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An Empirical Study on Settlement Pattern and Architectural Features of Rural Housing in Haor-basin Region of Bangladesh

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Abstract

The Haor region is characterised by annual flooding, with over 90% of the land submerged for half of the year. The compact rural settlements characterized by indigenous architecture and planning techniques enable the village to cope with the challenging hydro-meteorologic conditions while fostering social cohesion. However, recent developments using non-local materials potentially can disrupt social coherence, thereby creating adverse effects on community wellbeing. Since the rural settlements have gone through organic growth, maintaining vernacular patterns and formal documentation of the planning concepts are essential. This research identifies the settlement pattern from empirical study, on-site observation, and analysis of the pattern with an understanding of local norms and architectural knowledge. It is evident from the study that the rural houses are built aligned with the cardinal directions even when the site orientation is different. The settlement clusters are linearly aligned to the monsoon flood flow direction. Though the linear courtyards are subdivided in terms of ownership, practically, they are maintained as barrier-free connectivity among houses within the same housing cluster. This research will provide valuable guidelines for future planning in the challenging topography of the Haor Basin.

Keywords

Haor Basin, Housing, Community, Rural architecture, Vernacular settlement

1. Introduction

1.1 Rural Settlements in Bangladesh

The rural settlements of Bangladesh are influenced by different environmental and socio-cultural determinants such as topography, access to natural resources, religion, defense, culture, rituals, family structure, and occupation (“United Nations,1976; Mowla, 1997; Islam, 2003). Traditionally, outdoor spaces act as a platform for the socialization of people in Bangladesh, leading to formation of courtyards, lanes, bazaars (marketplace), chowk (land parcel), etc. (Mowla, 1997). Outdoor spaces are the prime emphasis of traditional morphology, whereas planned areas emphasize road networks. As a result, dedicated places for shared domestic, social, and occupational activities are accommodated in the indigenous settlements.

To study a typical Bengali house, understanding the social structure and its settlement system is mandatory (Mowla, 1999). Households (ghar) and homesteads are the smallest units of the rural social structures. A group of 4-6 isolated households around one or more courtyards typically form a homestead (Ahmed 2012). The courtyard is an informal gathering space for regular and occasional outdoor activities. The courtyard and built forms mostly are oblong throughout the rural areas. The dwelling units are accompanied by ancillary functions such as a granary, cattle shed, kitchen, husking space, fuel storage, pond, etc. (Hassan et al., 2000). The household can be divided into two distinct zones – a male-dominated formal zone in the outer part and a female-dominated informal zone in the inner part (Islam, 2003). The formal court holds occupational activities, such as crop harvesting and living zones for domestic animals. An outer house, which serves as a buffer between the formal and informal zones, typically accommodates male guests and visitors. The inner court is used for family gatherings, food preparation, cloth drying, and crop drying. The entrance to this court is more private and indirect. The houses in the inner court often have a shaded veranda towards the court, which is convenient for sleeping at night. The informal zone sometimes is terminated by a small pond at the rear side used for bathing and domestic activities. A neighbourhood, locally known as 'para,' consists of around 5-10 homesteads, and a village, the largest rural settlement unit in Bengal, consists of 4-8 such neighbourhoods (Mowla, 1997).

1.2 Haor Basin

The Haor Basin, shallow wetlands formed by bowl-shaped depressions, is located in the northeastern districts of Bangladesh, mainly in Sunamganj, Moulvibazar, Sylhet, Kishoreganj, and Netrokona. This unique geomorphological tectonic depression provides refuge for almost 19 million people (Chowdhooree et al., 2020) in about 24,265 square kilometers – nearly 20% of the total land area of Bangladesh (Alam & Hasan, 2010). These areas experience shallow to profound flooding during the monsoon season (Murata et al., 2011; Ministry of Environment and Forests, 2005) and the floodplains are inundated to depths of 1.8 to 3 m, thereby becoming isolated water basins (Alam & Choudhury, 2003). In some years, the region can experience early flash floods from April; while in others, the flood can extend until September (Salauddin & Islam, 2011). Despite having only a single harvesting season per year, this agriculture-based community contributes 20% of the total rice production in Bangladesh. Apart from the dynamic landscape, the Haor Basin has distinct ecological diversities, human settlements, and seasonal hydrology. These wetlands are habitats for unique ecosystems, aquatic species, and dynamic wildlife, providing important economic and ecological value. As a result, some wetlands in the Haor Basin are protected by the Ramsar Convention. The whole area acts as a tank for storing and draining stormwater in the northeast region.

1.3 Problem Statement

The rural settlements in the Haor Basin are distinctive from the rest of the country. Most of the settlements were developed organically and guided by vernacular practice. Physical factors such as topography, site surroundings, transportation network, built-form, orientation, building materials, and dynamic hydrology, as well as intangible factors such as affordability, religion, spatial use, and economic and domestic activities, influence the development process, settlement pattern, and building typology of the Haor Basin region. Population growth and occupation change have greatly influenced this region's development pattern. Though the development density is very low, this region's supply of habitable flood-free land is very limited. As a result, using courtyards for domestic works and informal circulation networks creates a unique planning language in the area. With an

increased population, the subdivision of housing areas and the creation of new buildings are not following the indigenous settlement techniques. These changes may hamper the resilience of the settlements in coping with environmental and socio-cultural disruptions. Besides, global climate change has adversely impacted this region, increasing vulnerability and increasing community hazard risks. Therefore, the three-dimensional relationship between environment, planning, and vernacular knowledge must be established for resilient development.

1.4 Scope and Objectives

Though coastal and flood-plain settlements recently have gained the attention of researchers, architectural research on Haor Basin settlements has yet to be explored in Bangladesh. The government of Bangladesh is taking various steps to reduce the infrastructural development gap between urban and rural areas. Documentation of settlement patterns and vernacular techniques is vital to ensure sustainable infrastructure development in rural areas. This is true not only for planned housing projects but also for the organic development of rural households, which requires more attention and sensitivity. Providing rural planning guidelines and vernacular toolkits can help bridge the gap since there is a lack of technical support for rural communities. This study will reduce the existing gap in the corresponding research and practice and open a new dimension for future research on a regional scale. The objectives of this research were threefold: i) document existing settlement patterns of the Haor Basin; ii) develop an understanding of socio-cultural aspects, vernacular influences, and local practices for hydro-meteorologic and social resilience; and iii) identify the distinct archetypes and building typologies of the Hoar Basin.

The government and several non-government organizations are interested in working on the resettlement of the marginal communities living in the Haor Basin. However, in most cases, these resettlements do not respect the existing architectural practice and socio-cultural factors. The self-built architecture practiced in the Haor Basin requires extensive research to identify the local building skills and craftsmanship. This study can aid in identifying potential housing and land scarcity problems in the Haor Basin. Research on their existing settlements also can be vital for an inclusive social and environmental infrastructure design process.

2. Literature Review

2.1 Environmental Challenges in the Haor Settlements

Existing literature on the Haor region mostly discusses the spatio-temporal changes in the land cover of the settlements due to flooding from an environmental perspective (Salauddin & Islam, 2011; Yasmin, 2018). The inadequacy of elevated lands results in the region's high-density compact settlements built on linear levees or raised artificial mounds (Islam, 2003). During the monsoon season, they become physically isolated tiny islands, as the seasonal roads remain underwater for months. Water-based transportation is the only mode of social connection during that period (Alam & Hasan, 2010). The high growth rate of the population, which almost doubled in the first quarter of the century, also is causing severe infrastructural problems in terms of difficulties in housing expansion, employment opportunities, and illegal wetland acquisition (Yasmin, 2018). Subsequently, the Haor ecosystem is under severe threat of environmental degradation. In most cases, unemployment and flooding forced the inhabitants to push migration to the already dense urban settlements.

Several researchers highlighted the importance of community participation at different levels and the application of local knowledge for climate change adaptation (Chowdhooree et al., 2020; Anik & Khan, 2012). Sandbags and riparian plantations are popular practices that provide inexpensive but effective protection to

the edges of the raised earthen platforms, potentially vulnerable to erosion and collapse due to flash floods and strong currents (Anik & Khan, 2012). Recently, NGOs and the government have supported the inhabitants in reinforcing the edges with concrete blocks and brick walls (Chowdhooree et al., 2020).

2.2 Theoretical Framework to study Rural Settlements

We reviewed McCartney and Krishnamurthy's (2018) theoretical framework for analyzing the morphology of rural informal settlements. The framework considers several spatial and non-spatial factors. Spatial factors include various planning and architectural aspects of the settlement that directly characterize the informal settlement. Among the planning features are settlement patterns, informal networks, and connectivity. Settlement pattern maps the two-dimensional relationship between built forms and outdoor spaces, while connectivity examines both planned circulation networks and informal negotiated movement. Architectural features such as formal orientation identify the basis of informal spatial planning in traditional buildings and building typology determines the diversity of built forms. The extension and sub-division of spaces also contribute to morphological diversity. Non-spatial factors encompass socio-cultural, economic, and political characteristics that may directly or indirectly impact spatial planning. For instance, vernacular knowledge aids in hydrometeorologic risk and climate change adaptation, while shared spaces contribute to social resilience. These spatial and non-spatial factors, particularly formal and informal connectivity, orientation and built-form typologies, and socio-cultural aspects, also can be relevant for the identification of rural settlement patterns of the Haor region.

2.3 Review of form and Planning

Several cultural and environmental practices impact the layout and shape of the house forms. Homesteads in Haor communities predominantly are longitudinal and rectangular (Ahmed, 1991). Pitched roofs of oblong shapes very commonly are used to shed rainwater swiftly. A veranda attached to the internal rooms serves as a semi-outdoor space, which is very important to the socio-cultural aspect of this region. Trees are planted surrounding the houses and courtyards to provide shade against the sun and protection from storms and floods (Seraj & Ahmed, 2004). Moreover, the materials used to construct the houses mostly are semi-permanent and locally available materials. So, selecting trees to be planted on the houses' west and north sides is crucial. The other influential factor in creating most of the settlement clusters that are linear in shape with north-south elongated property footprints is the natural water flow of the Haors during the flood.

In the Haor area, recently developed, planned roads are used as the primary means of formal circulation, providing connectivity to settlements. During the monsoon season, primary roads get inundated and detached, and settlements become isolated. The waterways are the most convenient transportation mode at that time. However, the secondary walkways connect the primary roads to the linear central courtyards, which provide internal connectivity among the houses. These connections also allow direct access from water transport to individual houses during the monsoon season. Due to blurred land ownership, less legislative control, and seasonal transportation mode, frequent informal movements through the settlements are visible, mainly in shared circulations, aisles, and waterways (Rashid, 2020). To summarise, seasonal dynamics of hydrology and organic growth directly shape spatial morphology. In addition, the Haor communities have developed a socio-cultural and environmental resilience that characterises their built-form and planning.

