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# Diffusion of Disaster-Preparedness Information by Hearing from Early Adopters to Late Adopters in Coastal Bangladesh

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**Abstract:** The successful social implementation of a rainwater-harvesting tank can save millions of people in coastal Bangladesh from drinking saline water and health risks. However, previous studies have shown that several potentially effective, innovative disaster-preventive technologies failed to disseminate even after proactive promotional campaigns. People at risk worry about adopting innovative preventive measures because of the uncertainties attached to the new technology, such as its merits, cost, maintenance, durability, social acceptance, etc. Instead of mass media, people rely on social networks to obtain trusted, verified, and personal information. Hearing plays an important role, through which information diffuses from pioneer adopters to late adopters or potential adopters across settlements, starting from the village to district to region. Unlike conventional studies, limited to understanding the regional dimension of diffusion, this study investigated how the information diffuses from pioneer adopters to potential adopters at both the macro-level (e.g., districts, subdistricts, and towns) and micro-level (e.g., villages and neighborhoods). This study was based on field surveys through interviewing 196 innovative rainwater-tank adopters from 30 villages and communities in two subdistricts in coastal Bangladesh. We found that the macro-level pioneer adopters played a critical role in diffusing awareness knowledge, through which people in new villages, neighborhoods, and sub-districts, where mass media and change agents failed to reach, became aware of the existence of the innovative measure. However, macro-adapters alone failed to disseminate the innovation further, as the local communities intend to pay to heed the suggestions and experiences of the local (micro) pioneer adopters to understand the principle and how-to knowledge of the innovation. Information is diffused in the villages and neighborhoods through local pioneer adopters through direct, intimate personal contacts.

**Keywords:** information diffusion; disaster preparedness; social networks; salinity; Bangladesh



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## 1. Introduction

Millions of people in coastal Bangladesh are at risk due to drinking-water contamination by saltwater intrusion from the Bay of Bengal. The climate-change impacts, including storm surges, abnormally high tides, and sea-level rises, caused 100 km inland saline-water intrusion along the entire 720 km coastal stretch in Bangladesh [1]. Studies warn against the further aggravation of salinity intrusion due to reduced river flow, climate-change impacts [2–4], and ongoing human-made factors such as planned and artificial saltwater intrusion for shrimp cultivation [5]. In all six coastal districts, the salinity has increased by 45% within five decades, creating various health risks for more than 20 million people [3,6,7]. The salinity situation is most dire in Bagerhat and Satkhira districts [8]. Chronic exposure to salinity through drinking water may cause various health issues—diarrhea, hypertension, heart diseases, kidney stones, respiratory infections, skin diseases, and cholera, to name a few [9–11].

Water is abandoned in the riverine, coastal Bangladesh, but local communities lament drinking water. Water from conventional sources, such as domestic ponds and wells, is unsuitable for human consumption [12]. For more than one decade, starting from the 1980s, the Bangladesh Government intensely promoted shallow tube wells as an alternative drinking-water source to prevent waterborne diseases caused by surface-water consumption [12]. By the 1990s, when shallow tube wells had already penetrated 80% of rural households in the country [13], experts detected that water from shallow tube wells was unfit for consumption due to arsenic contamination [14,15]. A conservative estimate suggests that 30 million members of the Bangladeshi population are at risk of drinking arsenic-contaminated water; out of those, 1.2 million have already developed some symptoms of arsenicosis [8]. Studies have shown that chronic exposure to arsenic may cause skin diseases, lung cancers, and respiratory issues [16,17].

Given the increasing water salinity and arsenic contamination, coastal Bangladesh needs an alternative drinking-water source. Rainwater harvesting (RWH) at the household level has recently been promoted as a viable alternative to address the drinking-water crisis in coastal Bangladesh [18,19]. However, the critical challenge is to motivate coastal communities, which have tried different alternatives before, to try an innovative, alternative water system again. In reality, the social implementation of alternative drinking water sources remains elusive [12]. Very few studies have systematically investigated the factors impeding the dissemination of this innovative alternative drinking-water resource at the community level in Bangladesh [20].

In order to obtain a comprehensive perspective of the dissemination of the innovative disaster-preventive technology, rainwater-harvesting technology in coastal Bangladesh, this study focused on information dissemination through hearing activities (from person to person) and the role of different pioneer adopters in this dissemination process. Understanding hearing activities is critical because hearing helps potential adopters to reduce their information gap for the new technology and decide to adopt the technology [21]. The role of the pioneer adopters is critical in the dissemination process because, through them, the information about the new technology starts to travel from person to person. We further argue that the pioneer is a relative term depending upon the scale (macro and micro) and definition (village or district) of the community. Therefore, this study aimed to investigate how the information about rainwater-harvesting tanks, an innovative disaster-preventive technology, diffused from person to person through hearing and how pioneer adopters instigated this information diffusion in regional (macro) and local (micro) areas in coastal Bangladesh.

### *1.1. Hearing and Disaster-Risk Communication*

The dissemination of innovative disaster-preventive technologies, such as RWH, is found to be challenging because the potential adopters are unaware of the outcome-expectancy of the technology, such as its merit and demerits, quality, durability, cost, etc. [22–24]. Due to the lack of knowledge, individuals face high uncertainty when adopting preventive measures [25,26]. Often, the lack of information prevents the dissemination of preventive measures [27].

We argue that hearing is a critical information-processing activity that empowers potential adopters to reduce decision uncertainties and adopt new technologies and measures for disaster preparedness. Hearing can assist individuals in learning the software aspects of an innovative disaster-preventive measure, including its price, function, operational methods, quality, affordability, and social acceptability [21]. Through acquiring knowledge about the software aspect of the new preventive measures, hearing enables potential adopters to obtain comprehensive knowledge on two critical aspects of the new preventative measures.

First, by hearing, individuals become aware of the *principles knowledge* [28,29] of the innovative disaster-preventive technology. The *principles knowledge* depicts the functioning principles of the technology—how a technology works to solve an issue. Hence, hearing

may make potential adopters aware of their needs and enhance their willingness to adopt the technology to resolve the matter. Second, hearing provides *how-to knowledge* [28,30] for the innovation, which includes the operational blueprint of the technology. Therefore, hearing is a critical information-seeking activity for potential users to make prudent adoption decisions. Besides *principles knowledge* and *how-to knowledge*, hearing also offers *awareness knowledge* [31,32]—information about the existence of the technology—to the community members.

In the hearing process, senders and recipients of information enjoy engaging in a reciprocal communication loop. Both, especially the recipient of information, can tailor the content and types of the message according to their needs, wants, and concerns [33]. Hearing may offer potential adopters the opportunity to rigorously pursue their queries with the information senders, mostly existing adopters of innovation. Therefore, hearing allows individuals to obtain more customized, authentic, subjective, and implicit information from senders [21].

Hearing is not a location-specific activity. Senders and receivers can share information without necessarily being engaged in face-to-face interactions. However, hearing can take place through telephonic discussion or other modes of virtual correspondence. Furthermore, hearing permits individuals to disseminate and share information without being geographically or physically close to the technology. For example, an RWH tank owner can inform their colleagues about this innovation in the office without showing the technology. Due to this advantage, the information flows through hearing rapidly and reaches a large population and geographical territory [34,35].

### *1.2. Dissemination of Disaster-Preventive Technologies through Social Networks of Hearing*

Individuals can hear about innovation from mass media and social networks. The mass media is often ineffective in disseminating information at the grassroots level due to its inability to instigate two-way risk communication [36–39]. Individuals capitalize on their social networks, such as friends, relatives, colleagues, and comrades, to reduce the knowledge gap. The information individuals receive through social networks is more culturally viable, subjective, and context-specific [39–42]). Hence, individuals can make prudent adoption decisions that are more socially and culturally acceptable, and locally feasible in their context [26]. In addition, social capital creates social pressure [43,44] on its members for adopting new technology. Social networks, therefore, enhance the effectiveness of risk communication and facilitate the dissemination of potentially viable countermeasures for disaster prevention.

