasis in urban areas. The natural and living wall not only provide valuable information about the changing land pattern but also makes air clean, maintain carbon footprints and balances the ecology of the township. Assessment of fortification wall and pavements sometimes helps in recovering the rare, endangered or alien species and also help in understanding ecological problems and parameters. Thus the wall flora can also be referred as cultural landscapes and is significant in understanding the ancient objects and ecological features of any urban ecosystem.

Keywords: - *wall flora, floral diversity, urban ecosystem*

---

1. INTRODUCTION

Wall floras are special environment conditioned by anthropogenic activities [1], providing new ecological niches and occupied by different types of life-forms [2].They are extensively distributed urban ecosystems acting as a habitat, favoring a usual cosmopolitan assemblage of plant taxa's [3]. Plants from old walls enhances ornamental element and are significant as they realizes importance of architectural and historical objects [4]. Historical buildings and their wall surfaces with structural heterogeneity support biological diversity and provide a variety of habitats for flora and fauna [5]. Stone wall field boundaries are cultural landscapes acting as 'novel' ecosystems because of their specificity in the landscape especially in isolated or exposed regions, and their morphology requires lot of research that describes the potential ecological properties of these ancient forms of field boundary [6]. It has been observed that in urban areas the vertical surfaces of walls contains diverse plants and thus there is a need for characterizing plant species composition and distribution pattern growing in these habitats towards a better understanding and management and protecting the walls and improving ecological services of their associated vegetation [7].

Restored and cleaned walls are a unique structure with spontaneous colonization of the diversified surrounding landscape flora [8]. The inventory data overview becomes necessary for the conservation of plant diversity because a large number of species of high conservation value present in remnants of near-natural vegetation, high native species richness of urban area and a rich flora composed of native species that are well adapted to anthropogenic disturbance, along with a variety of species that are non-native or of uncertain origin, can be assessed [9]. These ecosystems should be managed carefully as it supports both the cultural heritage and rare and unique anthropogenic habitats [5]. Sometimes the plant assemblages found on the walls within urban biodiversity are significant and can be examined for ecological engineering of walls [3]. There should be a broad assessment of wall surface heterogeneity with special emphasis on species composition as well as the effectiveness of cleaning methods [5]. Thus there is a need to effectively increase physical complexity and quality of walls possessing a substantial potential habitat within urban areas, the development of wall ecology, highlighting the special characteristics of the walls that have ability to support plant species [3]. Therefore the wall flora, with complex habitat quality can act as an 'ecological tool' in assessing and characterizing urban biodiversity.

2. STRATEGIES

Strategies that combine both societal targets, the preservation of historic monuments and of species diversity should be preferred. Applying boosted regression tree analyses and non-metric multidimensional scaling techniques wall surface structure can be quantified to detect the influence of abiotic site conditions on biodiversity and it was observed that species richness can be promoted by wall surface heterogeneity whereas the species composition by restoration techniques [5]. Sometimes the large tree species creates basic problem for the preservation of walls. Thus frequent restoration and cleaning of walls generate a unique opportunity for spontaneous colonization by different types of landscape flora present in the surroundings [8]. The urban ecological heritage needs protection from non-advantageous and adverse impacts and the conservation of walls and their companion plant species could avoid deteriorating these crucial enabling factors [10]. Canonical correspondence analysis can be used to study the relationship between the environmental factors and composition of families, life forms, life strategies and dispersal strategies of flora in wall microhabitats [2].

Image analysis techniques can be used to study cyanobacteria biofilms on building surfaces, distribution of photosynthetic microorganisms, their interaction with the colonized substratum, and the three-dimensional structure of the biofilms along with the impact of local seasonal microenvironments and bio receptivity of stone and interaction among biofilms and their substrata [11]. Optical and electron microscopy analysis of the microorganism biofilms on limestone surfaces reveals the presence of cyanobacteria. Further, denaturing gradient gel electrophoresis and energy-dispersive X-ray spectroscopy analysis reported the presence of eukaryotic algae, fungi and bacteria containing high content of scytonemin that are responsible for dark pigmentation of the stone [12].