2.4 Review of Socio-Cultural Spaces

Due to the lack of available flood-free land, collaborative working cultures are prevalent in Haor areas. The linear courtyards and the seasonal outdoor area known as the Khola hosts communal events. Most secondary walkways that connect the villages pass through the Khola. It serves as a venue for social events, religious festivals, and activities like agricultural harvesting and processing zones, mainly during the dry season. The courtyards, along with being the means of internal circulation, also are used for domestic utilities such as fuel processing, drying crops or clothes, and recreational activities (Seraj & Ahmed, 2004). Land ownership patterns are unique to this region's socio-cultural and climatic aspects. One single family usually owns lands within different parts of the settlement cluster. For example, the houses are built on the highest lands with the best protection against the annual flood. The vegetable gardens, which are close to the houses, form another cluster that may not be attached to the residential plot/land area. The Khola is comparatively higher land with better protection from flood but lower than the Uthan (courtyards). Several families collaboratively oversee a Khola, allowing communal use and better access through shared pedestrian trails from the crop field. The land ownership boundaries are specified, but the collaborative use of Khola creates better feelings of community and social integration for the people. Generally, these types of large community-owned lands do not have any defined boundary. In summary, dynamic ownership patterns uniquely influence the governance of multipurpose socio-cultural spaces, which provide social, cultural, spatial (accessibility), and economic values to the communities.

2.5 Review of Architectural Features

The Haor region consists of different types of house forms. These houses can be distinguished by their roofing styles, form shapes, availability of veranda, etc. Due to the intense precipitation in this area, rectangular inclined roofs are widely used for building homes. Corrugated Iron (CI) sheets are widespread roofing materials (Ahmed, 1991; Hasan et al., 2000). The shape of the roof defines the typology of the houses and plan profile instead of materials since roofing and partition materials change over time, keeping the same spatial quality of the houses. Previously, thatched roofs and walls made of Ikra, a straight and tall straw-like material, were common. This type of wall has a high thermal capacity to protect the rooms from solar radiation. On the other hand, thin walls made of Ikra have high permeability that allows passive ventilation and quick discharge of trapped heat from indoors.

The dwellers' traditional beliefs and climatic factors influence building orientation in the Haor Basin areas. The house forms typically are oriented east-west despite their position and proximity to other landscape features, such as rivers, canals, and roads. A courtyard typically is surrounded by a row of house forms, which is very common in rural areas and is crucial in improving house air circulation (Bodach et al., 2014). Unlike the rural settlements in other regions of Bangladesh, the north-south facing house generally is discouraged in Haor areas, influenced by certain social practices and beliefs. While the impacts of roof shape and orientation are visible in characterising building typologies initially, the effects of informal extensions and subdivision strategies in later phases require further investigation in future.

3. Research Framework and Methodology

3.1 Research Design

The research followed an empirical method, as the results were based on direct observations and phenomena from real-life experiences by the researchers. There are four major steps in this research: selection of study areas; identification of settlement pattern; understanding of the vernacular knowledge; and suggesting policy recommendations for sustainable settlement planning into the future (Figure 1). The selected study areas vary in size and distance from the nearest urban centers. They are located in four different districts of the Haor Basin region. Maintaining diversity in the study area selection ensured a more comprehensive range of data collection. It facilitated the analysis of study features to find common patterns throughout the Haor Basin region.

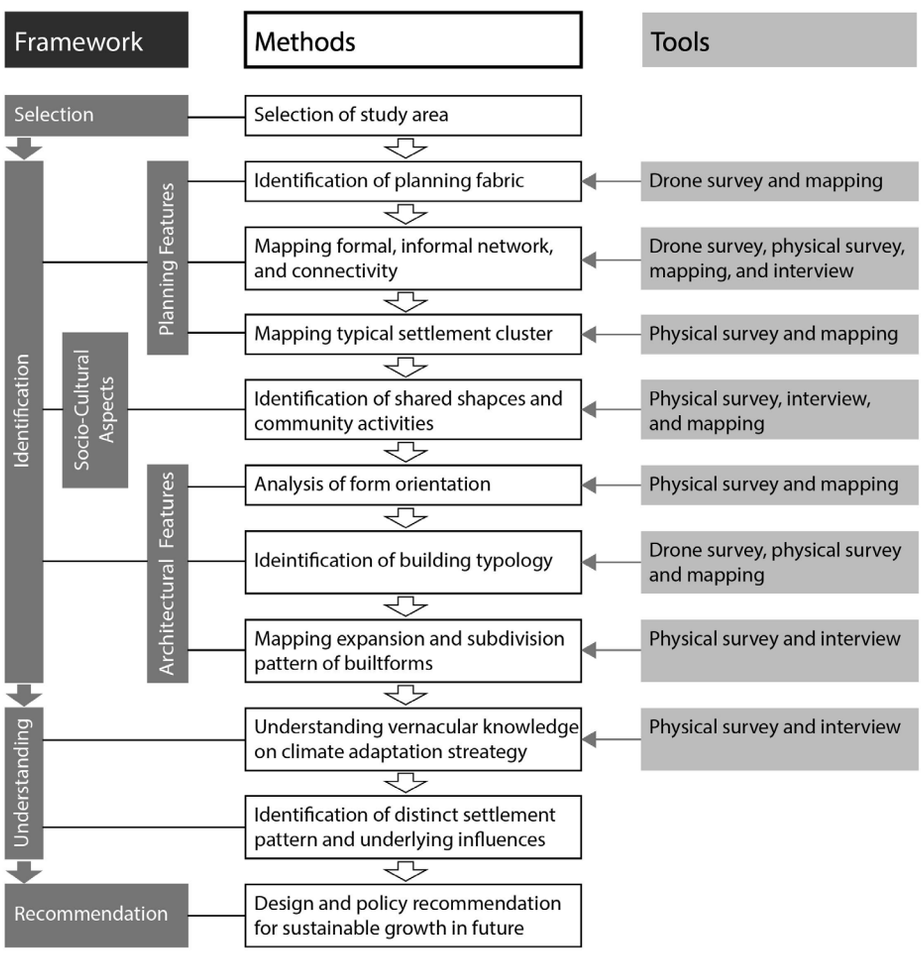


Figure 1. Research framework and methodology.

The settlement pattern identification started with a macro scale that covered the planning features. Since the study areas are quite large in scale and the settlement fabric can be better understood with a zoom-out view of the entire area, the data collection started with a drone survey. Then, the drone images and satellite imagery were used as base maps to prepare the detailed settlement maps through physical survey and sketching. The physical survey was conducted during the dry and monsoon seasons to identify the different transportation modes and connectivity networks to access the settlement clusters and individual houses.

Extensive interviews with local people were crucial to determining some informal networks and planning features that are important in that context but challenging for a visiting researcher to identify. The smallest unit in the planning scale is the individual settlements that have been thoroughly studied to identify the important components and similarities in pattern to define the typical settlement cluster. In the next step, community use of outdoor courtyards and common social places was studied to realize the socio-cultural significance of these spaces. Macro scale study and analysis of architectural features started with identifying the orientation and frontage of individual built forms. In the next stage, the built forms were subdivided into typologies based on the structure's spatial organization and development phase. This architectural analysis ended with a simplified illustration of the sub-division process of house units and the growth of the structure to accommodate the increasing demand for space. Drone surveys, physical surveys, mapping, interviews of the locals, and photography have been used to record authentic first-hand data and support the documentation process.

The next phase of the research focused on a technical understanding of vernacular approaches to settlement design. Haor Basin has a challenging topography and the people cope with the annual flood using passive design approaches instead of fighting against natural forces. The next stage addresses the understanding of the community climate and hydrometeorologic risk adaptation strategies and vernacular knowledge.
The vernacular planning solution, typical settlement pattern, and transfer of knowledge through generations play a crucial role in enhancing the sustainable development of this region. A better understanding of these aspects informs the preparation of future development guidelines for settlement planning and future expansion of the villages to accommodate the increasing population.

3.2 Study area Selection

The low-lying lands of Haor Basin are spread over six different districts. This study covers six villages (Figure 2) spread over four districts- Habiganj, Sunamganj, Moulvibazar, and Netrokona. The catchment area of the field survey in each village is defined on a neighborhood scale and consists of one or multiple settlement clusters locally known as Para or Hati. Each cluster consists of 15 or more homesteads. Overall, we documented 611 household units, of which Satgaon (205) and Maijdi (152) had the greatest number of units. All the sites were situated in rural areas remote from the district hub and two of them (Pirojpur and Satgaon) were located relatively deeper into the Haor. They could be accessed either by seasonal roads during the dry season or water transportation during the monsoon when the seasonal roads remained flooded. The topographical characteristics among the sites were almost homogenous. In most cases, the settlement clusters are located beside a river or connected to the river through lowlands that get flooded at the very beginning of the monsoon.

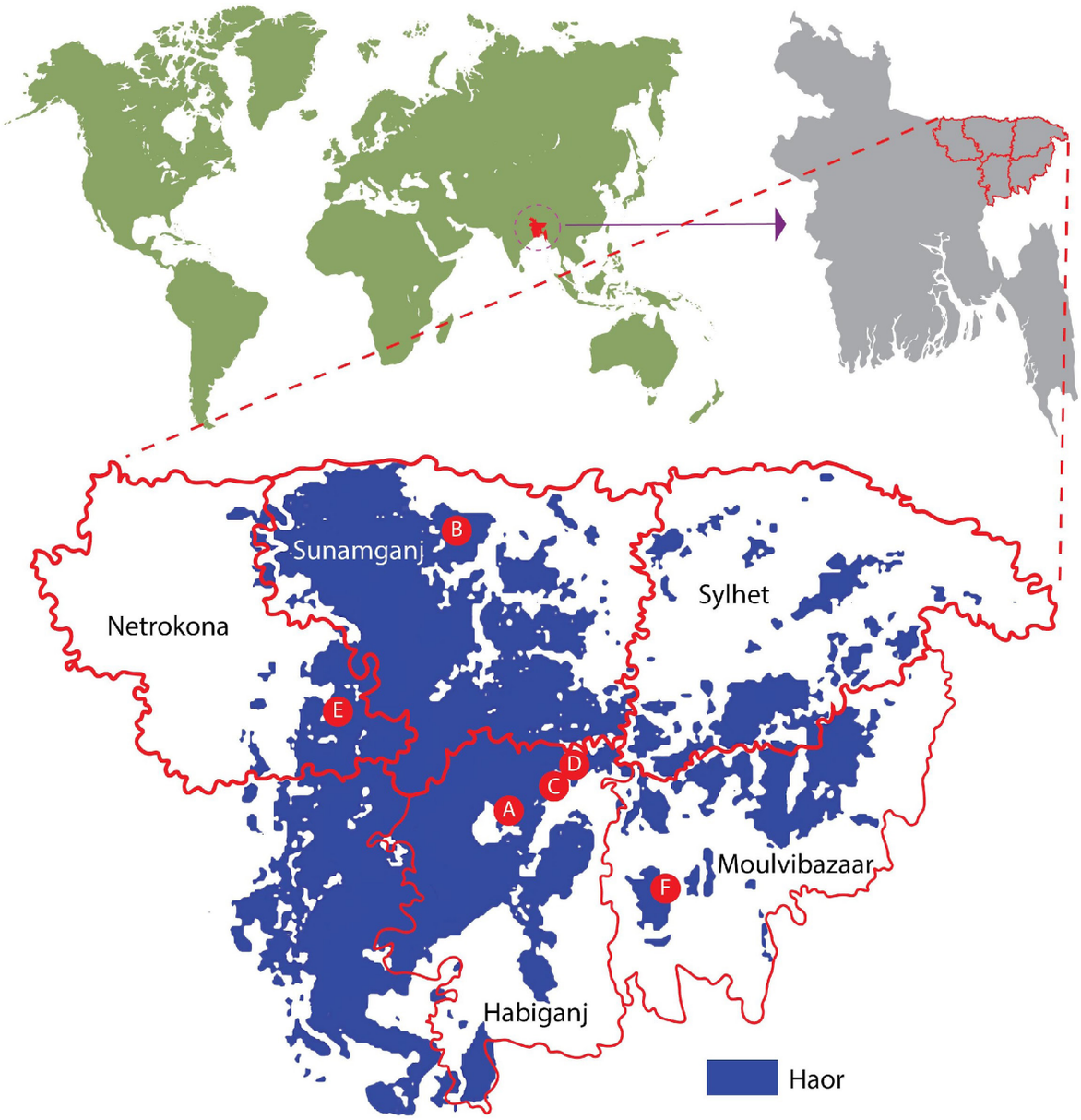
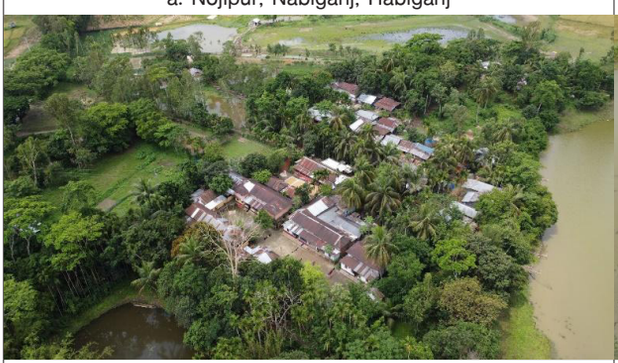


