ABSTRACT
Since 1990, Uzundere district has attracted the attention of national and international organizations due to its rich ecological values, where different projects have been launched in various fields, such as agriculture, environment, tourism, urbanism and architectural heritage. Uzundere region has strong vernacular heritage shaped by the climate, topographic conditions, local materials, culture and social lifestyle. In this study, various types of rural houses are surveyed in villages in the region. The plan and section of the houses are prepared through the author’s field survey, measurements, sketches, observation and interviews with local people. Then, the architectural response of houses to the climate is evaluated in terms of physical form and architectural typology of buildings. The outcome of optimized usage of materials, construction techniques and climatic considerations occurred in the region during centuries can be utilized in today’s architectural practice, while the modern architecture needs environment-friendly buildings.

1. Aims and background
The architecture of vernacular rural settlements in Uzundere region reflects its lifestyles and traditional values of the past. Vernacular buildings are built by local people whose building techniques are influenced by their geography, climate, traditions, cultures and materials (Misra 2016). The local people with special knowledge about their region have achieved these techniques through long-term experiences (Anna-Maria 2009; Zhai and Previtali 2010). The term vernacular architecture is defined as buildings built not by professional architects or builders but by local people that, for example, may be thought-out as “popular” architecture in rural housing (Ghaffarian Hoseini and Dahlan 2012). These buildings were planned for optimal use of local materials. Local materials, such as stone, adobes and timber, have been determinant of local architectural aspects and construction methods, which were completely adapted to the environment (Philokyprou et al. 2017a; Ren 2018). Traditional houses generally refer to time and space in the past, while vernacular houses have less to do with time; instead, they are more place-specific. Local builders adapted or developed vernacular houses over time, as their needs changed (Ju, Omar, and Ko 2012). Vernacular houses have various spatial design and create more thermal comfort than modern houses; so, spatial design principles of these houses are still of high value to modern building design (Du, Bokel, and van den Dobbelsteen 2016; Enai et al. 1993; Philokyprou et al. 2017b). The bioclimatic comfort is the climate conditions in which human feels healthier and more dynamic (Ozyavuz, Aytin, and Ertin 2018). These design techniques not only decrease energy use but also increase the inhabitant’s satisfaction (Jamaludin et al. 2014; Hong et al. 2017).

Generally, vernacular architecture is the functional architecture of local people, which is shaped by the environmental characteristics, climate, local materials, socio-cultural features and traditional technology. It tends to benefit from local building resources as well as passive and low-energy strategies, which not only causes no damage to the environment but also protects natural sources (Upadhyay, Yoshida, and Rijal 2006; Basaran 2011; Esin and Yukse 2010; Sousa Santos 2016; Saljoughinejad and Sharifabad 2015). Vernacular architecture is unique to each region in the world, since it is adapted to respond the environmental requirements including climate, topographic conditions, local materials and social lifestyle (Engin et al. 2007; Alonso Monterde et al. 2016; Shastr, Mani, and Tenorio 2014).

Owing to the recent globalization, the unique local and regional architectural identity has faded and there has been little emphasis on the physical form of buildings and architectural typology of regions (Abdelkader and Park 2018). Developing countries welcomed the import of a modern construction system, which seemed impression and unprejudiced instead of developing their own methods, while they were afraid of being out-of-date (Lainez and Verdejo 2007). Today’s
growth of buildings does not meet the needs of users. So meeting users’ needs and values are necessary for delivering quality buildings (Moghimi, Bin Mohd Jusun, and Mahdinejad 2017). Rural villages play essential environmental and economic roles in development models (Stringer 2017). It is essential to study the vernacular architecture and abandoned buildings in various rural villages before getting destroyed or decayed, which is a great threat in developing countries (Shitara 2006; Vural et al. 2007; Choi and Yu 2011; Krag and Stochholm 2017). Vernacular architecture and rural buildings demonstrate an important part of the architectural and cultural heritage (Tao et al. 2018; Acici, Kose, and Demirel 2018; Sbarcea and Tudor 2016; Ren 2017). Better understanding of them may preserve the cultural heritage of past civilizations for the future generations (Tuçokulu et al. 2015; Durak, Erbil, and Akınıncıtürk 2011; Garcia-Esparza 2014; Dimen, Borsan, and Gaban 2018; Ertas et al. 2017).