3. EXPLORATION OF GLOBAL WALL FLORA

Several studies conducted at historical and old cities across the world presented a picture of varied taxonomical and life-form complexities among the flora. The analyses of wall flora in the world's oldest city Varanasi in India documented dicotyledonous angiospermic group of native woody plants [13], whereas another research in different site of the city represents dominancy of therophytes mainly the exotic species, over other life forms [14]. The inventory of the vascular flora of metropolitan Rome enlisted taxa that are non-native to the Italian flora [9]. The vascular wall flora of the Anatolian side, of Istanbul represents a distinctive urban ecologic wall habitat having a unique combination of Euro-Siberian, Mediterranean, E. Mediterranean, Irano-Turanian and unknown phytogeographical taxa [15]. The documentation of wall flora of a historic building in Sanliurfa, South-east Turkey recorded majority of vascular plants showing dominancy of heliophilous to shade-tolerant plants and high number of alien species containing hemicrytophyte and therophytes as most common life form [16]. Phytosociological study of the wall flora of the Roman archaeological sites observed different plant associations of phytosociological classes [17].

Flora species documentation at National architectural reserve of the old fortress wall on antique Pautalia and medieval Velbuzhd reveals a characteristics European and Mediterranean wall floras with a decrease in the species diversity from base to top and annual species are bigger on the wall surface compare to perennials, which are more at the base and neighbouring area [4]. The vascular flora of the walls of Siena, Monteriggioni, Pienza, Grosseto, Arezzo, Massa Marittima, Pitigliano,Sansepolcro and Cortona represents a therophytes and hemicryptophytes and their chorological analysis shows predominance of boreal-tethyan with respect to the eurosiberian and boreal and the species living on walls are mostly ruderal and stress tolerant [18]. Study of species diversity richness in Gingee fort walls and temple towers in Villupuram, Tamil Nadu represents most of the life-form like herbs, shrubs, trees and climbers [19]. Analysis of the fragments of the fortification wall and the pavements of the Nebet Tepe Architectural Reserve in Plovdiv (Thracian Plain) reveals a relatively high proportion of ruderals and weeds with hemicryptophytes and therophytes being the largest flora group [20], whereas Byzantine Wall floras of the city of Thessaloniki shows an inventory of taxa of vascular plants of various life forms [21].

Urban wall flora study in Christchurch and Dunedin cities in New Zealand reveals that majority of species were non-native; and lichens, and some bryophytes, prefers the higher areas of the wall; and lichens prefer rock surfaces whereas bryophytes prefers the joints [22]. Similarly, an investigation in Gorakhpur, India about murophyte diversity reveals a majority of dicots compared to monocots [23]. Urban river walls study of the river Thames in central London indicates 'an urban cliff effect' on wall habitats and plant species richness varied between different wall types. The majority of species associated with disturbed areas represents riparian habitats supporting 'mass effect' concept and reaching to the conclusion that the flora is managed by propagule pressure arising from traces or introduced habitats in urban areas [24]. Evaluation of masonry retaining walls in Hong Kong reveals a wide assemblage of species and trees followed by ruderals and garden escapees were dominant growth forms with natives more in number compared to exotic species [10]. The analyses of wall flora of southern and western Moravia in Czech Republic recorded vascular plants along with bryophytes, neophytes and alien species [2].

The analyses of cave ecosystems equipped with artificial and natural lights represent subterranean habitats with dominance of diatom taxa that are generally aerophilic and cosmopolitan in nature [25] [26].
Moreover, there are evidences of the importance of the secondary sources data as a case study in Pune, India, that helps in documenting past and current species of dicot and monocot families from wall flora [27].

4. FAVOURABLE CONDITIONS FOR EMERGENCE OF WALL FLORA

A survey conducted in temples of Gingee fort in Villupuram, Tamil Nadu reveals that PH, macro and micro nutrients favours the abundance of flora which requires mechanical and chemical control methods [19].Precipitation, thermal amplitude, hygrometry sea distance and proximity to vegetation are environmental parameters along with some other factors like nature of the façade coating, mineral substrata architecture, and formation of damp conditions that influences the colonization of algae and cyanobacteria on building façades [28].The heavily engineered urban river corridors represents plant species richness higher on brick walls than that on sheet piling, due to key differences between materials based on surface integrity [24]. The warmer temperature increase flora diversity in cave ecosystem [25].