Figure 2. Location of Bangladesh in world map (top left); location of Haor Basin region in the map of Bangladesh (top right); and location of study areas throughout the Haor Basin region (bottom) Source: Modified by the author from original map by the local government engineering department, Bangladesh.

The aerial photographs of the study area shown in Figure 3 give an idea of the site context. The socio-demographic status of the selected settlements was similar, with the majority of the people engaged in the agricultural sector. The economy of villages in the Haor Basin region is heavily dependent on rice cultivation and fishing in the wetlands. More than 53 percent of the total population depends on agriculture, and up to 10 percent are involved in different types of business (Farid, 2017). Since the agricultural lands are submerged for almost half of the year, it forces most people out of work for a very long time (Kazal et al., 2010). So, the poverty rate in the Haor Basin region is comparatively higher than the national average, especially since the farmers and fishermen are most vulnerable economically in the Haor region (Alam & Hasan, 2010). However, the adaptation technique to the hydrometeorologic and climatic challenges and the skill to use local materials help these poor people to survive.

a. Nojipur, Nabiganj, Habiganj

b. Pirojpur, Biswambarpur, Sunamganj



c. Tajpur, Nabiganj, Habiganj

d. Madhobpur, Nabiganj, Habiganj

e. Satgaon, Mohongonj, Netrokona

f. Maijdi, Sreemangal, Moulvibazaar

Figure 3. The aerial image of the study areas. Source: authors.

4. Result and Analysis

4.1 Planning Features

4.1.1 Identification of planning fabric

The linear settlement pattern is common in the Haor area (Figure 4). Better adaptability with seasonal floods, and accessibility with the inner houses of linear highlands, made this settlement typology the most sustainable for this region. Figures 5-10 represent the mapping of the six villages from the perspective of physical planning. To understand the settlement pattern, key land-use features such as residential blocks, courtyards (uthan), community spaces, roads, green spaces, and waterbodies were traced. The linear courtyard, represented as brown patches, is one of the most important planning features.

Figure 4. Linear settlement surrounded by flooded areas (left). Compact arrangement of built-forms in flood free lands (right). Source: authors.

Figure 5. Planning and settlements at Najipur, Nabiganj, Habiganj.

Figure 6. Planning and settlements at Pirojpur, Biswambarpur, Sunamganj.

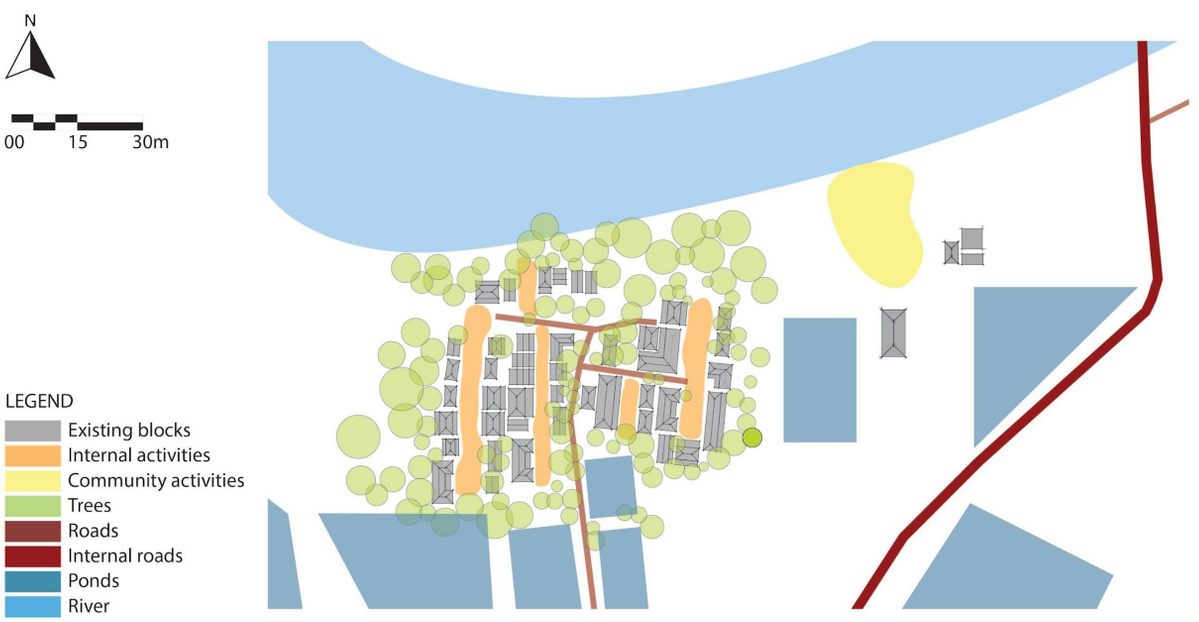


Figure 7. Planning and settlements at Tajpur, Nabiganj, Habiganj.

Figure 8. Planning and settlements at Madhabpur, Nabiganj, Habiganj.

Figure 9. Planning and settlements at Satgaon, Muhongonj, Netrokona.

Figure 10. Planning and settlements at Maijdi, Sreemangal, Moulvibazaar.

Regardless of the overall shape and size of the village, the individual housing clusters are developed in linear character along an uninterrupted courtyard. It is very unusual to construct a new house that disturbs the linearity of the courtyard. This arrangement is intended to accommodate some low land between housing clusters to allow water access during monsoon season.

Analyzing the study area maps, we found that the entire village is not linear in Najipur (Figure 5). The river is across the main road with no direct access from housing clusters (para). Parallel clusters are developed to ensure a linear settlement pattern alongside the linear court. The low-lying land between the clusters provides access to water transport during the monsoon season. Large ponds are placed in these adjacent areas. The other study area, Pirojpur (Figure 6), comprises single linear cluster in a comparatively much smaller area. A small canal on the east provides water access to the residents.

Tajpur (Figure 7) and Madhabpur (Figure 8) have similar settlement patterns, located on either side of the river. In both villages, the linear courtyards are perpendicularly terminated into the river providing uninterrupted access to the residents through courtyards. House clusters are developed at a moderate distance from the main vehicular road, and the in-between spaces are developed into pond, khola, and plantation areas. In Satgaon (Figure 9), the village has a linear development parallel to the river. The house footprints did not follow the direction of the major road at a certain distance away to the north. Those spaces are occupied by ponds and dense plantations. The sixth study area, Maijdi (Figure 10), is not so linear as a whole. However, the individual clusters (para) are developed around a linear court, and parallel linear clusters divide the rectangular site into several linear settlements.

4.2.2 Mapping network and connectivity

Modes of connectivity among the house clusters or with the distant settlements changes by season (Figure 11). Most of the villages in remote Haor areas are connected by submergible roads during the dry season. During the monsoon, the roads are submerged under flood water along with surrounding lowlands and boats become the only mode of transportation. So, the roads and canals are developed in such a way that they can complement each other during the transitional period when flood water is not that high, although the agricultural lands remain underwater. Developing the settlement clusters in linear form helps the communities connect to the roads on one side and the water on the other side of the cluster. Sometimes, the road and canal can be placed on the same side, and the anchor point of the boat changes with the change in water level throughout the monsoon.

Figure 11. Majority of the houses getting direct connection to water transport during moonsoon (left). Secondary roads at the peripheral area of the linear settlements and continuous connection through linear courtyard during dry season (right). Source: authors.

The internal connection among houses belonging to the same para/hati remains consistent throughout the year, and the uthan serves as the spine of internal communication (Figure 12). Typically straight like a road, the uthan allows for soft spatial divisions created by various activities, enhancing the sense of community without obstructing movement. Semi-outdoor verandas create a smooth transition between indoor and outdoor spaces. In most cases, spatial connectivity between neighboring houses sharing the same uthan enhances better social bonding among the families. Commonly, khola is placed towards one end of the uthan and pond/river is located at the other end. In this case, the uthan is used like a private road that does not restrict access for any resident from the house cluster in reaching the khola or river. It is prohibited to build any fence to define the boundary of a house that can restrict access through the uthan. Though the ownership of the space is not specified with land boundaries, a series of lands owned by different owners creates a continuous nexus.

Figure 12. Linear uthan (courtyard) and parallel houses aligned to the courtyard. Source: authors.

Figures 14-19 represent the mapping of the six villages from the perspective of physical connectivity. The connectivity works on two levels: formal connectivity through roads and informal connectivity through waterways, courtyards, and walkways. Secondary roads parallel to the uthan that run beyond the private zone connect different para together and narrow alleyways between the houses connect the uthan with the secondary road (Figure 13). Generally, these secondary roads are walkways or light vehicular roads which are placed between the water body or vegetable garden and the main residential units, as indicated by deep purple lines. The unique connectivity through uthan is indicated with a brown shaded area and a black dotted line. All these connections serve as a complete network to connect the households together.

Figure 13. Secondary road running parallel to the linear uthan maintaining privacy of the internal court(left). Narrow alleyways perpendicular to the linear uthan providing access to the backyards and gardens (right). Source: authors.