Innovation dissemination is not an instantaneous but a phased, inchmeal process. Instead, all community members adopt the innovation simultaneously; some adopt early, and some, late [28]. Those who adopt early become the repositories of information for potential adopters [45,46]. By adopting the risk-preventing technology earlier than others, the pioneer adopters create *awareness knowledge* (there exists an innovation) in a community [28]. Furthermore, pioneer adopters' first-hand experiences of the preventive technology, both successes and mistakes, develop *principles knowledge* (how the technology functions for risk prevention) and *awareness knowledge* (how to use the technology) among the community [47]. The pioneer adopters are the critical source of information for the potential adopters in a community to recognize the relative advantages, cost, function, and durability of the risk-preventive technology before finalizing adoption decisions [48]. However, pioneer adopters do not enjoy such privilege from source information from their social referents to reduce decision uncertainty. However, in the due course of the dissemination, the pioneer adopters become potential game changers because their recommendations, suggestions, and voices critically influence potential adopters' decisions [20,49,50].

### *1.3. Diffusion at Macro (Regional)- and Micro (Local)-Scale*

The information of the disaster-preventive technology travels from pioneer adopters to late adopters and non-adopters through social connections embedded among friends,

neighbors, colleagues, relatives, and acquaintances. However, the pioneer adopter is a relative and capricious concept largely depending on the definition and delineation of the community [20,51]) (see Figure 1). The definition of pioneer adopter may vary according to the scale of the community—*micro-communities* (e.g., neighborhoods and villages) and *macro-communities* (e.g., districts and cities). Individuals who are late adopters in a macro-community (for example, a town) could be pioneer adopters in the micro-community (for instance, a neighborhood). Alternatively, it could be the other way around (see Figure 1).

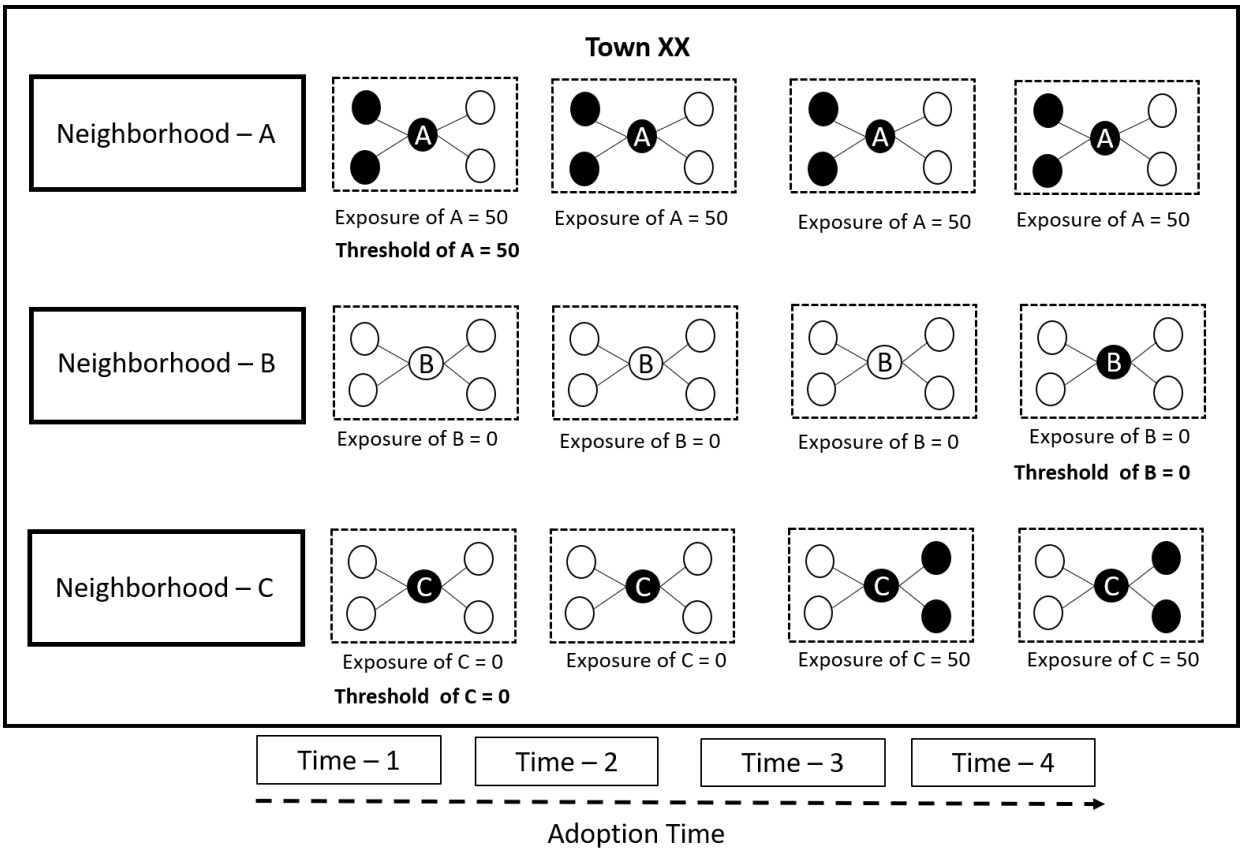



**Figure 1.** An illustration of the relative positions of pioneer adopters according to micro (e.g., neighborhood)- and macro (e.g., town)-community. Note: There are three neighborhoods in Town XX. Person A from 'Neighborhood A' adopted the innovation very early (Time 1) with respect to the entire town. Person A is a pioneer adopter in Town XX (macro community). However, when Person A adopted, two of his/her neighbors had already adopted the tank. Therefore, Person A may not be a pioneer adopter in his/her own neighborhood. On the contrary, Person B from Neighborhood B who adopted is a late adopter with respect to the entire town. However, Person B is a pioneer adopter in his/her neighborhood (micro-community). Person C from Neighborhood C is a pioneer adopter in Town XX and his/her neighborhood.

Social networks among the members in a macro-community are primarily indirect, weak, loose, or dispersed [52]. In a macro-community, individuals do not enjoy the opportunity to learn from others through the direct and intimate exchange of information. A lack of face-to-face connections lessens trust in information [53]. The dissemination becomes sluggish. However, indirect, weak ties enhance awareness knowledge, bringing new ideas and information from outside the group into a community [54].

## 2. Methods

### *2.1. Case-Study: RWH Tanks in Salinity-Prone Bagerhat District*

This study investigated a case study of disseminating an innovative water resource management initiative in Bagerhat district, Bangladesh as a case study. Under this water resource project, an NGO installed household rainwater-harvesting (RWH) tanks to collect rainwater from the rooftop of the residential building during the monsoon season (May to October) to meet the household drinking-water demand in the dry season (November to April). The tank size was 4400 L, and the cost was BDT 40,000 (see Figure 2). The household RWH tank can meet the drinking-water demand of up to 6 members for six months in the dry season. To foster tank dissemination in the community, the NGO introduced a micro-credit scheme that allowed beneficiaries to pay, initially, only 25% of the tank cost and pay the rest of the money in a monthly installment scheme for two years.

**Figure 2.** Rainwater-harvesting tank (4400 L) of a household in a village community in Bagerhat District, Bangladesh.

The door-to-door visit was the primary awareness strategy adopted by the NGO to motivate people to buy RWH tanks. The NGO also organized a few village meetings, cultural functions, and focus-group meetings as a part of the awareness campaign. More than 400 tanks were installed in the Bagerhat district. We selected three main dissemination areas for our case studies, as shown in Table 1.