The evaluation of vernacular architecture is a mean to comprehend significant element of their environment and construction (Gunewardene 2016). A better approach will be found through the study on the past production and the atmosphere in which they formed (Özdemir et al. 2008). Understanding of vernacular architecture in terms of the relationship between site, building and climate provides vital lessons for the current architectural practices in the area (Indraganti 2010). It can also play an important role in reducing the energy demand of buildings (Rubio-Bellido, Pulido-Arcas, and Cabeza-Lainez 2018).

Sustainable building mentions to both a structure and the application of proceedings that are environmentally responsible and resource-efficient through a building’s planning, design, making, utilization, preservation, renovation, and destruction. Sustainable buildings are environment-friendly buildings, which attempt to have minimum negative environmental impact by efficiency and moderation in the use of materials and energy. (Karahan and Davardoust 2019) According to the definitions of vernacular architecture, which mentioned above we can identify vernacular architecture as an example of sustainable architecture.

This study evaluates the vernacular settlements in Uzundere region in terms of architectural typology and physical form of buildings based on passive design principles that are responsible for the bioclimatic character of the region. The importance of sustainable development cannot be disagreed in the construction industry (Achim, Stan, and Dragolea 2018; Ballice and Paykoc 2014; Kiray and Yildizci 2014). So this study tends to put forward a theoretical proposition concerning the adaptation of vernacular architectural features into the sustainable development projects being performed in the region.

Since 1990 the Uzundere region that has rich ecological resources, witnesses the different activities of the national and international organizations in the field of agriculture, bio-environment, rural tourism, urbanism and architecture. In last 10 years, some works and activities such as Eastern Anatolia Tourism Development Project (DATUR), Uzundere Strategic Development Plan, Uzundere Tourism Master Plan and Uzundere Biodiversity Strategy and Action Plan, are implementing in Uzundere. In addition to analyzing the specifications of the local buildings, this research suggests some principles for design of form, context and spatial specifications for new buildings. In other words, it suggests some principles that are obtained from studying the local buildings, which could be used for designing the hotel, tourist villages, ecological villages, rural life museum and other ecological buildings that are among the aims of rural development in the region.

2. Uzundere

2.1. Location of Uzundere

Uzundere is ecologically located in Eastern Anatolia Region, in the Eastern Black Sea Region. There is a considerable height difference between the valleys and hilly areas in this region. This difference varies from 600 to 3650 meters. Uzundere and Tortum districts have been established on the Erzurum-Artvin highway (950–02) in the Tortum Creek valley. Uzundere is located 84 km away from the city center of Erzurum and the
transportation is provided by asphalt road (Karahan et al. 2011). The location of the research area is given in Figure 1.

2.2. Climatic data

Uzundere district is influenced by natural environmental factors such as attitude, air mass, landscape view and mountain extension started from out of the zone. In the last 50 years, the average rainfall is measured 434.9 mm in Uzundere district. The maximum rainfall occurs in May, while the minimum rainfall is in September. Annual humidity average is 59%. In Uzundere, temperature differences are high between day and night or over seasons. For these reasons, the local houses in this region are made of stone, clay and soil that have high thermal mass which, will be explained in detail in walls and roofs sections.

The annual average temperature, however, varies from 8.3 C to 14.5 C. The annual average of frost days is 125.3, while the number of warm days is 161. According to Figure 2, total solar radiation of Uzundere varies from 1450 to 1650 (KW/M2-year). The solar radiation for northern residents of the area can be considered between 1450 and 1550 (KW/M2-year) while it is between 1550 and 1650 (KW/M2-year) for southern residents of the area (Canka Kılıç 2015). Considering the climatic specifications, for optimized use of the solar energy, the local houses of this region are built on the southern slopes of the v-shaped valleys, which are located in the west-east direction. It shows that ecosystem data of the region used to be analyzed by the local people and it was used for forming the rural residents. Local climatic knowledge and strategies of sustainable designing for thermal facilities are important knowledge in selecting the location and development of necessary infrastructure for rural tourism and other ecological activities in the region. The climatic data shown in Table 1 use Uzundere station data.