Figure 14. Connectivity map of Najipur, Nabiganj, Habiganj.

Figure 15. Connectivity map of Pirojpur, Biswambarpur, Sunamganj.

Figure 16. Connectivity map of Tajpur, Nabiganj, Habiganj.

Figure 17. Connectivity map of Madhabpur, Nabiganj, Habiganj.

Figure 18. Connectivity map of Satgaon, Muhongonj, Netrokona.

Figure 19. Connectivity map of Maijdi, Sreemangal, Moulvibazaar.

In Najipur (Figure 14), the primary road network aligns with the river, while several secondary walkways enhance connectivity to individual settlement clusters. In Pirojpur (Figure 15), the courtyard is directly connected to the main road. Additionally, several tertiary connections, marked with red arrows, provide shortcuts to the houses during the dry season. A canal flowing parallel to the internal courtyard, ensures water access for individual houses.

Tajpur (Figure 16) features four parallel linear courtyards that terminate into the river at one end and connect to a secondary road at the other end. A walkway along the river, situated on the north side, remains accessible for 5-6 months during the dry season. In Madhabpur (Figure 17), internal courtyards connect to the main road via a major secondary road. Two of the four linear courtyards lead to the river on the south side, while the other two rely on shared access through courtyards or community spaces to reach the river.

Satgaon (Figure 18) demonstrates a strong connection to the river, despite the main road being situated further north. Several secondary roads link the fragmented linear courtyards to the main road, and these secondary roads also terminate at the river, indicating a higher level of river use in the villages located deeper within the Haor. Maijdi (Figure 19) relies entirely on its road network for connectivity. Most internal courtyards are well connected to the secondary roads with a buffer zone.

Among all the study areas, Maijdi is the only exception, without river access. This site also has a higher elevation and is less prone to flood, All other study areas are close to the river and depend on water transport. However, in recent years, the water level in the river has become very shallow during the dry season, so water transport only is functioning during the monsoon season. Road networks have been expanded to remote villages to provide better connectivity throughout the year, evident from the maps. The placement of secondary walkways, connected to internal uthan through alleys, holds similar character throughout the region.

4.2.3 Mapping typical settlement cluster

A typical homestead consists of three major types of spaces at three different elevations (Figure 20). The highest lands accommodate an internal courtyard called uthan and buildings for residence, service, and storage. The second type of space is raised above the historically low flood level and used for processing the rice after harvesting. This space is called Khola, and it usually is submerged at later stages of the monsoon season after the completion of rice processing. Small vegetable gardens and ponds also are placed in this zone on the same or opposite side of the main housing area. This space also connects the houses with secondary roads. The lowest level is the community spaces used for large social gatherings vegetable gardens, and playground during the dry season.

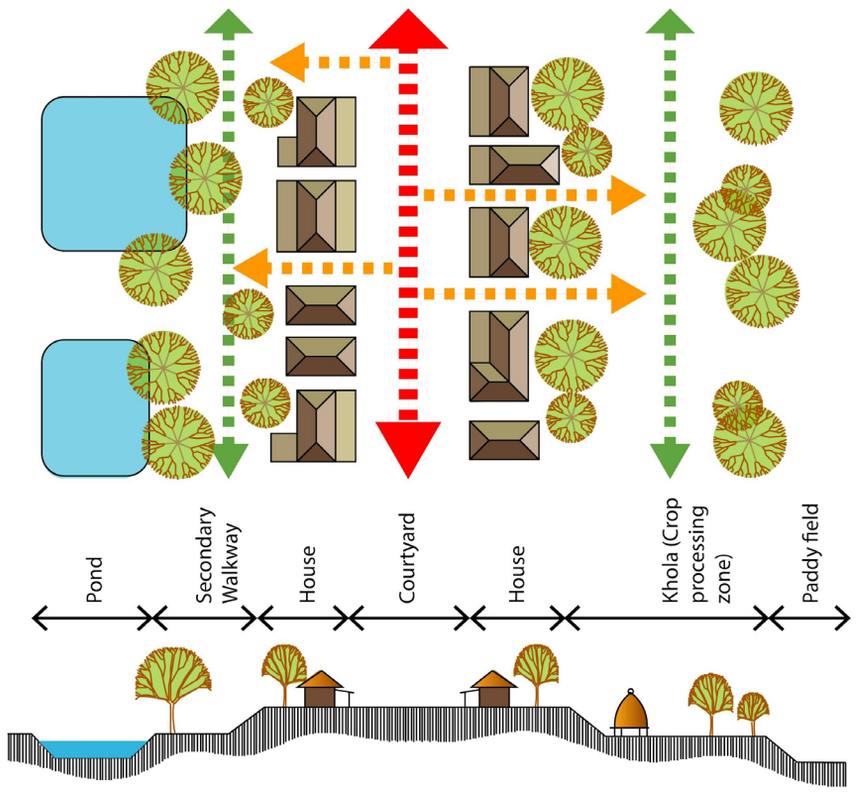


Figure 20. Organization of households on a settlement cluster.

In Figure 20, the red dotted line represents the linearly connected central courtyard, which is a semi-private passage allowing all the neighbors from the entire settlement cluster to move around the individual houses. The green dotted line indicates the public walkways that can be used by the residents of that cluster, villagers from other clusters, and visitors from other places to move around the village. The orange lines represent the narrow alleys between neighboring houses to connect the inner courtyard with the outer garden, pond, and khola. During the high flood, the orange lines become very important to ensure accessibility for individual houses, as the public walkways are submerged. If the river or canal is not parallel to the linear courtyard, the residents must go to end of the red line to access the river or paddy fields. It is a social norm to allow inhabitants to freely move through the inner courtyard to access the service at the end of the cluster.

4.3 Shared Spaces and Community Activities

Due to the scarcity of flood-free highlands, the shared use of outdoor spaces becomes crucial in this region. Some activities are performed in the Uthan that remain above the water level around the year, while other activities at the Khola require larger scale space but do not need to be conducted during high floods (Figure 21). If there is only one cluster in any village, the khola will be placed at the end of the cluster towards the side of agricultural land so that the paddy can be transported to the khola first and then moved to storage at individual houses after processing. In case of multiple house clusters, large-scale khola can be placed strategically to connect the house clusters and become a hub for socio-cultural gathering (Figure 22). Though the primary functional purpose of the khola is to accommodate domestic activities related to agriculture, it becomes a social meeting point after the crop harvesting period. Temporary fairs, cultural programs, and

religious festivals are organized in this space. It also serves as a playground for young children. On the other hand, the Uthan is mainly used to dry rice or wood for cooking. Due to the close proximity to the houses, the uthan is used by females for recreational purposes in the afternoon. To conclude, overall activities, timing, usage, and other characteristics of the shared spaces were similar across the six villages.

Figure 21. Activities at Uthan (left) and Khola (right) as shared space. Source: authors.

Figure 22. Common Khola located between agricultural land and residential settlements. Source: authors

4.4 Architectural Features

4.4.1 Analysis of form orientation

The orientation of the built forms is examined with reference to the angle of the form compared to cardinal directions, where the front side of individual forms is recorded from the survey (Figure 23). From the interviews of the locals, it was confirmed that the houses are constructed according to the cardinal directions. So, in the following maps, any built form within a 15-degree angle to the cardinal directions is categorized into east-facing, west-facing, north-facing, and south-facing. Buildings not within a 15-degree angle from cardinal directions were examined separately to determine the influence behind the change in orientation.

Figure 23. Housing cluster aligned to the cardinal direction but does not follow the alignment of the adjacent major road (left) and near the river that strongly follows the east-west direction and created a minor angle with the river shoreline (right). Source: authors.

The following map (Figure 24) highlight the house orientation and frontage of Study area Najipur, Maps of other five study areas included in the appendix section (Appendix i-v). In most cases the longer side of the built form faces the courtyard, but in some cases when the form is subdivided several times and the new land parcel is quite narrow, then the narrower side of the building faces the courtyard. The formal expression of the front of the building is highlighted with a veranda that creates an approach to the courtyard. The houses were categorised according to the orientation and frontage (East, West, North, South) for the pattern analysis (Figure 25).

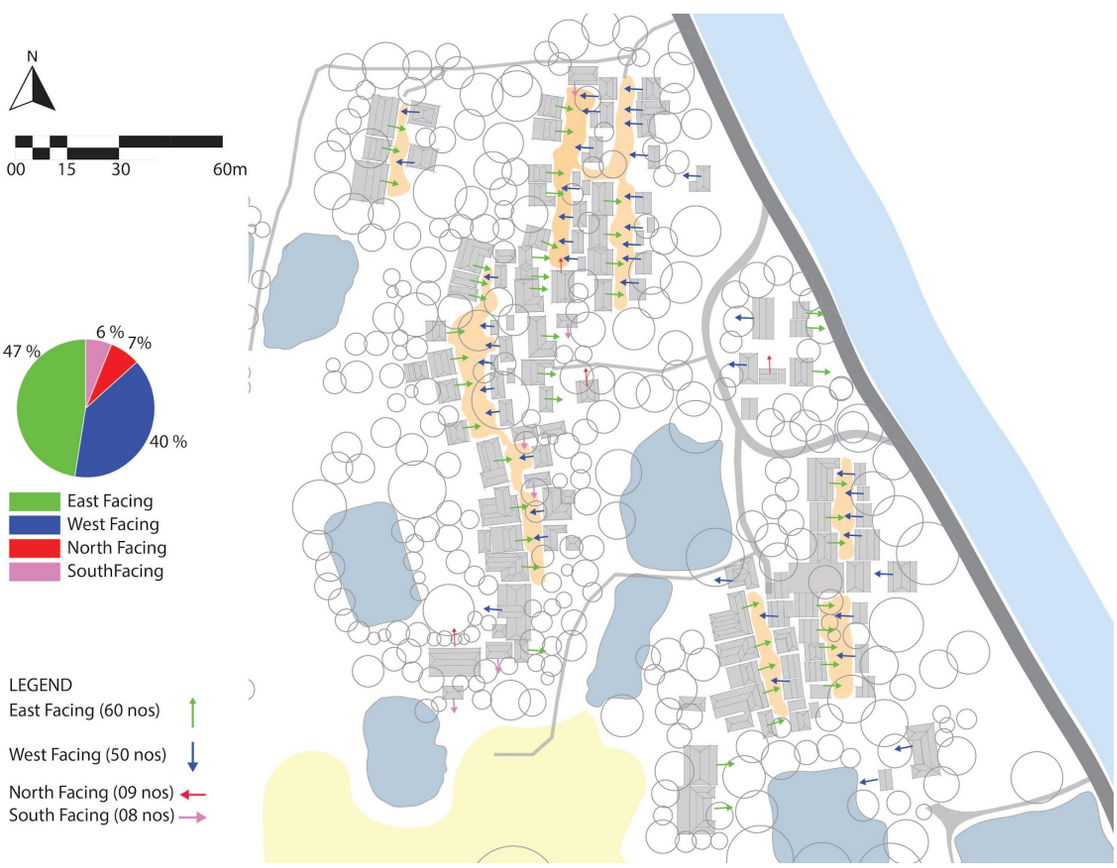


Figure 24. Orientation of houses and frontage at Najipur, Nabiganj, Habiganj.

