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An archaeological and historical exploration of the origins of green roofs

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ABSTRACT

The origin of green roof could be interpreted as old wine in new bottle and traced to antiquity. Archaeological and historical records and contemporary geographical-ecological assessments provide ample evidence to interpret the birth and progressive evolution of the cultural heritage. Studies in different places find early shelters using different natural materials. Humans living in harsh climates need particularly effective weather-proof enclosures to survive. The Arctic region with natural resource deprivation furnished the cradle for green roof initiation and refinement. The versatile and rather ubiquitous earth, widely used since Neolithic times to build dwellings, offered learning opportunities regarding properties and applications. The primitive flimsy conical shelters were sealed by earth daubing, permitting nature's seed rain to establish a vegetative cover to form the spontaneous meadow roof as green roof precursor. Subsequent progression to the house form, separating walls from roofs, required innovations to enhance weather-proofing and durability. Cutting from natural meadows mat-like sods with soil bound by dense fibrous roots into portable strips for roofing was better than plastering. Tantamount to transferring the sod ecosystem en masse from nature to roof, it permitted instant vegetation establishment and bypassed the erosion-vulnerable bare-earth stage. The invention denoted birth of the intentional sod roof. The materials and construction methods of the traditional multiple-layered sod roof are explained with the help of preserved technology. Employing research findings, eighteen hypothesized ecosystem services of sod roofs are identified and explained vis-à-vis modern counterparts.

1. Introduction

The ancient green roof invention, as part of the earthen structure, has been traced to at least the Neolithic, with archaeological remains spanning a long period (Kristjansdottir et al., 2001; Loveday, 2006; Bathhurst et al., 2010). The prominent old cases are substantial or monumental buildings of the royalty, aristocracy, or religious establishment. In the historical times, notable ruins and standing samples dated back to the ninth century AD (Hoffecker, 2005). The turf house innovation was initiated and honed by the Norse people in response to the extreme cold and harsh Arctic climate and resource deprivation (Sawyer, 1997). However, casual reference to green roof history tends to leapfrog from the Hanging Garden of Babylon in circa 500 BCE (Dalley, 2013) to some medieval European cases (UNESCO, 2016a). It then jumps to modernization in materials and designs in Germany in the 1960s (K & hler and Keely, 2005; Thuring and Dunnett, 2014).

It is worthwhile to explore the high-latitude origin of this special vernacular architecture and track its dissemination with the spread of Viking influence in Europe, and briefly in North America. The native Inuits of North America have developed similar turf houses (Morrison and Germain, 1995; Snow and Forman, 2009). Nomadic people in the treeless Central-Asian temperate grassland (steppe) have used the abundantly available sod to build houses (Ching, 2012). Their convergent adaptation to harsh nature with a meager resource base demonstrates cultural equifinality of human ingenuity. Expression of environmental determinism echoes similar human endeavors to develop dwellings to overcome constraints and suit local conditions (Gottmann, 1957; Rotne and Albjerg, 2010; Sørensen and Møller, 2010).

In the modern age, turf houses have been largely abandoned as it could not compete with the convenience of modern factory-made materials (van Hoof and van Dijken, 2008). The cultural heritage and traditional skills have been conserved in some northern lands. They include Iceland (Sigurðardóttir, 2008; Wunderlich et al., 2015), Arctic islands such as Greenland (Sørensen and Gulløv, 2012) and Faroe (Dahl, 1970). Occasional remnants have been found in Shetland (Hansen, 2000), Orkneys (Hedges, 1983), Svalbard (Jørgensen, 2005), Norway (Alnaes et al., 1950; Kavli, 1958), Sweden (King, 2011), Scotland (Fenton, 1968; Wilkinson, 2009), Ireland (Evans, 1973), the Isle of Man (Gelling, 1962), Alaska (de Laguna, 1936), Aleutian Islands (Bank, 1953; Rogers, 2011), Labrador and Newfoundland (Loring and Arendt, 2009; Rankin, 2015), and Siberia (Price, 1912). To facilitate representation of the timeline, the Neolithic refers to 8000–4000 BCE, ancient refers to 4000 BCE–500 CE, medieval 500 CE–1500, early modern 1500–1900, late modern 1900–1999, and recent 2000

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onwards.

The sod houses and roofs have been built and maintained sparingly through the medieval times and rarely in modern times. Turf houses in reasonably good condition are uncommon (Evans, 1940; Wilkinson, 2009). Sigurðardóttir (2008) described that the Skagafjörður Historical Museum in Iceland has actively preserved the practical knowledge and skills and traditional tools. Iceland has taken the initiative to submit in 2011 an application to UNESCO (2016b) for World Heritage recognition of exemplary old turf houses maintained by the National Museum of Iceland. Sigurðardóttir (2008) and Wilkinson (2009) explained with photographs the construction methods. Outside the Arctic region, records of sod roof are scanty, such as Abyssinia (now Ethiopia) encountered in 1806 (George, 1809).