**Table 1.** Case-study areas of rainwater-harvesting tank dissemination in Bagerhat District, Bangladesh.

| Area Name | Rural/Urban | Subdistrict | Total Tanks Installed | Total Villages /Neighborhoods | Total Village Unions/MUNICIPALITIES | Tank-Dissemination Time | Total Dissemination Period (in Days) |
|---|---|---|---|---|---|---|---|
| Chitamari | Rural | Chitalmari | 47 | 7 | 5 | 5 January 2005–20 June 2008 | 1263 |
| Morrelganj Rural | Rural | Morrelganj | 88 | 20 | 9 | 1 June 1999–31 December 2008 | 3502 |
| Morrelganj Town | Urban | Morrelganj | 61 | 9 | 1 (Municipality) | 27 May 2002–26 October 2008 | 2345 |

### 2.2. Data Collection

The study was based on field surveys in three RWH tank-dissemination areas—Chitalmari, Morrelganj Rural, and Morrelganj Town in Bagerhat district. We interviewed 196 RWH tank adopters in 36 villages and neighborhoods in Chitalmari and Morrelganj sub-districts. The heads of the households were the primary respondents. We conducted face-to-face interviews at an agreed time at the homes of the tank owners. The interviews were carried out in the local language, Bengali.

This study collected the following information from tank adopters. *Time of adoption*: We asked the respondents to state the final dates of their tank installation. The information was later verified with NGO records. The dates were converted into days. Day one is the first tank installation in the area (please see Table 1 for further details). We used the time of adoption data to categorize the adopters at the macro- and micro-levels to understand the dissemination nature and pace at the regional and local scales.

*Source of Information:* An individual's primary sources of information, especially the sources of hearing, of the RWH tank were collected by asking the respondents, "*Please identify the sources where you first heard about the RWH tank*". The respondents reported three major sources of information—(i) *NGO Staff*, (ii) *Community members*, and (iii) *Outside the community or district* (anonymous persons). Interestingly, none reported mass media (TV, radio, and internet) as their sources of information.

*Social networks for hearing*: We collected RWH tank owners' social networks of hearing to understand the role of social capital in information dissemination among adopters. The tank owners were asked, "*Please name us three persons from whom you first time heard about the RWH tank*". The respondents were asked to refer their social network (hearing) partners within their own area—Chitalmari Upazila/Morrelganj Rural/Morrelganj Town.

*Residential address*: We also collected respondents' home addresses to map the social networks of adopters and identify internal–external information flow.

### 2.3. Data Analysis

#### 2.3.1. Innovation Diffusion and Adopter Category

Adopters were categorized into chronological groups based on their tank-installation time to systematically map the RWH tank-dissemination pattern at the macro (region or town)- and micro (village or neighborhood)-levels. The adopter categorization was critical for understanding the process of RWH tank dissemination at the micro- and macro-levels.

Diffusion at the macro/regional level (town or sub-district):

To understand the tank diffusion at the macro- or regional/town level, we categorized adopters into four groups based on their adoption time—(i) First Phase Diffusion, (ii) Second Phase Diffusion, (iii) Late Phase Diffusion, and (iv) Last Diffusion. (i) First Phase Diffusion: the time of adoption is greater than one standard deviation earlier; (ii) Second Phase Diffusion—the time of adoption is one standard deviation earlier; (iii) Late Diffusion—the time of adoption is one standard deviation later; (iv) Last Diffusion—the time of adoption is larger than one standard deviation later.

2.3.2. Diffusion at Micro-Level (Village /Neighborhood)

To understand the diffusion at the neighborhood or village level, we categorized each macro-adopter phase into four micro-groups as follows: (a) Pioneer, (b) Early Adopter, (c) Late-adopter, and (d) Laggard. We used a threshold degree to categorize adopters at the micro-level. The threshold model of social networks defined an individual's adoption threshold as his/her personal adoption exposure level at the time of adoption (see Figure 1). Personal adoption exposure is the percentage of adopters in an individual's personal network [51]. Using the threshold value, we defined the adopter's category as (a) Pioneer—the threshold value is more than one standard deviation earlier; (b) Early Adopter: the threshold value is one standard deviation earlier. (c) Late Adopter: the threshold value is one standard deviation later; (d) Laggards: the threshold value is more than one standard deviation later.

2.3.3. Centrality

We used the following social-network centrality measures (see Figure 3) to understand the different dimensions of information flow from early adopters to potential adopters in the innovation diffusion process—*degree centrality* represents an individual's direct social ties in a community. *In-degree centrality* depicts the number of social ties an individual receives. It signifies an individual's direct source of information, information options, and access [55]. *Outdegree centrality* represents the number of direct ties sent from an individual. It means the power of the individual to send direct and personal information to others [55]. It also denotes an individual's power and capacity to convince others [51].

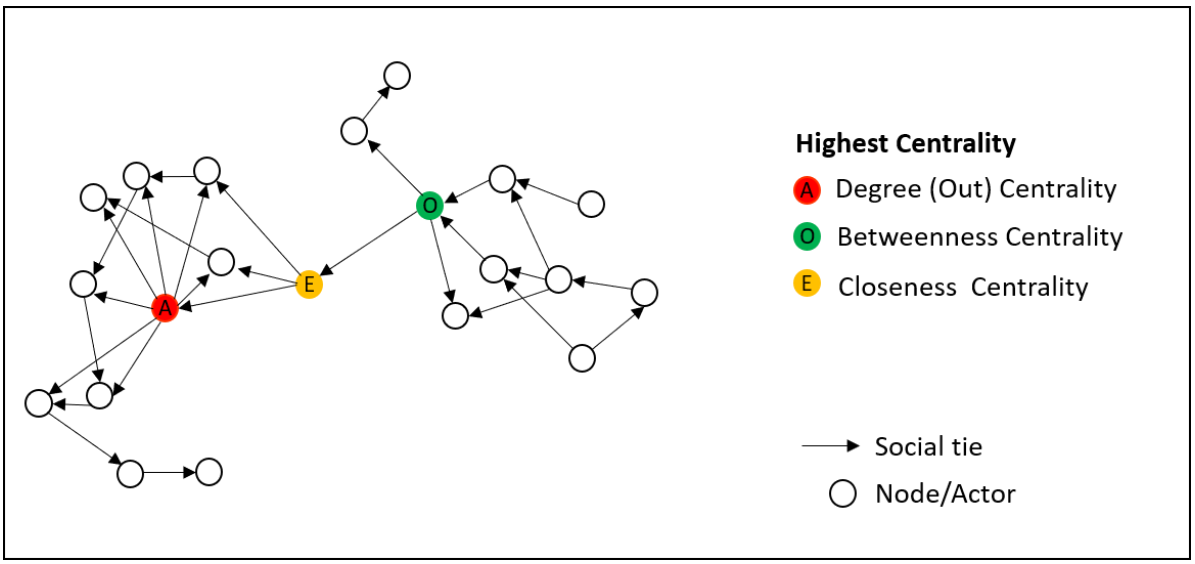



**Figure 3.** An illustration of the highest degree (out), betweenness, and closeness centrality in a network.

The indegree or outdegree centrality is used as the measure of node importance in a directed network/graph. In the directed network/graph, the outdegree centrality of a node $i$, denoted by $C_d^{out}(i)$, is calculated by Equation (1).

$$C_d^{out}(i) = \frac{d_{out}(i)}{n-1} = \frac{\sum_{j \in N,\, j \neq i} a_{ij}}{n-1} \quad (1)$$

where there are $n$ nodes in the network/graph having $N$ as the node set, and $d_{out}(i)$ is the outdegree of node $i$ in the directed network/graph, which is the summation of the binary values (0 or 1) of $a_{ij}$s denoting whether there is an edge/link/tie outgoing from node $i$ to any other node $j$. Similarly, we can calculate the indegree centrality $C_d^{in}(i)$ of a node $i$ in the

directed network/graph. They are the measures of how important a node is to send (or receive) the information to (or from) other nodes in the network/graph.