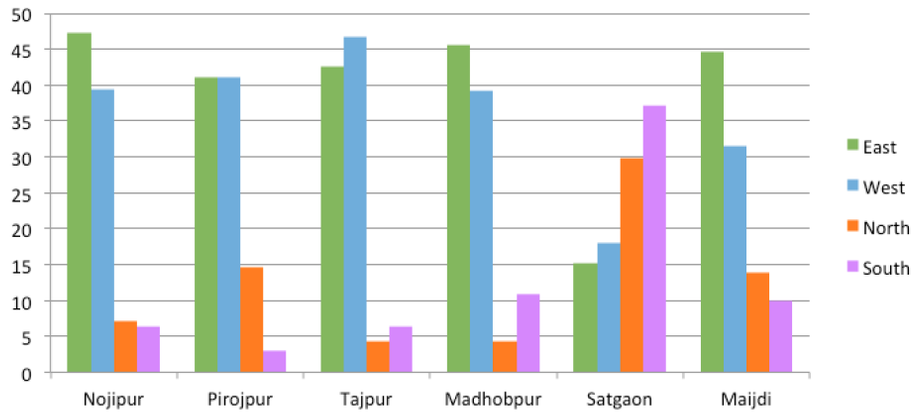


Figure 25. Comparative analysis of orientation and frontage of the houses from different study areas. Y axis denotes the percentage of houses facing different directions.

The number of houses facing different directions has been summarized from map analysis Figure 25 categorizes the orientation of houses facing the four cardinal directions after analyzing the maps of six study areas. It was an interesting finding that most of the houses in the study area aligned with the cardinal direction. Strong site forces like rivers and main vehicular roads do not influence the house orientation. Instead, the people keep faith in their traditional practice and construct the building aligned to the cardinal direction. In most other regions of Bangladesh, south-facing houses are the most popular. However, this research identified a very high percentage of east and west-facing houses in the Haor region. This type of arrangement allows direct sunlight from the south into the courtyard. Since the houses are very close to each other due to land scarcity, any house facing the north/south will cast a shadow on the courtyard. The only exception is Satgaon, where the south-facing houses have the highest numbers. Since this village has only one row of settlements, they adapted to the climate by locating secondary courts in the south, placed on the open land next to the river.

4.4.2 Identification of building typology

The house forms have diverse plan profiles, sizes, and materials (Figure 26). The size and plan of the house influence the roof profile and shape. So, the house typologies are defined through the roof geometry that reflects the inner plan and is easily determined through aerial images. The houses are divided into eight typologies as follows:

Type 1: *'Ekchala'* has one inclined roofing plane only, *'Ek'* means one, and *'chala'* means roofing plane. Typically, the size of Ekchala buildings is very small and used for service functions.

Type 2: *'Dochala'* is the most common type of house with a top ridge and two roofing planes. The word *'Do'* in *'Dochala'* refers to two, corresponding to the two roofing planes. Gable ends are placed at the sides of the house and inclined roof planes are placed at the entry and back of the house.

Type 3: *'Chowchala'* is another prevalent type of house where the roof has four planes with triangular or trapezium shape. *'Chow'* in *'Chowchala'* refers to four, directly corresponding to four roofing planes. Usually, this type of house has verandas at the front and back, but they also can be added at the sides.

Type 4: This type of house is L-shaped, with additional rooms on one side of the house in the front. The room at the front is called *'Fotik'*, commonly used as a guest room or living room. This extended main roof over the Fotik creates a right angle with the main roof, forming an L shape of the house.

Type 5: This type of house is similar to type 4 but has extra front rooms at both ends of the front façade. These rooms with extensions of the main roof at both ends create a U shape of the house. One of these extra rooms is used as a formal living/seating area for guests and another room serves as an extra bedroom for the family.

Type 6: These houses have an extension of the main roof at the center of the front façade. This space sometimes is converted into a room and sometimes kept open as a semi-outdoor space. The profile of the main roof for these houses looks like T.

Type 7: Represents all houses that modified a lot and lost any specific characteristics similar to any of the first six typologies. Several phases of expansion and modification of the house due to changes in family size and functional requirements created complex shapes for some houses, including multiple wings.

Type 8: These houses are made of brick and concrete and covered with RCC (Reinforced Cement Concrete) floor slabs and are known as 'Pucca' buildings. The house plan consists of indoor and semi-outdoor spaces similar to other typologies, but the addition of stairs and regular geometric shapes makes it different from its neighbours.

After defining the typologies, all the houses of the study areas were traced under a plan and categorized based on the typologies outline in Figure 26. Colour coding of each typology in the map gives a holistic idea of the dominant house types and a mixture of different typologies in the villages (Figures 27-32).

Figure 26. Different types of roofs of houses (source: author photos and drone imagery).

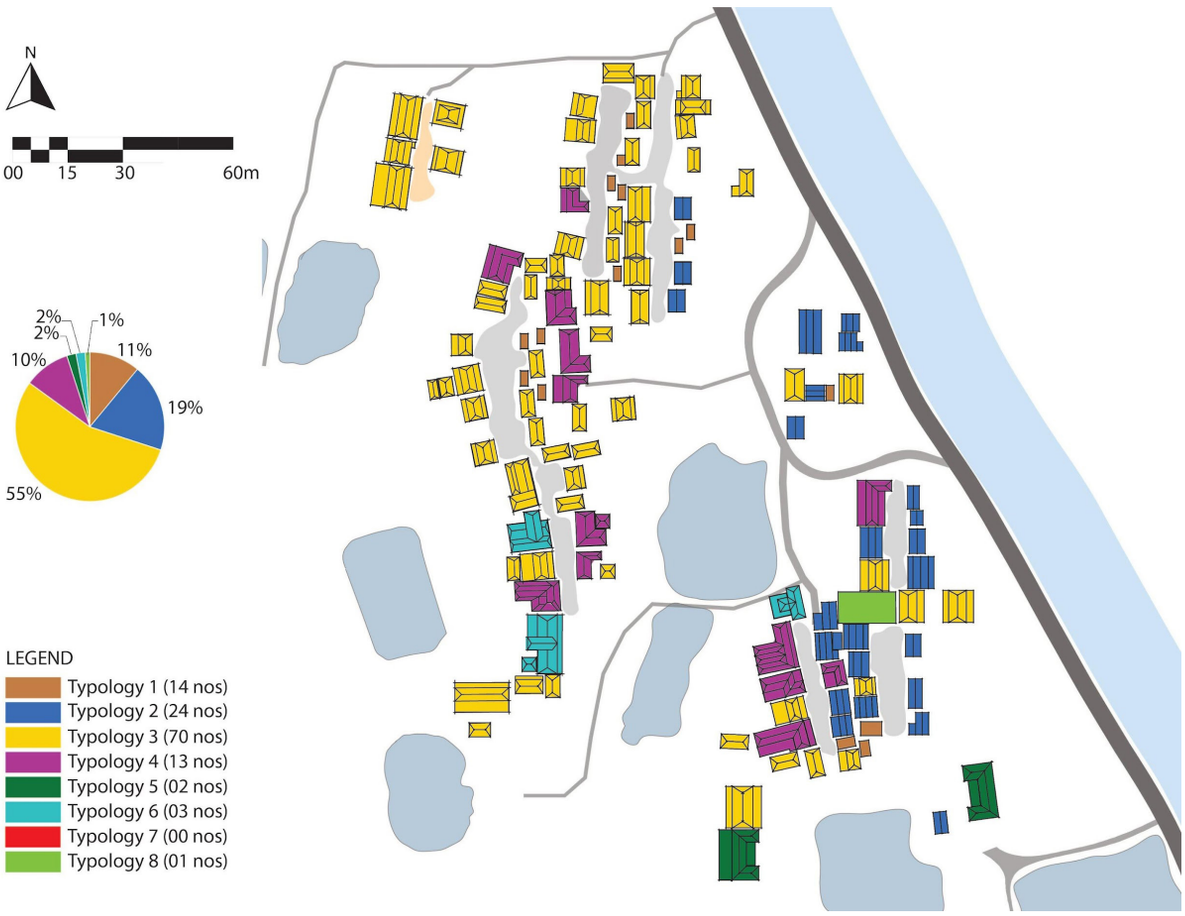


Figure 27. Typology of Houses at Najipur, Nabiganj, Habiganj.

Figure 28. Typology of Houses at Pirojpur, Biswambarpur, Sunamganj.

Figure 29. Typology of Houses at Tajpur, Nabiganj, Habiganj.

Figure 30. Typology of Houses at Madhabpur, Nabiganj, Habiganj.

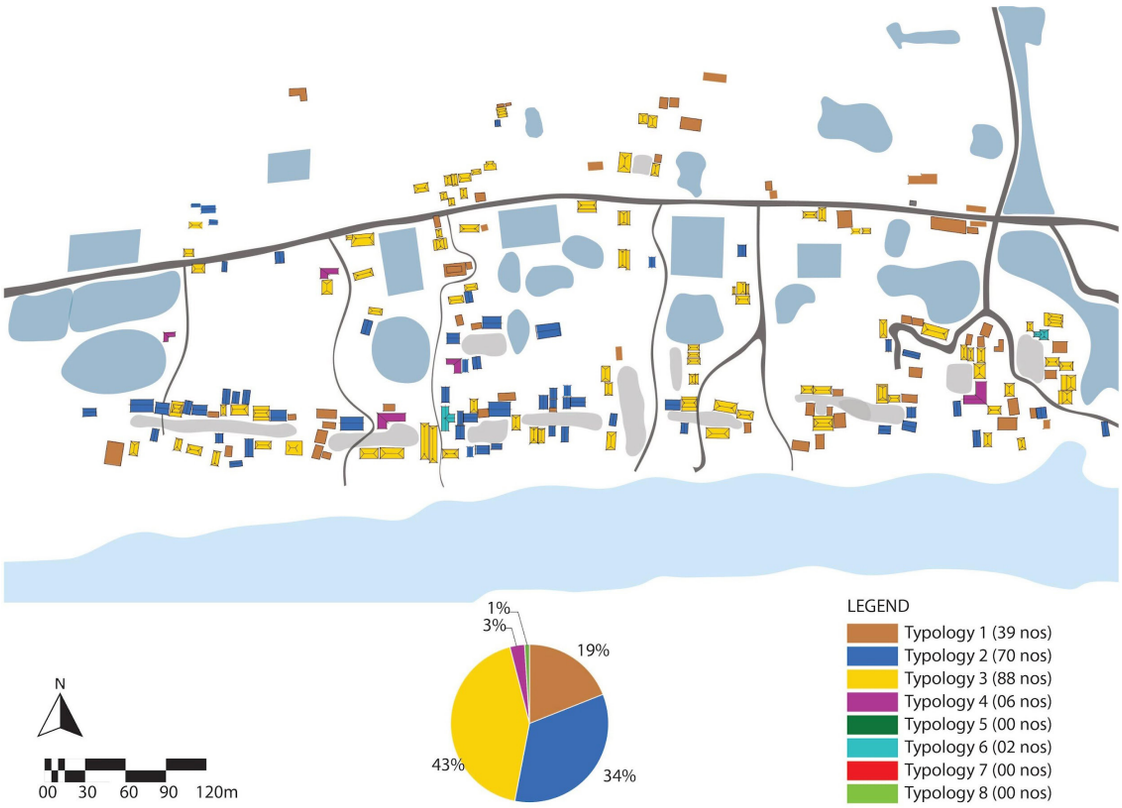


Figure 31. Typology of Houses at Satgaon, Muhongonj, Netrokona.