This study attempts to fill a knowledge gap in green roof origin. It is based on interdisciplinary interpretations of the relevant literature dispersed in anthropology, archaeology, ecology, ethnography, geography, history, and natural history. The human-nature interactions provide the paradigm to evaluate human ingenuity and resourcefulness to build dwellings in the harsh Arctic landscape. The exploration begins by assessing the functional origin of green roof in a two-stage human innovation. Earth as an ancient building material was plastered on primitive shelters for weather-proofing, and spontaneously colonized by plants to form the spontaneous meadow roof. It was followed by conscious harvesting of sod, with soil plus living grasses and their roots, from natural meadows to form the intentional sod roof (Section 2). The geographical origin of green roof was traced to the Arctic lands where nature would circumscribe the pre-conditions for people to innovate despite the odds. The Nordic people, constrained by natural deficiency in building materials, harsh weather and economy of scarcity, developed the turf house as a survival strategy (Section 3). The materials and procedures of installing a sod roof and the associated tools and terminology are then explained based on traditional technology preserved by the northern countries (Section 4). The multiple ecosystem services of sod roofs are postulated and compared with modern research findings. Eighteen groups of benefits of sod roofs have been enumerated and explained in conjunction with modern green roofs (Section 5).

2. Earth on ancient human shelters as a precursor to green roofs

Primitive human ancestors sought refuge in caves. Roaming in the wilderness in search of food, temporary shelters were necessary to ensure survival in harsh weather. It complemented clothing as essential protective tools. The fundamental functions of primitive habitations included shielding from the elements, housing the family together, keeping inhabitants healthy, providing privacy, and storing personal belongings (Anderson, 1962; Rapoport, 1969). The basic qualities were simplicity, practicality, integrity, durability, labor economy, availability of materials, and suitability to the local climate and general environment.

The key challenges of human shelters were temperature extremes, gravity, wind, rain, running water, burrowing creatures, wild animals, aggressive plant growth, and earthquake. Three kinds of natural materials were suitable. The hard, strong and durable include stones, wood and bones. The living foliage, dead organic litter, tree bark and animal hide and felt are relatively soft, pliable, flattish but degradable. Soil or mud is intermediate in properties and amenable to digging, cutting, molding, shaping and plastering. Since the Neolithic times, humans have used soil to build dwellings of different forms (Rapoport, 1969; Loveday, 2006). The versatile earth was enlisted especially where stone and wood were deficient (Davey, 1961). It is abundant, easily extractable and handled, recyclable, and its use would not impose grave environmental impacts. Remains of ancient rammed earth structures are confined to dry areas (Fig. 1).

The primitive shelter was likely a simple conical form, such as the native American tepee, without differentiation between wall and roof. Mud was plastered on a wood or bamboo mesh covered by straw,

Fig. 1. Two notable old earthen structures: (upper photo) The ruins of Persian rammed-earth fortress, the Greater Kyz Kala, built in the sixth century CE for defense purpose in Merv, Turkmenistan. Photo attribution: Creative Commons, by Hergit, CC BY-SA 3.0, created 16 September 2011. https://en.wikipedia.org/wiki/Merv. (lower photo) The Ksar of Ait-Ben-Haddou in Ouarzazate province in south Morocco is a sprawling earthen structure built for fortification in the seventeenth century. Photo attribution: Creative Commons, by Donar Reiskoffer, CC BY-SA 3.0, created 14 December 2005, https://en.wikipedia.org/wiki/A%C3%AFt_Benhaddou.

exemplified by the wattle and daub method in archaeological remains of Swahili people in Tanzania (Fleisher and LaViolette, 1999; Cook, 2005) and Kenya (Wilson and Omar, 1997). In Central Asia, old records described a wooden roof frame covered with branches on which mud is plastered to support sod and vegetation growth (Schuyler, 1876), a method that is still used (Friesem et al., 2014). Native Americans built hogan houses in a similar manner (Hait, 1983; Nabokov and Easton, 1989). Felts and skins of animals were sometimes used (Holland, 1920). They show diverse forms and sophistications (McHenry, 1984).

The invention of agriculture in the Neolithic time fostered sedentary living, requiring more permanent shelters, which evolved into the house form with vertical wall and slanting roof. Soon humans learnt that thicker walls and roofs could keep out not just wind and water, but moderate the indoor thermal environment to reduce intrusion of heat in summer and heat escape in winter. Strong materials such as stone and wood formed the structural framework, and mud would be spread on the external surface to seal walls and roofs (McHenry, 1984). With tightly-packed small sticks covered with dry leaves, it was practical to plaster the entire surface (Friesem et al., 2014). With large logs, only the gaps were sealed. To reduce material needs and construction efforts, and to enhance protection against the weather, the early permanent dwellings were usually semi-underground in the form of pit houses (Danachair, 1955/1956; Danachair, 1955; van Hoof and van Dijken, 2008).

The roof could not support heavy materials. Leaf blades, bark sheets and animal skin were light weight but not durable. Flattish stones such as slate would be long-lasting, but they are not always easily available. These small or light pieces are susceptible to detachment by wind and rain. Soil could provide a suitable veneer, but it could be lost easily