2.3. Vernacular architecture in Uzundere

According to the classification by International Conservation, Uzundere is located in the Çoruh (Choruh) valley in the west part of the Caucasus Ecoregion, which is considered as one of the 200 important ecological regions of the world. The natural ecosystem (i.e. flora, fauna, water, soil, climate and geographic factors) of the Coruh valley has created a culture aged for thousands of years. This culture has also led to the emergence of examples of local traditional architecture using building materials based on the geology and flora (forest trees). The traditional features of the cultural heritage survived in the Coruh valley until the mid-1970s when road transport facilities began to develop. Since 1990, in the Coruh valley, the number of unplanned and unidentified reinforced concrete structures increased rapidly and the process of destruction of traditional local architectural examples was started. This research is prepared in order to contribute to the documentation of diminishing vernacular architectural examples.

3. Experimental

Uzundere region has a strong vernacular character, which is shaped by the climate, topographic conditions, local materials and the social lifestyle. This study examines the most important architectural forms found in Uzundere region that play an important role in the evolution of vernacular architecture of the region. The methods used are as follows: (1) For evaluating the vernacular settlement of Uzundere region, six villages are selected. After visiting and studying the region, the ancient and traditional villages are selected because they correspond with villager’s needs, location and also region’s facilities. The status of rural houses, like their construction date, materials and techniques, are efficient factors in the selection of these six villages named Gölbəş, Sapaca, Balıklı, Çağlayan, Dikyar and Kirazlı. Two houses from Sapaca village (type b,c) and one house from the other five villages.
are selected as the following: Dikyar (type a), Kirazlı (type d), Gölbaşı (type e), Balıklı (type f) and Çağlayan (type g). The location of villages is given in Figure 3. The environmental data is gathered through the author’s field survey, measurements, sketches, observation and interviews with local people. The gathered data is the outcome of on-site examination of vernacular rural houses in six villages of Uzundere region. In the next step, the vernacular architectural of Uzundere region is evaluated in terms of typological analysis and physical form of buildings. These evaluations include the layout (orientation towards the sun and wind, aspect ratio), spacing (open space), openings (size-position, semi-open spaces) and building envelopes (walls, roofs).

This research is prepared in order to contribute to the documentation of diminishing traditional vernacular architectural examples. The results presented in tables can be utilized as design recommendations in today’s architectural practice in the area and also as an ecological pattern in sustainable development projects performed in the area in the future.

4. Results and discussion

4.1. Typological analysis

Typical examples of dwellings in Uzundere region are introduced to clarify their vernacular characteristics. These types of buildings were built gradually by local people according to their traditions and cultures and evolved over many generations. These people possessed specific knowledge about their place and plants. The dwelling units are analyzed based on their layout, plan configuration and functional characteristics, i.e. patterns and variations of the basic form. The analysis is presented in Table 2.

In Uzundere region, architectural synthesis besides structural formation can be easily understood in the general layout of the dwellings; the building structure

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**Table 1. Climatic data.**

| Season | Winter | Spring | Summer | Autumn |
|--------|--------|--------|--------|--------|
| Month  | Dec.   | Jan.   | Feb.   | Mar.   | Apr.   | May.   | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. |
| Mean temperature (°C) | -2.8   | -1.2   | 4.4    | 11.5   | 14.8   | 18.8   | 22.1 | 21.9 | 18.0 | 11.1 | 4.8  | -0.8 |
| Max. temperature (°C) | 2.6    | 4.4    | 10.6   | 18.2   | 21.5   | 25.8   | 29.1 | 29.2 | 25.5 | 17.9 | 10.6 | 4.5  |
| Min. temperature (°C) | -7.5   | -5.8   | -1.5   | 4.5    | 7.7    | 11.3   | 14.7 | 14.2 | 9.6  | 5.3  | 0.3  | -5.0 |
| Amount of rainfall (mm) | 12.6   | 19.3   | 16.2   | 30.5   | 41.9   | 48.2   | 26.1 | 17.4 | 8.8  | 38.5 | 28.2 | 20.0 |
| Relative humidity (%) | 67.1   | 61.3   | 49.3   | 43.9   | 48.1   | 49.0   | 47.1 | 46.8 | 44.0 | 59.0 | 65.7 | 66.8 |
| Number of frosty days | 26.4   | 61.3   | 49.3   | 43.9   | 48.1   | 49.0   | 47.1 | 46.8 | 44.0 | 59.0 | 65.7 | 66.8 |
| Average wind speed (m/sec) | 0.3    | 0.6    | 0.5    | 0.5    | 0.5    | 0.4    | 0.5  | 0.4  | 0.4  | 0.3  | 0.2  | 0.2  |
| Prevailing wind direction | NE    | NE     | NE     | SW     | NE     | SW     | NE   | NE   | NE   | NE   | S    | SW   |