Seasonal variation shows significant impact on wall floristic composition representing a typical "urban characteristic" at some places. Seasonal angiospermic wall flora composition in at the Banaras Hindu Campus Varanashi [29] and Buxar of Bihar state [30] in India recorded angiospermic wall flora with majority of the non woody wall flora in rainy and winter seasons with Asteraceae, Poaceae and Amaranthaceae as dominant families [29] [30]. Seasonal analysis of wall flora in Gorakhpur, India recorded maximum species during rainy followed by winter and summer season and murophytic species occurs throughout the year on the wall of the study site [23].

In wall ecosystem the presence of lichen-moss are indicators of the water-nutrient factor. The large tree shows dependency on the larger-scale habitat size factor whereas the medium-sized plants, including herbs, shrubs, seedlings, requires dual influence of water-nutrient and habitat connectivity. Natural ecosystems with spatial contiguity assure continual supplies of seed, water, nutrient, genial microclimate, and clean air to foster wall vegetation growth [10]. Colonization of walls by vascular plants strongly depends on the availability of diaspores from the surrounding semi-natural vegetation [2].

5. BENEFITS

The stone retaining walls helps to stabilize the vertical faces between adjoining hill slopeplatforms and creating a developed land by harbor reclamation and terracing hill slopes. These artificial cliffs embedded in the urban matrix are been colonized by spontaneous-ruderal vegetation. The polymorphic roots possessing morphological plasticity and self-grafting nature, along with multiple modes of interactions with wall niches, shows firm attachment on the vertical habitat and exploration of proximal soils. The aft-soil behind the walls helps in catchment for normal root functions [31].

The conservation of green spaces and wall flora provide baseline data for analysing rapidly changing urban land use in the township [27]. Existing natural wall flora and living roofs and walls installed in urban regions are significant tools and important 'bottom-up' techniques supporting reconciliation ecology concept. They also support a range of taxa at local scales and thus can be established as a 'science model' of human and non-human use of urban regions [32]. In urban ecosystems the heavily engineered urban river walls are the most common habitat to riparian species and are potential sites for the enactment of reconciliation ecology [24]. Green walls in urban areas are well-known for their insulation and air cleaning capacities [33] Covering the façade of a building with a vertical garden exhibits several environmental benefits, like reducing the energy consumption and the overall carbon footprint. Therefore special focus should be given for future design and evaluation of vertical gardens [34]. Some plant species like ivy (*Hedera helix* L.) plays a biodeteriorative role as its rootlets exploit cracks and holes on building walls and provides bioprotection on wall surface microclimates and also checks frost and salt deterioration, thus contributing to their conservation [35]. In some case environmental parameters, such as light nitrates and water content becomes limiting factors for the distribution of the plant communities growing on the walls. The vegetation of the upper part changes to shrub and this is useful for evaluating the biodeterioration problems and for studying the plant communities as bioindicators of the environmental parameters [17].

Wall flora investigations are sometimes significant in recovering rare and endangered plant species. During the study of fortification wall and pavements of Nebet Tepe Architectural Reserve in Plovdiv, the species like *Cerastium tauricum Spreng* and *Melica transsilvanica Schur* were recorded from the flora of the Thracian Plain floristic region [20]. Similarly, analysis of campus flora in Pune Maharashtra, India recovered a rare species *Acacia greggii* [27].

6. LIMITATIONS

The historic monuments of the cities of Rabat and Sale (Morocco), exhibits rich and diversified annual therophytes and the dicot adventitious species, along with perennial trees undergoing the phenomenon of fissuring and possessing serious threat for bulwarks walls and degradation of the site of Chella (Roman ruins) [36]. Green algae and fungi shows significant impact in biodeterioration of stone cultural heritage and requires a deep ecological study by employing new molecular and laboratory-based simulation techniques along with creation of robust models integrating biotic and abiotic factors that can be used in prediction and management of microorganisms growths on these historic stones [37]. Cyanobacteria biofilms causes biodegradation of the substratum causing aesthetic and structural damage of cultural heritage [11].

Human designed cave ecosystems equipped with all accessories like artificial lighting systems helps in the growth of autotrophic organisms also called lampenflora. They are mainly composed of blue-green algae, diatoms, chlorophytes, mosses and ferns and produces exocellular polymeric substances (EPSs) that are made of polysaccharides, lipids, proteins and nucleic acids. The anion enriched EPS matrix combines with intercellular communications and participates in chemical exchanges with the substratum, and helps in activating the adsorption of cations and dissolved organic substances during the cave formations. During this phenomenon the corrosion of the mineral surfaces occurs due to metabolic activities of heterotrophic microorganisms that are colonizing biofilms [26].