*Betweenness centrality*: this represents an individual's role as a bridge passing information from one group to another (see Figure 3). Individuals with a high centrality can circulate information among different isolated social groups. Betweenness centrality helps new information to travel across groups.

The betweenness centrality of a node $i$, denoted by $C_b(i)$, is calculated by Equation (2).

$$C_b(i) = \sum_{j,k \in N,\ j \neq k \neq i} \left( \frac{\sigma_{jk}(i)}{\sigma_{jk}} \right) \tag{2}$$

where there are $n$ nodes in the network/graph having $N$ as the node set, $\sigma_{jk}(i)$ is the total number of shortest paths from node $j$ to node $k$ that pass through node $i$, and $\sigma_{jk}$ is the total number of shortest paths from node $j$ to node $k$ in the network/graph (a.k.a information pathways). It is a measure to consider how important the nodes are in connecting other nodes.

*Closeness centrality* represents how quickly (shortest path) an individual reaches all the other community members using fewer intermediary ties (direct and indirect ties). Individuals with high close centrality can diffuse information fast and reach everyone without much effort.

The closeness centrality of a node $i$, denoted by $C_c(i)$, is calculated by Equation (3).

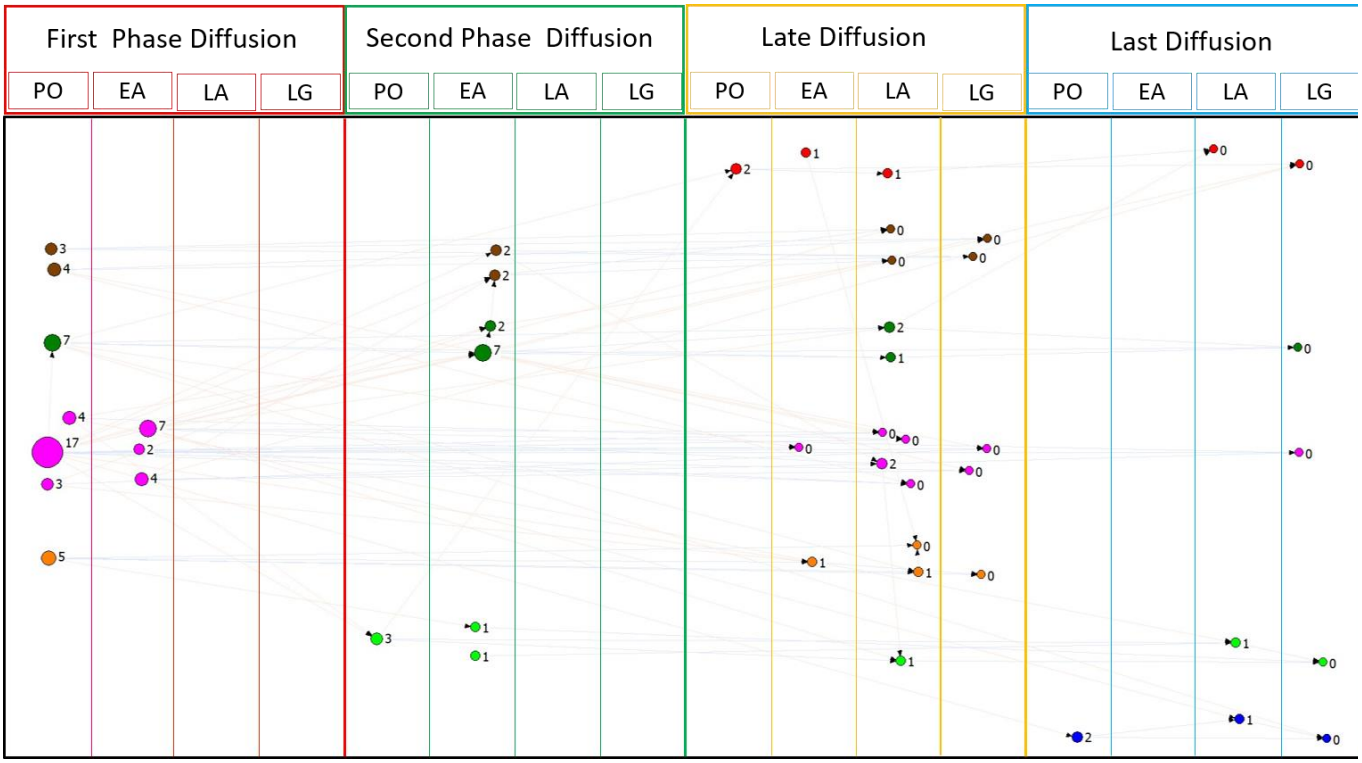
$$C_c(i) = \frac{n-1}{\sum_{j \in N,\ j \neq i} dist(i,j)} \tag{3}$$

where there are $n$ nodes in the network/graph having $N$ as the node set, and $dist(i,j)$ is the length of the shortest path from node $i$ to node $j$ in the network/graph. It measures the mean distance from a node to other nodes, i.e., how fast one can reach others. The higher the value of $C_c(i)$ of the node $i$, the smaller the average shortest path length to other nodes.