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**Figure 3.** Location of research villages.
### Table 2. Typological analysis.

| Appearance | Plan, section, Description |
|------------|-----------------------------|
| House a    | ![Diagram](image1)           |
| House b    | ![Diagram](image2)           |
| House c    | ![Diagram](image3)           |
| House d    | ![Diagram](image4)           |
| House e    | ![Diagram](image5)           |
| House f    | ![Diagram](image6)           |

For all houses:

- L-living room
- F-family bedroom
- K-kitchen
- S-storage
- D-dry food storage
- T-terrace
- A-attic
- B-barn

(Continued)
is simple, clear and easy to understand. In addition, spatial dimensions of rural houses match human proportions. Flexibility of rural human is high. The parts of the house such as stairways, terrace, oven, etc., are built according to minimum dimensions. In Uzundere, vernacular architectural style is highly evolved in its structure and plan. The plan of houses essentially varies in two major types: (A) a single-room house with thick stone walls, where all activities take place in one room; (B) in the second type of rural houses, plans vary in the quality of detailing, not in fundamental function. These buildings are formed in great harmony with the activities of the occupant. More than one family usually lives in one house, so there are spaces allocated for a family, such as family bedrooms, in these buildings. Since there is no independent dining room and kitchen in most of the rural houses, the living room is usually multi-functional as the major part of the building. The whole or a part of the ground floor is mostly allocated to barn space to keep houses warm and avoid humidity; so most of the houses are built above the ground level or on barns. There are also spaces like hayloft, attic and dry food storages for keeping firewood, chaff and fodder and garden and agricultural products. Usually, there is no restroom inside the building, while it is generally located in terrace or yard. Most houses have a roofed space as terrace that connects the interior and the exterior to adjust the temperature. This space is also used as a sitting place in the summer.

4.2. Architectural typology and building physics analysis

Associated with the bioclimatic design elements, vernacular architecture of Uzundere region is evaluated in terms of physical form and typology of buildings, including layout (orientation towards the sun and wind, aspect ratio), spacing (open space), openings (size-position, semi-open spaces) and building envelope (walls, roofs) (Table 3).

**Layout (Orientation):** Dwellings are oriented at an angle of 20° along the northwest axis.

| Appearance | Plan, section, Description |
|------------|----------------------------|
| House g    | ![Diagram](image)           |

**Layout (Aspect ratio):** The term “aspect ratio” is used to define the ratio of the longer dimension of a rectangular plan to the shorter. In Dikyar and Sapaca villages, prevailing winds are westerly; so the N/E and S/W walls are longer than N/W and S/E walls to protect the building from prevailing winds and benefit from sunlight in the cold climate. However, in Kirazlı, Gölbashi, Balıklı and Çağlayan villages, prevailing winds are southerly; so the N/W and S/E walls are longer than N/E and S/W walls to protect the building from undesirable winds. The “aspect ratio” varies from 1.00 to 2.05.

**Spacing (Open spaces):** Courtyards can be found scarcely in mountainous areas and if it is found, they are usually in limited size due to topographical constraints and climatic conditions that limit the possibility for outdoor activities. So, household and social activities usually occur at the semi-open spaces as well as public streets and alleys.

**Opening (Size-position of openings):** Openings are placed according to the climatological requirements. Their types, proportions and sizes are specified by the orientation of the wall. In Dikyar and Sapaca villages (a, b and c types) that prevailing winds are westerly, the number of openings on N/W and S/E walls are limited to avoid excessive heat loss, while the maximum number of openings are embedded on N/E and S/W walls to benefit from sunlight in the cold climate. In Kirazlı, Gölbashi, Balıklı and Çağlayan villages (d, e, f and g types), prevailing winds are southerly; so there are several N/W and S/E openings whereas east-facing openings are fewer in number and smaller in size. The ratio of opening to wall area varies from 0.0% to 14.60%. Using small and low number of openings in these houses is another solution for the cold climate.