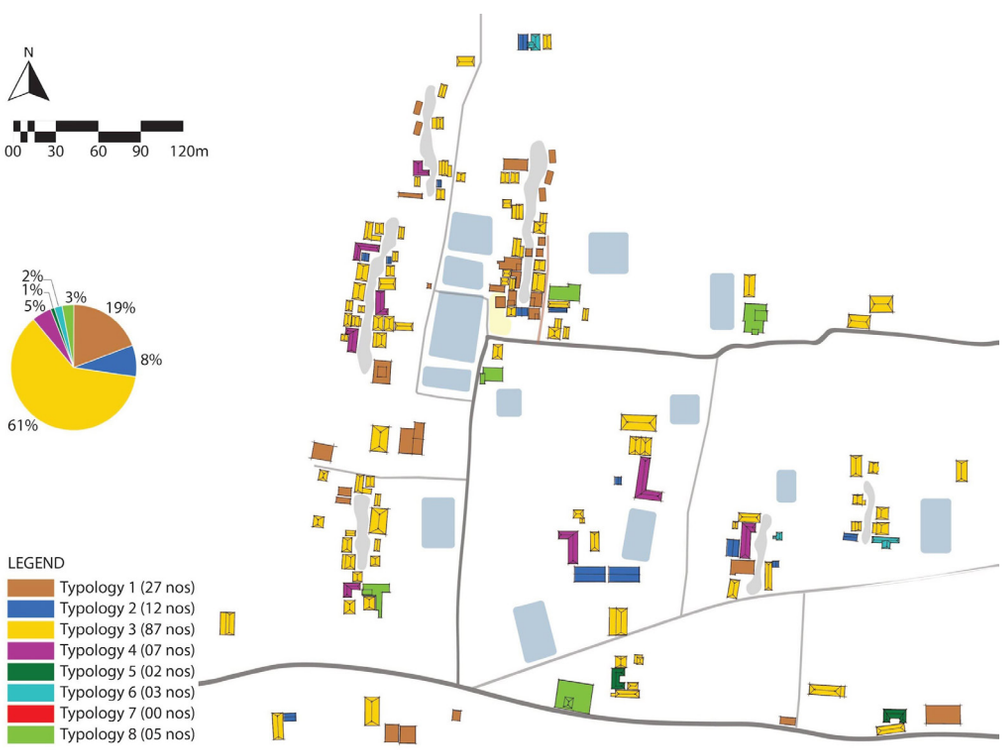


Figure 32. Typology of Houses at Maijdi, Sreemangal, Moulvibazaar.

In Najipur (Figure 27) and Pirojpur (Figure 28), the chowchala typology is the most popular, comprising more than half of the buildings. However, the distribution of other building types varies between the two villages. In Najipur, dochala, chowchala, and L-shaped buildings are present in similar proportions. In contrast, Pirojpur has a higher number of dochala houses, accounting for nearly 40%, the highest ratio among all study areas. In Tajpur (Figure 29), Madhabpur (Figure 30), and Satgaon (Figure 31), dochala houses make up around 35%, while chowchala houses are less than 50%. This suggests a relatively lower number of financially solvent families in these locations. Satgaon (Figure 31) and Maijdi (Figure 32) have the highest number of ekchala houses, which is influenced by financial capacity and the availability of land for constructing separate structures for service functions.

Figure 33 shows that chowchala houses are the most common type in all the villages. Dochala houses are the second most common type in most study areas, except Maijdi where ekchala houses are the second most common type. The higher elevation of land in Satgaon, due to its geolocation, allowed for the construction of buildings to spread across larger areas of the village. Typologies 6, 7, and 8 are found in very small numbers in Najipur, Madhabpur, and Maijdi. This indicates a few wealthy or extended families living in these villages with better financial capacity and social status, compared to the majority of the local population.

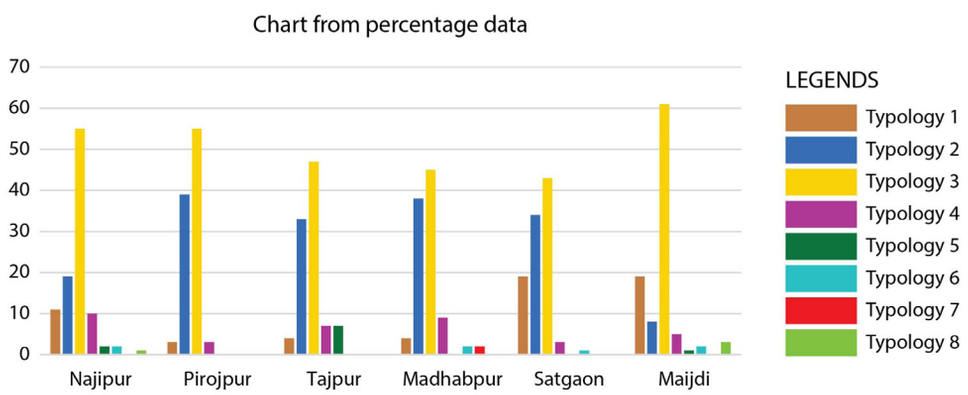


Figure 33. Percentage of house typologies in the study areas.

4.4.3 Expansion and subdivision process of built forms

In most cases, a house expansion is influenced by the increasing need for space due to increasing family members. In some cases, it can be a visual expression of the increased financial capacity or wealth of a family living in that house. In Figure 34 the phase 1 house is a basic chowchala house that added a front and back veranda in phase 2. The front veranda enhanced the spatial quality and privacy of the inner rooms with the semi-outdoor spatial character. The back verandas usually are indoor spaces where the kitchen, dining area, and storage can be placed to retain the central area for only the bedrooms. In phase 3, we can see the main roof transformed into an L shape which covered a portion of the front veranda to convert the semi-outdoor space into one extra room. However, the expansion towards the courtyard was kept within a limit that did not hamper the continuity of the linear courtyard. As a result, when even more space is needed, the back veranda can be replaced by another layer of extended veranda or bedrooms under an additional layer of the dochala/ chowchala roof. It is evident that the expansions were not happening at the sides of the house. This is due to the limited width of the plot, which is caused by subdividing linear and compact flood-free lands into several plots for individual families. Almost all the houses leave only a narrow passage at the side to provide access between the courtyard and the back of the house.

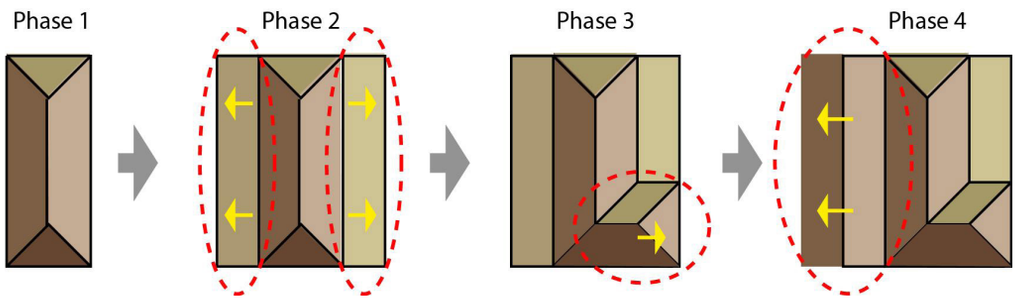


Figure 34. House expansion process.(Front of the house towards right)

Figure 35 illustrates three different examples of house units being subdivided into several individual units. In the case of house A, the width of the existing built form was adequate to divide them into two units. The main roof was structurally subdivided to allow the new units (A1 and A2) to independently construct or repair the roofs. House B was similar in size but needed to be subdivided into three units. Since the width of the new units (B1, B2, B3) was inadequate due to the limited width of the plot, this house had to be further expanded towards the back to ensure enough space in the new units. So, the main roof extended up to the back veranda and the direction of the top ridge of the roof was changed. When one of the new families requires even more rooms, the back veranda can be converted into rooms (B1). In the case of house C, the required number of new units was more than the capacity of the plot. In such conditions, some of the new families need to move into a new area or expansion area of the village. These scenarios are developed based on real case studies from the survey areas and interviews with local people who shared their experience in developing and expanding settlement clusters over the years.

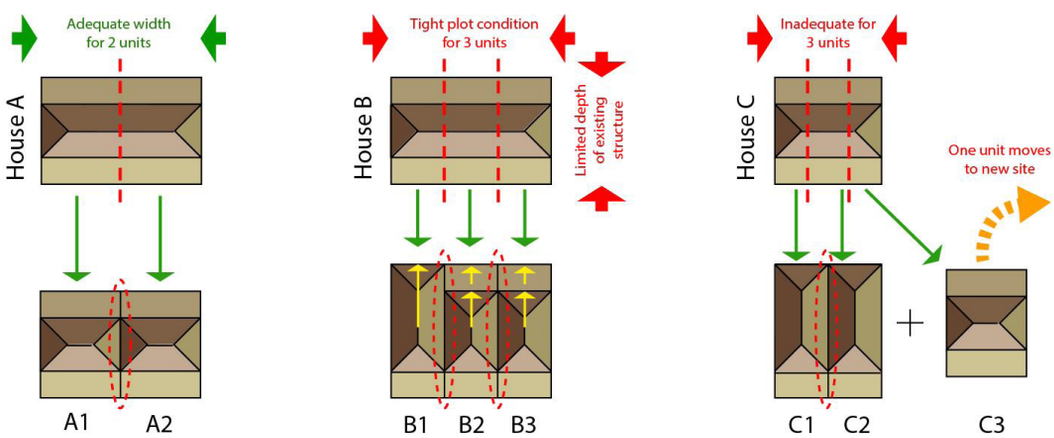


Figure 35. House subdivision process. (Front of the house towards bottom)

During the expansion and subdivision process, it is important to follow certain geometric styles and norms. Traditionally, the gable end of a house is not considered as the entry side. So, when a single dochala roof is divided into several parallel roofs and the direction of the top ridge changes, a sloped roofing segment needs to be placed above the entrance on the front side of the house. Even if there is a veranda at the front to provide a better entrance scale, the main roof's gable end cannot be shown at the front side of the house. It also is not suitable to add a veranda at the gable end side. Therefore, the roofing structures are subdivided into several chowchala roofs. Additionally, chowchala roofs can better handle the wind pressure of storms and enhance the aesthetics of the house.