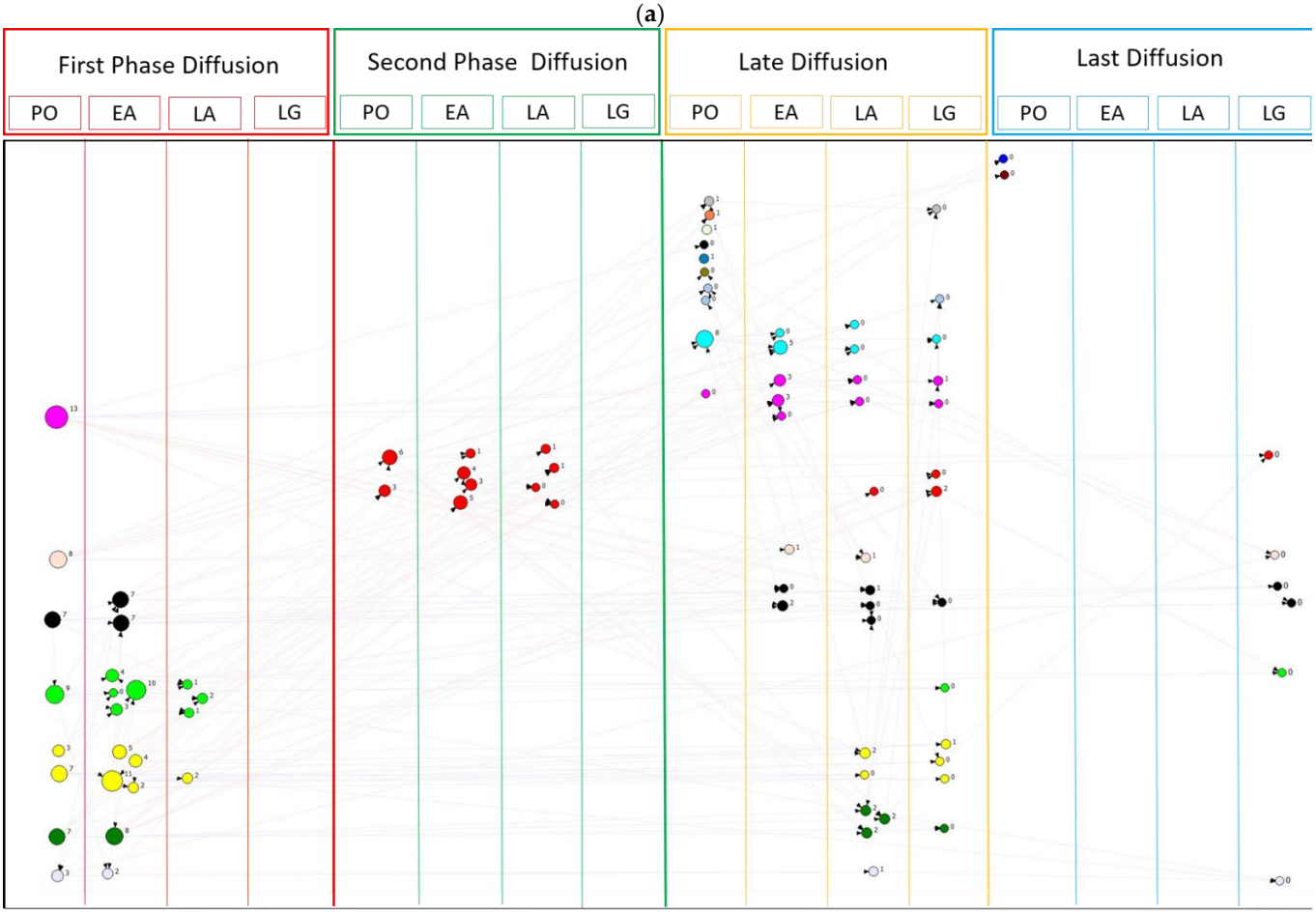
## 3. Results

### *3.1. RWH Tank Dissemination in Macro- and Micro-Communities*

Figure 4A–C show that the tank dissemination in all three areas was concentrated only in a few villages in the first stage. In many villages, the tank diffusion started from the first phase, yet the diffusion did not continue in the subsequent phases. In some villages, the tank dissemination started in the late-diffusion stage, but it persisted till the end. In many cases, the tank diffusion was sporadic, i.e., only one or two members in a village adopted the tank. In Morrelgan Rural, we found many villages with only one or two adopters.

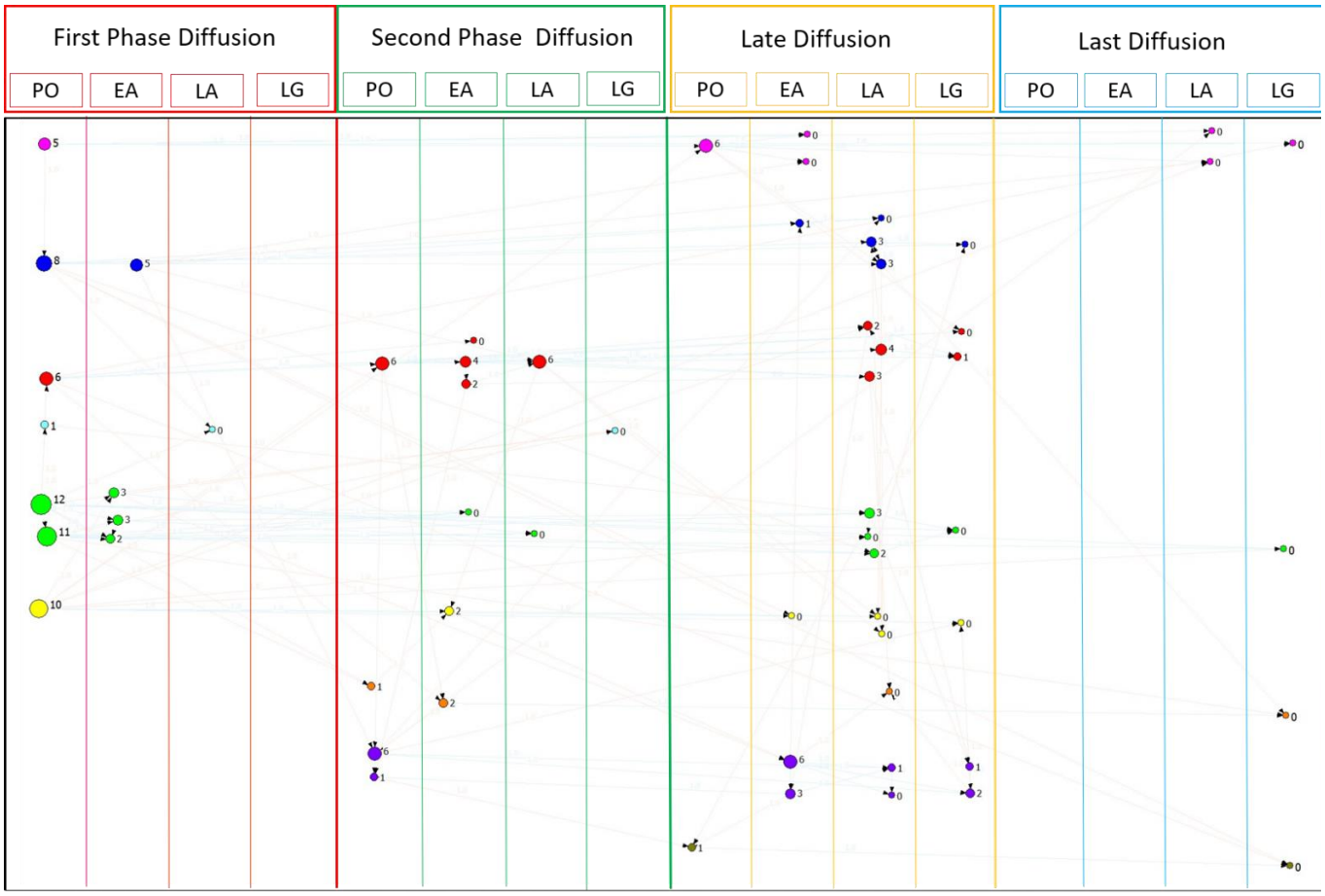



(**a**)




(**b**)

**Figure 4.** *Cont.*




(**c**)

**Figure 4.** Diffusion of RWH tank through social networks of hearing. (**a**) Chitalmari Sub-district; (**b**) Morrelganj Rural Subdistrict; (**c**) Morrelganj Town (Municipality). Note: *Adopter and Diffusion Stages*: There are four chronological macro-stages of tank dissemination: first diffusion, second diffusion, late diffusion, and last diffusion. Macro-diffusion stages are marked in distinctive colors for better visualization; each macro-dissemination phase is divided into four micro-dissemination stages as follows: PO = Pioneer Adopter; EA = Early Adopter; LA = Late Adopter; LG = Laggards. *Circle Size and Color*: The circle represents the adopters. The color of the circle represents the adopter's village affiliation. Circle size indicates the adopter's out-degree centrality score (information diffusion). *Arrow color and direction*: The arrow represents information networks through hearing from one person to another. The arrowhead shows the direction of the information flow. The arrow's color is used to indicate the internal (in-group) and external (out-group) information flow. The bluish color represents hearing networks within the neighborhood/village, and the light orange color represents hearing networks outside the village/neighborhood. *Scale*: The layout is not to scale. Legend: ○ Adopter ⟶ Hearing Social Networks . Sources of information.

Community members (social networks) were the pivotal source of information for adopters, as shown in Figure 4A–C. However, it took time to develop this social network of information dissemination. Figure 5 show that the adopters of the first phase of the diffusion, especially the pioneer adopters, received information mainly from the NGO workers. From the second or early diffusion phase onwards, the majority of the tank adopters reported community members as their primary source of information. This trend had further escalated in the later diffusion phases, including the late and last diffusion stages.