**Opening (Semi-open spaces):** Suffering from land availability in mountainous regions, semi-open spaces are limited in number in the typology of traditional buildings. Existing semi-open spaces are usually located on the top floor levels in the buildings. This location allows for benefiting from the maximum solar energy during the winter days, providing a warm place for family activities during sunny winter days. Dominant
shape of balconies is long covered timber balcony shaped in the main façade of the building. Thus, several S/W facades are chosen for semi-open spaces. This façade can gain the maximum solar energy for rear part of buildings whereas N/E facades have no semi-open spaces. In the villages like Kirazlı, Gölbaş, Balkılı and Çağlayan where prevailing winds are southerly, the terrace size is small on S/W or there is a terrace in S/E or N/E facades to protect the building from undesirable winds.

**Building envelope:** The mountainous regions provide abundant resources of local materials. The soil, stone and wood are the main local construction materials in building walls in the villages of Uzundere region. While the usage of new materials has become common due to the development of roads and transportation facilities, the traditional local ones are mainly being used in the houses of the region.

**Building envelope (Walls):** In vernacular rural houses in Uzundere region, the walls are of three types: stone walls, bağdadi walls (adobe and timber) and timber wall plates. The main building materials used for constructing the walls is stone since the stone is the most plentiful resource in the region. In these villages, stones are used in two forms of river stones and mountainous stones known as rubble stone. The use of river stones is limited in the walls and they are mostly used in minor spaces or as infilling materials; while mountainous stones are used in constructing stone walls. The space between stone walls is filled with mud and smaller stones. In stone walls, horizontal beams are usually used at vertical intervals of about 1–1.50 meters in order to combine the stone layers and keep the integrity of the masonry construction (Figure 4) (Cobancaoğlu 2001). The time lag of storing heat in these walls is high. The use of local materials such as stone and adobe as well as thick walls minimize temperature exchange between the internal and external space because they store heat during the day time and radiate it into the room at night when necessary.

The next common wall type in the region is bağdadi wall (Figure 5). It is a timber frame structure where small and light pieces of raw materials like earth, small stones and mortar are used as infilling materials. The use of timber frame on the first floor helps decrease the dead loads. The surface of bağdadi walls is covered by lath and plaster; the total thickness of wall reaches 15 cm and its maximum height never exceeds 3 m.

Timber wall plates are constructed as partition walls in the indoor and semi-open spaces (Karaman and Zeren 2015). They are built up from the wooden plates prepared in local workshops. They have a thickness of around 3 cm, width of 25–30 cm and are very light in construction. Although Scotch pine is the main timber material extensively available in Uzundere region, Juniperus Excelsa and Populus Nigra are also used for the timber plate construction.

**Building envelope (Roofs):** In Uzundere region, the roofs are classified as three types: flat roofs, single or double inclined roofs and wooden roofs locally called Kurlanguç. Flat roofs, which form a common design type, not only offer an efficient implementation and structure but also keep snow on roofs as thermal insulation in the cold climate. Timber beams that are covered with timber boarding (Figure 6) form the roof layers. Depending on the room depth, timber beams are either placed directly on the stone walls or on an additional central beam. These roofs consist of a thick layer of rammed earth, which is laid on the reed or straw. The reed or straw are used to prevent the decay caused by direct contact between the timber beams and the beaten earth and avoid insect attack. Then, the

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Table 3. Evaluation of the architectural typological and building physics.

| Types of houses | Layout | Aspect ratio | Openings | Size-Position | Opening | Semi-Open | Walls | Roofs |
|-----------------|--------|--------------|----------|--------------|---------|-----------|-------|-------|
| a               | a      | 1.20         | –        | NE:4.26%     | –       | –         | Stone; wall of high thermal mass | Single slope; roof of medium thermal mass |
| b               | b      | 1.50         | –        | NE:2.45%     | –       | –         | Stone; bağdadi; walls of high thermal mass | Double slope; roof of medium thermal mass |
| c               | c      | 1.00         | –        | NW:5.00%     | –       | –         | Stone; wall of high thermal mass | Flat roof; roof of high thermal mass |
| d               | d      | 2.05         | –        | NW:9.30%     | –       | –         | Stone; wall of high thermal mass | Of high thermal mass |
| e               | e      | 1.20         | –        | SW:6.60%     | –       | –         | Stone; wall of high thermal mass | Flat roof; roof |
| f               | f      | 1.80         | –        | NW:9.30%     | –       | –         | Stone; bağdadi; walls of high thermal mass | Flat roof; roof |
| g               | g      | 1.90         | –        | NW:9.83%     | –       | –         | Stone; bağdadi; walls of high thermal mass | Double slope; roof of medium thermal mass |
A flat roof is covered with a final layer of mud. These roofs have a thickness of 30–40 cm.