In Conclusion, the wall floras as a dynamic ecosystem plays a significant role in distinguishing floral diversity, sheltering various life forms and maintaining the ecological parameters with potentiality in specifying age old historical and natural ecology of urban region.

7. REFERENCES

[1]. Reis V A Dos, Lombardi J A and Figueiredo R A De (2006) Diversity of vascular plants growing on walls of a Brazilian city, Urban Ecosystems, 9(1) pp. 39-43.

[2]. Simonová, D. (2005) Alien species on walls in southern and western Moravia. In Ecology and Management of Alien Plant Invasions. Katowice, Poland: University of Silesia, Faculty of Biology and Environmental Protection, Department of Plant Systematics, Department of Geobotany and Environmental Protection, 2005. s. 81-81, 1 s. ISBN 2005.

[3]. Francis R A. (2011) Wall ecology: A frontier for urban biodiversity and ecological engineering, Progress in Physical Geography 35, pp. 43-63.

[4]. Nedelcheva A and Vasileva A (2009) Vascular Plants from the Old Walls in Kystendil (Southwestern Bulgaria), Biotechnology & Biotechnological Equipment,23:sup1,154-157,

[5]. Steinbauer, M.J., Gohlke, A., Mahler, C., Schmiedinger, A., Beierkuhnlein, C. (2013) Quantification of wall surface heterogeneity and its influence on species diversity at medieval castles – implications for the environmentally friendly preservation of cultural heritage Journal of Cultural Heritage 14: 219–228.

[6]. Collier M.J. (2013) Field Boundary Stone Walls as Exemplars of 'Novel' Ecosystems Landscape Research 38(1) pp.141-150.

[7]. Qiu, Y, Chen B.J.W, Song Y, Huang Z.Y.X, Wan L, Huang C, Liu M and Xu C (2016) Composition, distribution and habitat effects of vascular plants on the vertical surfaces of an ancient city wall, Urban Ecosystems, pp 1-10.

[8]. Nedelcheva A (2011) Observations on the wall flora of Kyustendil (Bulgaria). Eurasia J Biosci 5: 80-90.

[9]. Celesti-Grapow,L.,Capotorti,G.,Del Vico, E.,Lattanzi, E.,Tilia, A. and Blasi, C.(2013)The vascular flora of Rome, Plant Biosystems 147(4), pp.1059-1087.

[10]. Jim CY and Chen WY. (2010) Habitat effect on vegetation ecology and occurrence on urban masonry walls Urban Forestry & Urban Greening 9(3), pp. 169–178.

[11]. Ramírez M., Hernández-Mariné, M., Novelo E. and Roldán M. (2010) Cyanobacteria-containing biofilms from a Mayan monument in Palenque, Mexico Biofouling 26(4) pp.399-409.

[12]. Cappitelli F., Salvadori, O., Albanese D., Villa F. and Sorlini C. (2012) Cyanobacteria cause black staining of the National Museum of the American Indian Building, Washington, DC, USA Biofouling 28(3), :257-266.

[13]. Singh, A, (2015) Observations on the Woody Wall Flora of Varanasi City, India, International Journal of Scientific Research in Science and Technology (IJSRST), 1(4), pp.192-196.

[14]. Singh, A, (2014) Observations on the Vascular Wall Flora of Varanasi City, India International Journal of Modern Biology and Medicine, 5(2): 40-55.

[15]. Altay, V., Ozyigit, I. I. and Yarci, C. (2010) Urban ecological characteristics and vascular wall flora on the Anatolian side of Istanbul, Turkey. Maejo International Journal of Science and Technology, 4(3) pp. 483-495.

[16]. Aslan M and Atamov V, (2006). Flora and Vegetation of Stony Walls in South-east Turkey (Sanliurfa). Asian Journal of Plant Sciences, 5 pp.153-162.

[17]. Caneva, G., De Marco, G.; Dinelli, A.; Vinci, M. (1992) "The wall vegetation of the Roman archaeological areas" Science and technology for cultural heritage 1 pp. 217-226.

[18]. Lisci, Marcello (1997) The vascular flora of the walls of some towns in south-central Tuscany, Webbia, 52(1), pp. 43-66.