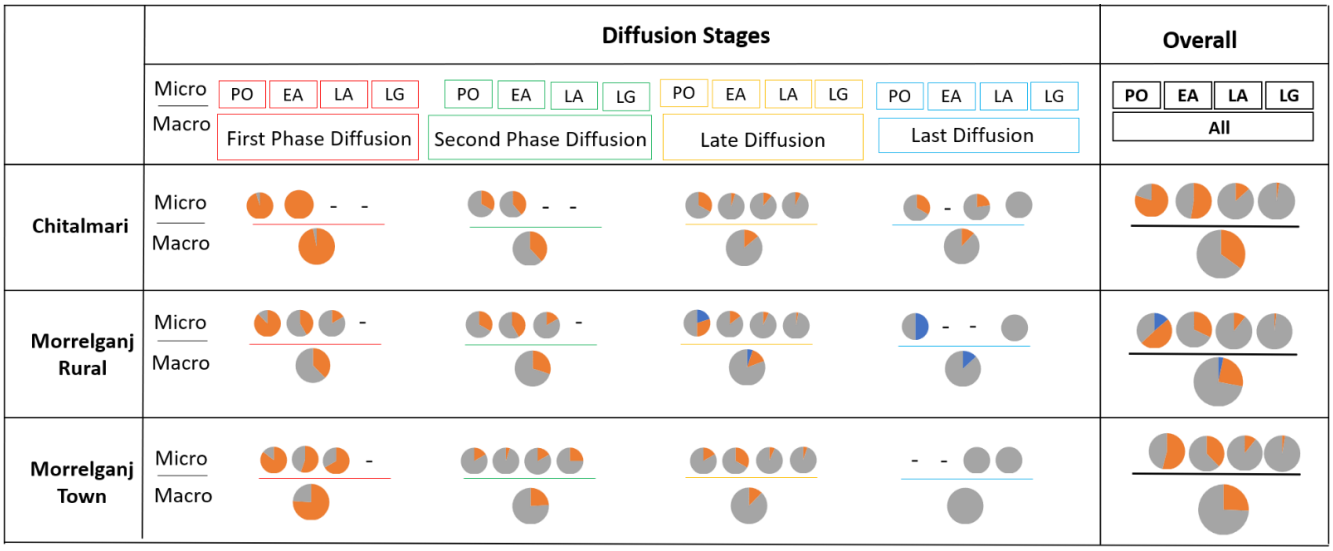



**Figure 5.** Primary source of information (percentage). PO = Pioneer Adopter; EA = Early Adopter; LA = Late Adopter; LG = Laggards. The layout is not to scale. Legend: NGO Workers Community Members Nowhere (Not Received).

Interestingly, respondents did not report mass media as their source of information. It is the change agent, local NGO workers, who first introduced the tank in the region. In all the areas, including Chitalmari, Morrelgang Rural, and Morrelganj Urban, the first diffusion stage adopter heard about the RWH tank from NGO workers. After that, the information disseminated further through social networks, as Figure 5 show that the percentage of people who heard about the tank from NGO workers drastically declined in the later stages of the diffusion.

### *3.2. Information Dissemination and Social Networks of Hearing*

#### 3.2.1. Direct Information through Personal Networks

Unlike the previous diffusion studies [28], Table 2 and Figure 4 suggest that all the macro-early adopters (adopters of the first phase diffusion) did not equally play a significant role in information dissemination. Not all the adopters in the first phase of the diffusion but the pioneer adopters received the highest centrality score. This trend is prevalent in all three study areas—Chitalmari, Morrelganj Rural, and Morrelganj Town (see Figure 4 and Table 2). The results suggest that the tank information first entered into the community through NGO workers. Then, the information diffused across communities mainly through pioneer adopters of the first phase diffusion.

**Table 2.** Hearing out-degree centrality (information sending) in different areas of Bagerhat district.

| Area | | Diffusion Stages | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | First Diffusion | | | | Second Diffusion | | | | Late Diffusion | | | | Last Diffusion | | | | Total | | | |
| | | PO | EA | LA | LG | PO | EA | LA | LG | PO | EA | LA | LG | PO | EA | LA | LG | PO | EA | LA | LG |
| **Chitalmari** | Micro | 6.57 | 4.33 | - | - | 7 | 1.83 | - | - | 2 | 0.67 | 0.42 | 0.20 | 1 | - | 0.66 | 00 | 5.6 | 2.17 | 0.46 | 0.10 |
| | Macro | **5.90** | | | | **2.97** | | | | **0.47** | | | | **0.33** | | | | **3.68** | | | |
| **Morrelganj Rural** | Micro | 7.13 | 5.25 | 1.50 | - | 4.50 | 3.25 | 0.50 | - | 1.20 | 1.78 | 0.64 | 0.31 | 00 | - | - | 00 | 3.55 | 3.68 | 0.77 | 0.21 |
| | Macro | **5.25** | | | | **2.40** | | | | **0.89** | | | | **00** | | | | **2.17** | | | |
| **Morrelganj Town** | Micro | 7.57 | 3.66 | 00 | - | 3.5 | 1.71 | 3 | 0 | 3.5 | 1.66 | 1.4 | 0.57 | - | - | 00 | 00 | 5.69 | 2.06 | 1.42 | 0.33 |
| | Macro | **5.89** | | | | **2.28** | | | | **1.40** | | | | **00** | | | | **2.30** | | | |

Table 2 further shows that the degree of centrality at the macro-level was steadily reduced from the first to the last phase of the diffusion. Similarly, the degree centrality

decreased steadily from pioneers to the laggards at the micro (local)-community level. Hence, the early adopters played a significant role in information diffusion at the macro- and micro-levels.

Pioneer adopters of the later phases of the diffusion also played a significant role in disseminating the information at the local level. Table 2 shows that, in every diffusion stage, pioneer adopters received the highest centrality score. Even, in many cases, the micro-pioneer adopters of the late diffusion stage received a higher centrality score than many macro-level early adopters. This study's results contrast the previous research suggesting that the role of all the late adopters is insignificant in information diffusion.

#### 3.2.2. Information Flow within and Outside the Community

Figure 6 shows that pioneer adopters of the first diffusion phase diffused information both inside and outside their community or village. The early and later adopters of the first diffusion phase send higher information percentages outside their local communities. In the subsequent diffusion phases, micro-pioneer adopters also circulated information but only inside their own community. The role of the adopters of the last diffusion stage in information dissemination was found to be negligible.