Lightweight and multi-layered structures of inclined roofs known as type 2 are constructed by timber rafters and covered by reed battens or straw, earth and a layer of clay tiles. These long-lasting roofs do not need continuous maintenance.

The third type is wooden roofs locally known as Kurlangu (Figure 7). These roofs cover the square-shaped houses and fit square corners. The first line of roofs is supported by legs and diagonally installed rectangular-edged rafters give an octagon shape to the space. The second line is fixed over the first line and it is shaped like a square; then, it is extended over the second line like an octagon. This process is evaluated continuously to reach the last level, shaping a hole to provide light and also ventilation. Diagram of daylight and ventilation of kurlangu roof is given in Figure 8.

Utilizing traditional building techniques as well as using environmentally friendly building and furnishing materials during construction have a minimal impact on the natural surroundings (Mehta 2010). Attempts to work with local community members, wherever possible, during initial physical planning and design steps of construction can be considered as an ecological challenge in the area.
Figure 6. Various flat roofs.

Figure 7. Kurlanguç roof.

Figure 8. Diagram of daylight and ventilation of kurlanguç roof.
5. Conclusions

This paper endeavors to reveal the secrets applied in such eco-efficient rural houses in Uzundere region, associated with the bioclimatic design elements using the pattern of rural houses, building typology and physical form of buildings. The conclusions are as follows:

- Keeping in mind the aspects of architectural typology, two dated and current types of typology are in great harmony with the activities of occupants. The two diverse types are the outcome of changing lifestyle of the occupants during the years. Each type of rural plans varies in the quality of detailing, not in fundamental function.
- Buildings are oriented according to climatological requirements. Protection from prevailing winds and utilization of maximum solar energy are two determinant factors in building orientation, which can minimize heat loss in this cold climate.
- Open spaces such as the courtyard can be found scarcely in mountainous areas due to topographical and climatological conditions. Semi-open spaces in form of long covered timber balconies are usually located at the front of main façade of the building, which provide shading during the summer and allow penetration of solar radiation in cold winter days. Using small and low number of openings in these houses is another solution for the cold climate.
- Using thick and high thermal mass walls help to store solar heat energy during sunny winter days and transfer it inside the houses during cold nights. In upper floors Bağdadi walls, which have rather less thermal mass than thick stone walls, are used. Because these walls show suitable behavior in earthquakes since they have stronger joints and structure also use of timber frame Bağdadi walls on the first floor helps decrease the dead loads. Flat roofs are a common roof type. These roofs not only offer an effortless implementation and structure but also keep snow on roofs as the thermal insulation.
- Construction materials in the studied rural houses are completely local materials extensively available in Uzundere region. The use of local material can be considered as an ecological challenge. Since local materials are abundant, reusable and recyclable, they have a low impact on the environment and cause a cash flow within the community. Local materials used in the studied rural houses are as below: soil in form of adobe and mortar; stone in two forms of river stone and rubble stone; timber materials in common types of Scot pine, Juniperus Excelsa and Populus Nigra. Therefore, the construction technology in vernacular architecture of Uzundere seems sustainable. The factors that lead to the development of such architecture are (1) Maximum use of clean solar energy and reduction of energy consumption by appropriate building orientation, using semi-open spaces on main façade using a low number of openings with small sizes, using thick and tall thermal mass walls, construction of flat roofs covered by snow as the thermal insulation. (2) Minimization of harmful environmental effects in constructions using recyclable and reusable local materials. (3) Preservation of architectural and cultural heritage by buildings, which are coordinated with the needs and values of indigenous communities and built by local skills, labor and knowledge in construction.

Disclosure statement

No potential conflict of interest was reported by the authors.

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