[19]. Rajalakshmi, S. and Shanthi, K. (2012) Survey of wall flora in Gingee fort and uncared gopuras in Gingee taluk, villupuram district, International Journal of Ayurvedic and Herbal Medicine 2(5) pp. 810-816.

[20]. Pavlova D and Tonkov S (2005) The wall flora of the Nebet Tepe Architectural Reserve in the city of Plovdiv (Bulgaria) Acta Bot. Croat. 64 (2), 357–368.

[21]. Krigas N, Lagiou E, Hanlidou E and Kokkini S. (1999) "The Vascular Flora of the Byzantine Walls of Thessaloniki (N Greece)". *Willdenowia* 29 (1/2). Botanischer Garten und Botanisches Museum, Berlin-Dahlem: 77–94.

[22]. De Neef D, Stewart G H. and Meubk C.D URban Biotopes of Aotearoa New Zealand (URBANZ) (III): Spontaneous Urban Wall Vegetation in Christchurch and Dunedin Phyton 2008, 48(1),pp. 133-154.

[23]. Dwivedi A. K. and Anand D. K. (2014) Investigation of diversity in murophytes in the campus of university in Gorakhpur, India, International Journal of Plant, Animal and Environmental Sciences 4(3) pp.569-575.

[24]. Francis, R. A. and Hoggart, S. P. G. (2012), The flora of urban river wallscapes. River Res. Applic., 28: 1200–1216. doi: 10.1002/rra.1497.

[25]. Smith T. and Olson R. (2007). A Taxonomic Survey of Lamp Flora (Algae and Cyanobacteria) in Electrically Lit Passages within Mammoth Cave National Park, Kentucky. International Journal of Speleology, 36(2), pp.105-114.

[26]. Falasco E., Ector L., Isaia M., Wetzel C.E., Hoffmann L. and Bona F., (2014). Diatom flora in subterranean ecosystems: a review. International Journal of Speleology,43 (3), pp. 231-251.

[27]. Nerlekar, A.N., S.A. Lapalikar, A.A. Onkar, S.L. Laware & M.C. Mahajan (2016). Flora of Fergusson College campus, Pune, India: monitoring changes over half a century. Journal of Threatened Taxa 8(2) pp. 8452–8487.

[28]. Barberousse, H., Lombardo, R.J., Tell, G. and Couté A. (2006) Factors involved in the colonisation of building façades by algae and cyanobacteria in France Biofouling, 22(2) pp. 69-77.

[29]. Singh, A, (2011) Observations on the Vascular Wall Flora of Banaras Hindu University Campus, India, Bulletin of Environment, Pharmacology & Life Sciences,1(1), pp: 33-39.

[30]. Singh, D.K. and Singh, R (2014) Study of angiospermic wall floristic composition of city Buxar, (Bihar) India, Journal of Pharmacognosy and Phytochemistry, 2 (5): 52-54.

[31]. Jim, CY (2014) Ecology and conservation of strangler figs in urban wall habitats, Urban Ecosystems, 17(2) pp 405-426.

[32]. Francis RA and Lorimer J (2011) Urban reconciliation ecology: The potential of living roofs and walls Journal of Environmental Management, 92(6), pp. 1429–1437.

[33]. Chiquet C., Dover J.W. and Mitchell P. (2013) Birds and the urban environment: the value of green walls, Urban Ecosystems 16(3) pp 453-462.

[34]. Natarajan, M. · Rahimi, M. · Sen, S., Mackenzie, N and Imanbayev, Y. (2015) Living wall systems: evaluating life-cycle energy, water and carbon impacts. Urban Ecosystems, 18(1) pp 1-11.

[35]. Sternberg T, Viles H, Cathersides A (2011) Evaluating the role of ivy (Hedera helix) in moderating wall surface microclimates and contributing to the bioprotection of historic buildings, Building and Environment, 46(2), pp. 293-297.

[36]. Baghdad, B., Taleb, A., Iñigo Iñigo, A.C., El Hadi, H. and Dalimi, M. (2014) The Vascular Vegetation Populating the Flora in Building Materials of Historic Monuments Cities of the West Central Region of Morocco. Open Journal of Ecology, 4, 565-570.

[37]. Cutler N and Viles H (2010) Eukaryotic Microorganisms and Stone Biodeterioration, Geomicrobiology Journal 27(6-7), pp.630-646.