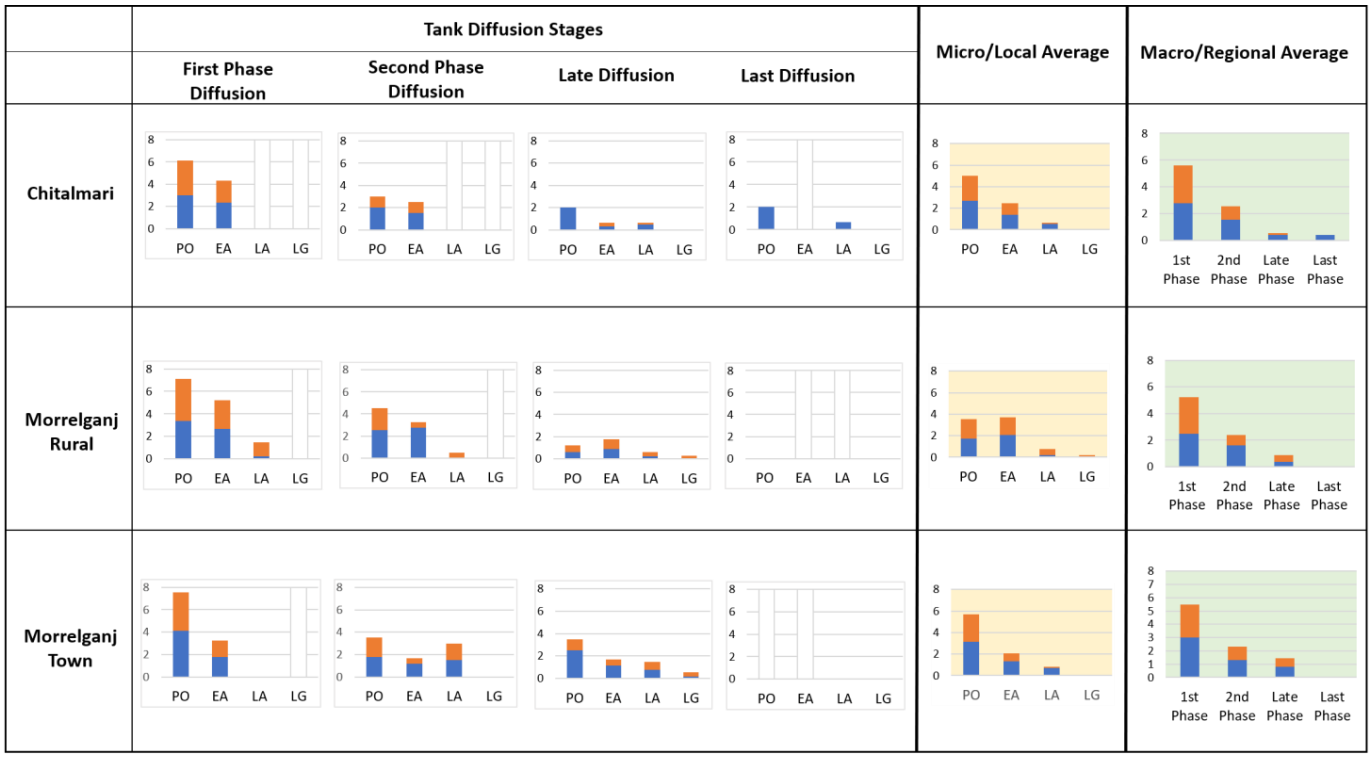



**Figure 6.** Outgoing information (score) within and outside the community. PO = Pioneer Adopter; EA = Early Adopter; LA = Late Adopter; LG = Laggards. (The layout is not to scale.)

From Figure 6, we can observe that, on average, the pioneer adopters and late adopters of the first diffusion phase diffused information approximately 50% within and 50% outside their community or village. In the second diffusion phase, the pioneer adopters and early adopters diffused the information mostly (in the range of 60–80%) within and the rest outside their community or village. In the subsequent diffusion phases, micro-pioneer adopters also diffused information more than 50% within and about 50% outside their own community or village.

Figure 7 shows that the first phase pioneer adopters played a significant role in providing information to new areas where the tank diffusion did not take place. Figure 7 shows

that the majority of the pioneer adopters in the second and late diffusion phases received tank information outside their village or neighborhood, whereas after they received information from outside, they spread it within their own community or village. Thus, Figure 7 shows that the majority of the late adopters and laggards received information from inside the community. Like outgoing information flow (see Figure 6), the incoming data flow gradually concentrated within the community as the diffusion progressed (see Figure 7).

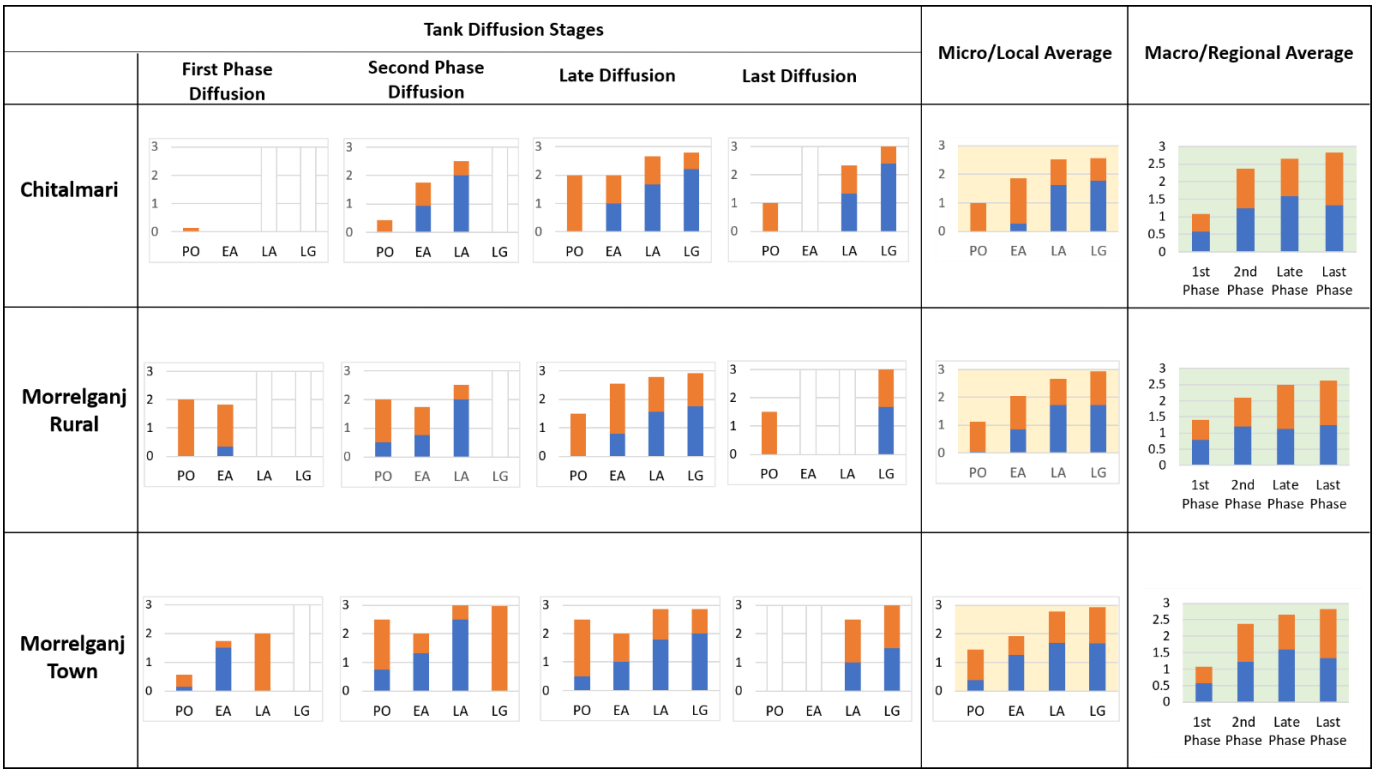



**Figure 7.** Incoming information (score) from inside and outside the community. PO = Pioneer Adopter; EA = Early Adopter; LA = Late Adopter; LG = Laggards. (The layout is not to scale.)

From Figure 7, we can observe that, on average, pioneer adopters of the second and third phases received the information mostly (in the range of 75–100%) from outside their community or village. Early and late adopters in the second diffusion phase received the information mostly (in the range of 60–80%) from within their community or village. In the subsequent diffusion phases, micro-late adopters and laggards mostly received the information within their own community or village (in the range of 60–80%).

In this survey, we considered a sample size (the total number of tank adopters in Bagerhat district distributed in three regions) of 196, which is much less than the total population of around 1,457,000 in the Bagerhat district. Hence, we are not drawing any statistical significance in this case.

### 3.2.3. Bridging and Indirect Information Flow

Table 3 shows the betweenness centrality score, which depicts the adopter's role as a bridge to diffuse information across the group through indirect communications. Macro-pioneer adopters did not receive a high betweenness centrality score. Micro-pioneer adopters played a significant role as a bridge for information dissemination. For example, pioneer adopters of the second and late diffusion stages in the Chitalmari received a high betweenness centrality score. Similar trends can be observed in the Morrelganj rural and Morrelganj town areas. We have already observed that, though neighborhood (micro) early

adopters of the second and late diffusion stage did not receive a high degree of centrality, they have received a significant betweenness centrality score in all three areas–Chitalmari, Morrelganj Rural, and Morrelganj Town.