4.5 Vernacular Knowledge and Climate Adaptation

The name Haor comes from the Bengali word ‘Sagor’, which means ‘Sea’. During the monsoon season, the Haor resembles a sea, with villages appearing as isolated islands amidst the water (Figure 36 and 37). In some cases, the Uthan and surrounding areas are inundated during high floods, leaving only the house plinths above the water. This situation exposes buildings to extreme storm winds and water waves. Over time, the local people have adopted various strategies to survive in such adverse climate and hydrometeorologic conditions. One design strategy is cutting ponds to collect soil in order to raise the Uthan well above historically high flood levels.

Figure 36. Small settlement clusters look like islands surrounded on flooded Haor, Source: author

Figure 37. Water transport becomes the only mode of connectivity when all the roads are submerged every monsoon season. Source: author

Since there is no natural high land for house development, the artificially developed earth mounds are found at two different levels (Figure 38). The highest level of the earth mound contains the central courtyard and buildings, which are relatively narrow and require annual repairs after the soil is washed out by flood waves. Bamboo fencing is utilized to safeguard the soil from flood damage, while riparian plantations are planted for soil stabilization. Khola is at the intermediate level and requires less earth filling and annual maintenance. Swamp trees are planted around the Khola and lower lands, as they can survive being partially submerged. Large trees are planted behind the buildings to protect them from storms, particularly on the northwestern side, which is the direction of the strongest storms. The profile and orientation of the settlement cluster also are consciously maintained to allow the free flow of flood water during the monsoon. This region's most common road construction technique involves constructing submergible roads that allow water flow during peak floods and restore road connections when the water level recedes.

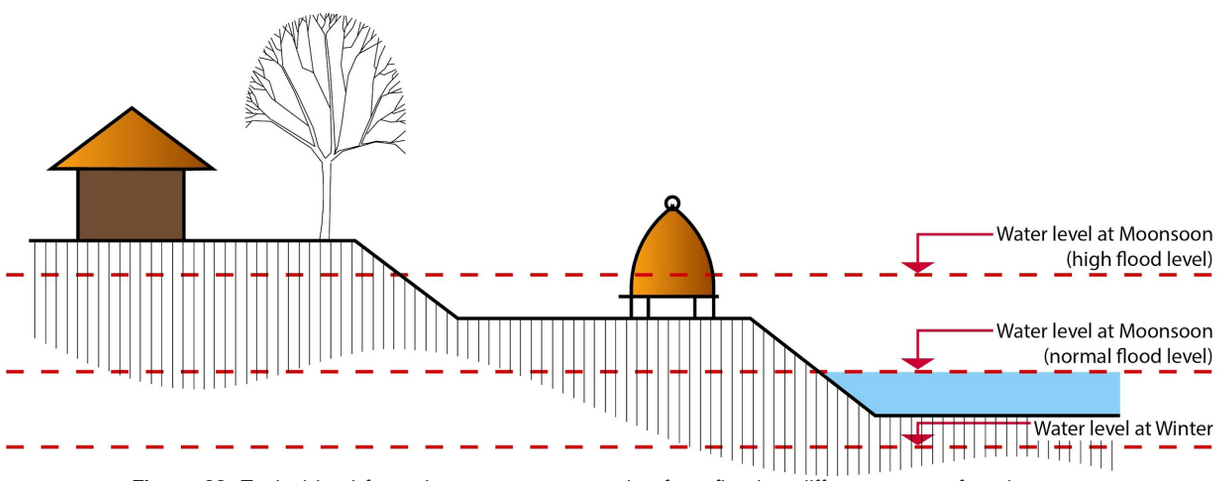


Figure 38. Typical land formation to ensure protection from flood to different zones of settlements.

4.6 Identification of Distinct Settlement Patterns and Underlying Influences

After analyzing the planning, architectural, and socio-cultural aspects of the settlements in the Haor Basin area, the following unique and prominent features were identified.

1. **Compact linear planning clusters.** Compactness is due to a limited amount of flood-free raised land, while the linear character minimizes the obstacle to flood water flow.
2. **Maintaining linkage to both water and road networks.** Most of the roads in these areas are submersible roads to allow the free flow of water during high floods. During that time water transport is the only solution. Moreover, water transport still is more popular and cheaper compared to road transport to the people from remote Haor areas.
3. **Continuous linear courtyards.** Central courtyards are the main pedestrian linkage for the residents of the entire settlement cluster, even in rare high flood situations. This is the only outdoor space that remains flood-free throughout the year.
4. **Blurred property line between plots.** Individual plots do not have boundaries or fencing to define the ownership. This enhances the social coherence and utilization of outdoor spaces.
5. **Large community spaces.** This type of space accommodates social gatherings and crop processing. In this community-owned space, individual families also can organize large functions.

6. **Varied elevations of ground levels.** Settlements are built on artificially raised earth mounds. Raising and protecting these lands is costly. So, only the central courtyard and building plinths are raised well above the annual flood level, while surrounding outdoor areas remain at an intermediate elevation, which can be submerged during high floods.
7. **Maintaining cardinal direction on house layout.** This is due to social customs and environmental benefits. North-south elongated linear courtyards ensure uninterrupted sunlight to each plot, which is crucial for crop drying.
8. **A dominant number of Dochala and Chowchala houses.** With linear semi-outdoor spaces, these typologies fit better with the linear cluster and also ensure privacy. The roof structure of these linear buildings is easy to construct and economical.

5. Discussion and Recommendations

Our research has characterized the distinct settlement patterns of this region that include compact settlement clusters, social coherence, and environmentally resilient design. Linear patterns enhanced the simplicity of spatial organization and easier spatial connectivity with secondary roads and water. Strong orientation of buildings maintained positive interaction with all the houses placed side by side. Also, the organized pattern of the villages with multiple paras can be regarded as the key character of spatial morphology. The continuous uthan plays a crucial role, especially being the only means of access within each settlement cluster during the monsoon season. Limited flood-free lands achieve better efficiency through multipurpose use of outdoor spaces. The social custom of not creating barriers or fragments on the uthan enhances security and creates strong social connectivity. These characters add more dynamic qualities to the socially owned spaces for community interactions. The remoteness from urban areas might have influenced stronger house typologies and indigenous building characteristics in deeper Haor areas. The house typologies were also influenced by the economic hierarchy of the inhabitants, as the most permanent houses belonged to the most economically solvent inhabitants.

Informal extensions and subdivisions help to define the roof shape and typologies of built forms. Most of the clusters reached their peak development density and required expansion. We observed a common trend in the expansions across the six villages. However, we also identified three different patterns for the sub-divisions. at the side would disturb the linearity of the land formation and create conflict with the traditional connectivity of outdoor spaces. So, in most cases, new settlement clusters are created to construct new houses, which is a sustainable approach, similar to creating satellite towns to reduce density in central urban areas. However, applying vernacular knowledge as well as formal planning tools such as feasibility study are essential when for allocating new lands for developing new settlement clusters.

5.1 Design Recommendations:

Linear settlement clusters are better adapted to annual flooding. Enthusiastic professionals are researching building materials, construction techniques, and house planning to mitigate flood risks. The new solutions should be consistent with the local context. For example, raising the plinth is more considered sustainable since the historically high flood level and flood cycle could be predicted from historical data. Recently, experiments on floating houses have been considered as an alternative for the Haor region. However, living in an floating or amphibian house could impact psychologically creating mental stress and functional discomfort.

Instead, the focus should be on protecting watersheds to reduce extreme flood risks. With more robust materials, multistoried houses could be another solution. However, the planning of rooms and the position of openings should respect the privacy of people.

5.2 Policy Recommendations:

Apart from design recommendations, we have concluded with some policy recommendations at three levels for the sustenance of vernacular identity and sustainable settlement growth.

1. Government-led initiatives: (i) separate planning guidelines for environmentally challenging regions will benefit dealing with localised issues in the Haor region; and (ii) monitoring the use of culturally imported or non-sustainable building materials through local municipalities, also is important to preserve the vernacular identity.
2. Partnership between stakeholders: (i) capacity-building through community workshops and training programs will increase community resilience; (ii) providing professional support by grassroots organisations also will develop their vernacular skills; and (iii) ensuring a higher level of community participation in the planning process.
3. Community-driven initiatives: (i) developing social cooperatives among communities through community leaders for social and economic resilience; and (ii) encouraging the placemaking process to continue cross-community interactions during the flood season.

6. Conclusion

In summary, this study focused on documenting and identifying the settlement morphologies and architectural characteristics from planning perspectives, with respect to vernacular practices to address hydro-meteorologic challenges. We primarily focused on socio-spatial and socio-cultural factors that directly influence settlement morphology while acknowledging that socio-political, socio-economic, natural resources and other external factors also may have indirect influences on settlement planning and local architecture. This requires further investigation on a micro-scale. The study relied on a longitudinal investigation and the methods were based on observational surveys and open-ended interviews. To accommodate a larger sample size, future research could incorporate more quantitative methods using indicators and questionnaire-based surveys. s

In this empirical research, the limitations open up future research directions for studying how other geophysical regions adapt to similar environmental challenges in a cross-sectional study. It also would be beneficial to explore the reliance on natural resources on a micro-scale, their abundance, and their potential as building materials for climate adaptation, which could benefit the community. Furthermore, it is important to study the governance of social spaces and the perception of blurred ownership from the stakeholder perspective. Further research on the interdependencies and negotiations among the actors may help in managing rural spaces for social resilience.

The research on settlement morphology and local adaptation techniques can help in achieving sustainable development goals, such as SDG-11: sustainable cities and communities. This research also could lead to a more community-oriented and inclusive approach to rural planning by the government of Bangladesh. Professionals in sustainable rural housing can use the findings and recommendations to design sustainable housing prototypes that meet the increased demands of new development while preserving the cultural landscape and local

practices. Overall findings can be used to create specific guidelines for this geophysical region that could be included in the existing building and planning codes.

Human Subject Declaration

All research procedures involving human participants were done in accordance with the ethical standards of the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Participation in the study was voluntary and informed consent was obtained for all research components that involved human participants, in accordance with standard ethical practice.

Author Contributions

Conceptualization, S. Das; methodology, S. Das, A. Rahman; validation. S. Das, A. Rahman; formal analysis, S. Das, A. Rahman; investigation, S. Das, A. Rahman; resources, S. Das; data curation, S. Das, A. Rahman; writing – original draft, S. Das, A. Rahman; writing – review & editing, S. Das, A. Rahman; visualization, S. Das; supervision, S. Das, A. Rahman; project administration, S. Das, A. Rahman; funding acquisition, S. Das, A. Rahman

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Data Availability Statement

Data may be obtained from the corresponding author upon written request.

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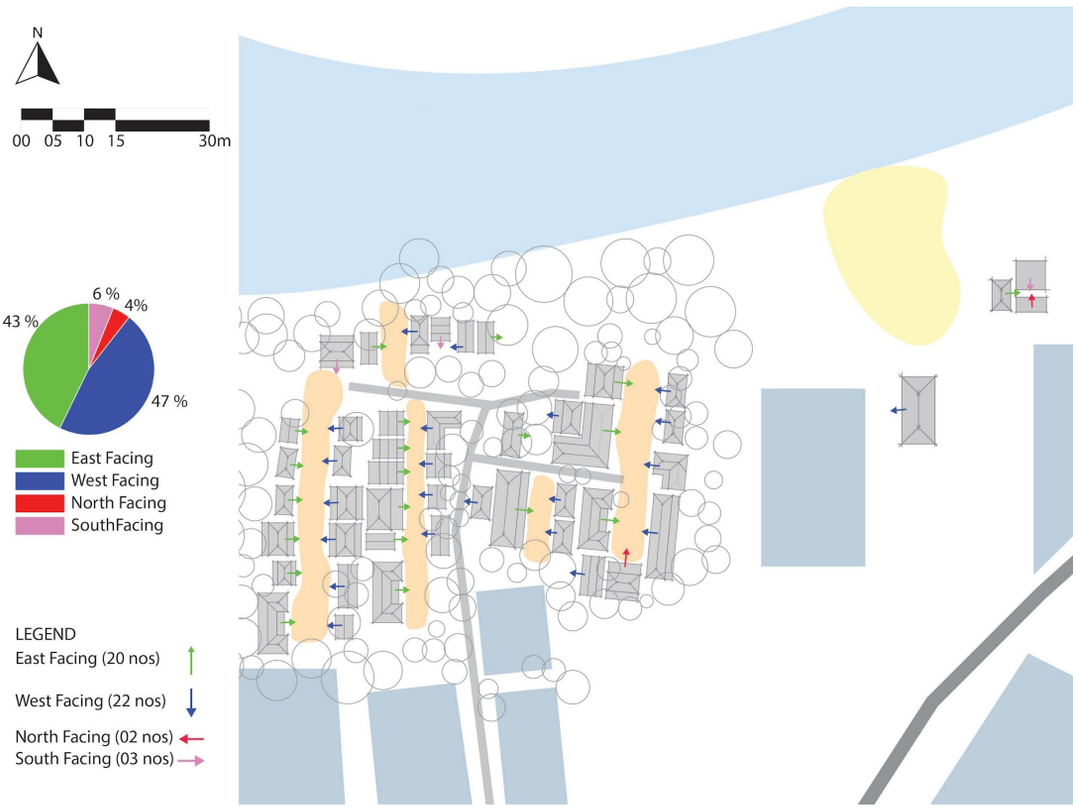
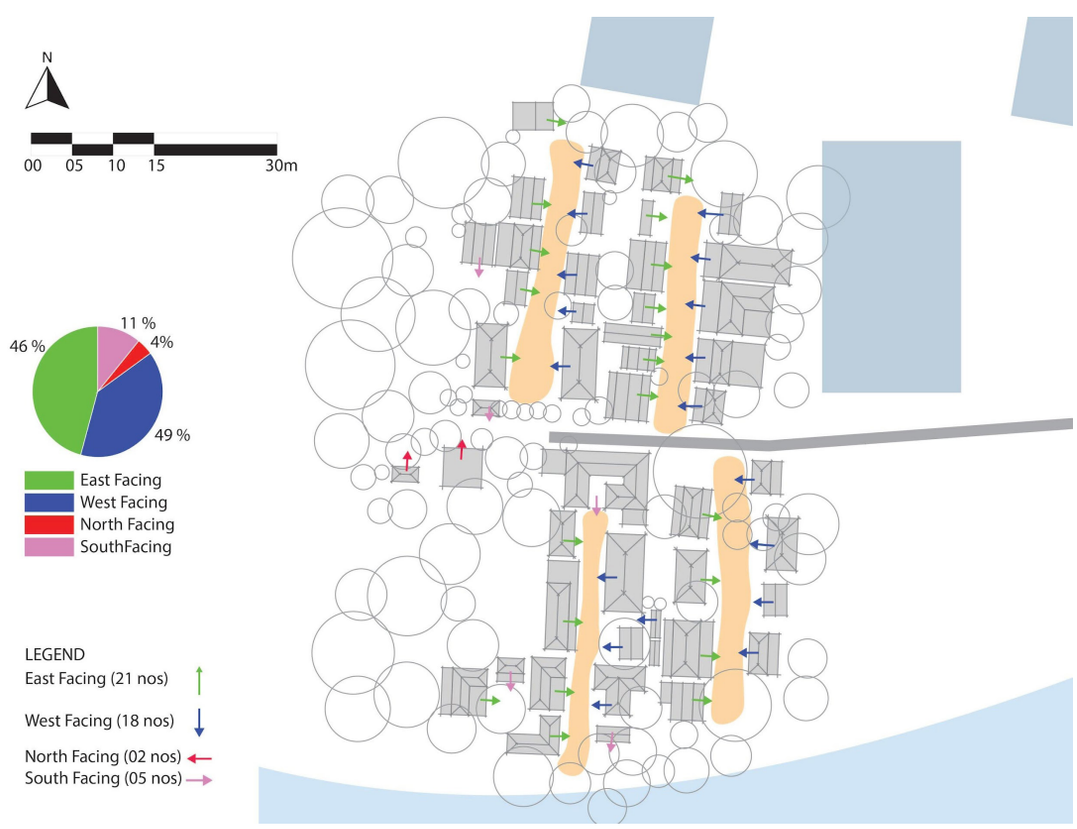
Appendix:

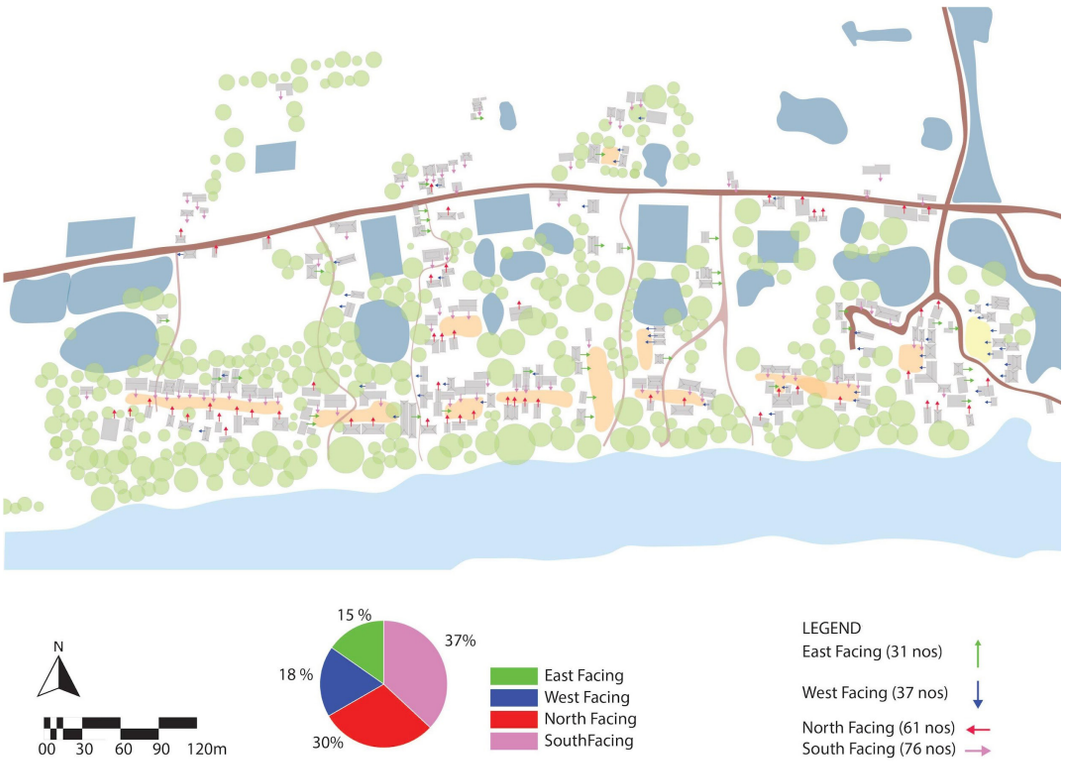
Appendix i. Orientation of houses and frontage at Pirojpur, Biswambarpur, Sunamganj.



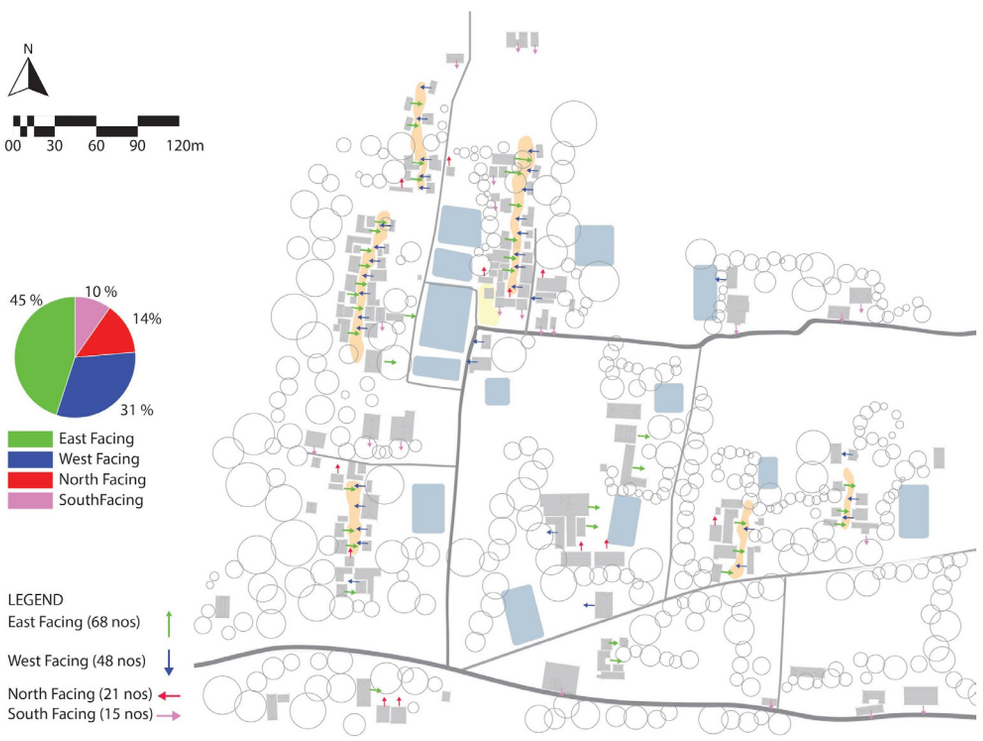
Appendix ii. Orientation of houses and frontage at Tajpur, Nabiganj, Habiganj.



Appendix iii. Orientation of houses and frontage at Madhabpur, Nabiganj, Habiganj.



Appendix iv. Orientation of houses and frontage at Satgaon, Muhongonj, Netrokona.



Appendix v. Orientation of houses and frontage at Maijdi, Sreemangal, Moulvibazaar.