**Table 3.** Betweenness centrality score in different areas of Bagerhat district.

| Area | | Diffusion Stages | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | First Diffusion | | | | Second Diffusion | | | | Late Diffusion | | | | Last Diffusion | | | | Total | | | |
| | | PO | EA | LA | LG | PO | EA | LA | LG | PO | EA | LA | LG | PO | EA | LA | LG | PO | EA | LA | LG |
| **Chitalmari** | Micro | 0.78 | 00 | - | - | 8.5 | 7.1 | - | - | 9 | 0.67 | 1.8 | 00 | 1.5 | - | 1.3 | 00 | 2.5 | 3.7 | 1.7 | 00 |
| | Macro | **0.55** | | | | **7.33** | | | | **1.55** | | | | **0.61** | | | | **2.02** | | | |
| **Morrelganj Rural** | Micro | 4.8 | 26.8 | 12.8 | - | 42 | 23.3 | 3.2 | - | 9.1 | 12.4 | 3.3 | 1.7 | 00 | - | - | 00 | 9.7 | 21.0 | 5 | 1.1 |
| | Macro | **17.09** | | | | **18.98** | | | | **5.86** | | | | **00** | | | | **9.9** | | | |
| **Morrelganj Town** | Micro | 5.8 | 6.8 | 0 | - | 27.3 | 15.5 | 34.6 | 0 | 15.2 | 18 | 10.5 | 6.7 | - | - | 0 | 0 | 13.9 | 14.8 | 11.9 | 3.9 |
| | Macro | | | | | | | | | | | | | | | | | 17.21 | | | |

### 3.2.4. Fastest Information Flow

Table 4 shows that the pioneer adopters reached all the adopters through the shortest path in the first, second, and late diffusion stages (closeness centrality). Therefore, both the micro- and macro-pioneer adopters diffused the tank information the quickest. Table 4 shows that the pioneer adopters of the first diffusion stage received the lowest closeness centrality in the entire community. This trend was observed in all three study areas. Therefore, not all the macro-early adopters could not diffuse the information quickly. However, the micro (village)-pioneer adopters were more effective in rapidly disseminating information in their local areas.

**Table 4.** Closeness centrality score in different areas of Bagerhat district.

| Area | | Diffusion Stages | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | First Diffusion | | | | Second Diffusion | | | | Late Diffusion | | | | Last Diffusion | | | | Total | | | |
| | | **PO** | **EA** | **LA** | **LG** | **PO** | **EA** | **LA** | **LG** | **PO** | **EA** | **LA** | **LG** | **PO** | **EA** | **LA** | **LG** | **PO** | **EA** | **LA** | **LG** |
| **Chitalmari** | Micro | 1522 | 1843 | - | - | 1754 | 2086 | - | - | 1978 | 2085 | 2131 | 2125 | 2024 | - | 2146 | 2162 | 1641 | 2025 | 2134 | 2143 |
| | Macro | **1618** | | | | **2038** | | | | **2116** | | | | **2142** | | | | **2003** | | | |
| **Morrelganj Rural** | Micro | 4513 | 5807 | 7332 | | 6622 | 6988 | 7548 | - | 7517 | 7368 | 7593 | 7616 | 7656 | - | - | 7656 | 6356 | 6557 | 7538 | 7628 |
| | Macro | **5630** | | | | **7138** | | | | **7539** | | | | **7656** | | | | **6984** | | | |
| **Morrelganj Town** | Micro | 1951 | 2703 | 3540 | - | 2718 | 2813 | 2819 | 3540 | 3218 | 3374 | 3281 | 3481 | - | - | 3540 | 3540 | 2382 | 2996 | 3273 | 3505 |
| | Macro | **2334** | | | | **2841** | | | | **3344** | | | | **3540** | | | | **3052** | | | |

## 4. Discussion

Studies on the diffusion of innovation argue that information on new technology first diffuses to local communities through mass media [28]. However, in this study, no one reported mass media as a source of information (through hearing). The rainwater-tank diffusion in coastal Bangladesh started with the initiative of an NGO. In fact, when the rainwater-harvesting movement started in this region, only a few initiatives across Bangladesh promoted this technology as an alternative drinking-water source [56]. Hence, the NGO persons were the primary source of information (through hearing) for the majority of the adopters in the first diffusion phase.

The previous studies on the diffusion of innovation suggest that early adopters do not rely on social learning or social recommendations for adoption decisions [46,57] (Wejnert, 2002). Instead, they depend on mass media and change agents (e.g., NGOs). However, our study findings show that this is partially true—not all adopters of the first diffusion stage (macro-level pioneer adopters) took the risk to adopt the innovative rainwater tank based on the change agent's information. Among the adopters in the first diffusion stage (macro-level), those who were also the first adopters in their villages and neighborhoods

(micro-level) relied solely upon the information from the NGOs. They were risk takers and did not wait to obtain social approval and advice before making adoption decisions. They did not have any social referents from whom to obtain information about the tank's merits, functions, durability, social acceptance, etc., as they adopted the tank when no one in their regions (macro-community) and villages (micro-community) had adopted it. Hence, this shows that their awareness knowledge triggered their adoption decisions.

However, many adopters of the first diffusion stage (macro-level pioneer adopters) were actually late adopters with respect to their villages or neighborhoods (micro-level). Their decision to adopt the tank was subject to the success and failure of the pioneer adopters in their villages and neighborhoods. Thus, our study findings show that, within the first diffusion stage, as the diffusion moved from pioneer adopters to late adopters, social networks within the village and neighborhood became the primary source of information, and the dependency on the NGOs and outsiders decreased or even disappeared.

However, the rainwater-harvesting-tank movement was limited to a few villages when it first started to diffuse. The reason could be that the local NGOs had limited resources and capacities for campaigning, which enabled the NGOs to diffuse the information of this innovative tank to limited micro-communities in the selected geographical and administrative areas. Alternatively, the NGOs may have campaigned in many villages to promote this tank, but only a few pioneer adopters in selected areas showed interest in installing the tank. The rest of the population preferred to wait to receive feedback from the pioneer adopters of the first diffusion stage before adopting it. Hence, the study findings show that the primary source of information for most of the village pioneer adopters (micro-level) in the second and third diffusion stages was community members outside their own villages or neighbors.

Thus, the pioneer adopters of the first diffusion stage played two critical roles—first, through their adoption, they disseminated the tank information inside their own communities (villages and neighborhoods); second, they diffused the tank information to new villages and neighborhoods in the later phases of the diffusion, where the NGO campaigning did not reach or work. Micro-adopters of the first diffusion stage played a critical role in encouraging new adopters to adopt the tank in areas where the rainwater tank movement did not reach till the second and late diffusion phase.

Then, these pioneer adopters in the new villages or neighborhoods (micro-community), although they were the late adopters in regional perspective (macro-level), became the key source of information for their local communities in the later phase of the diffusion. The ordinary people, especially the late adopters of the village, relied upon more on the information from the existing adopters from their own communities, as it allowed them to examine the tank's functions, merits, and durability more intensively and for a prolonged period, which helped them to make correct decisions from their subjective perspectives. As a result, the study findings showed that the source of information for the late adopters and laggards was the community members inside their own villages and neighbors. Similarly, pioneer adopters at the micro-level received a high outgoing centrality score. Apart from disseminating the information on the innovative tank to their own community member-, village- or neighborhood-level pioneer adopters (micro-level), though they were late adopters in the regional context (macro-level), they helped to disseminate the information on the tank to new communities where the people had no awareness about the existence of the tank and encouraged them to adopt the tank.

The previous study's findings [8,28,56] showed that, when the innovation is costly, permanent, and has no pre-trial option, such as the rainwater tank, information from indirect networks does not play any significant role. However, our study findings also showed that the neighborhood and village pioneer adopters (micro-level) were good at disseminating the information faster (high closeness centrality score) and across the disconnected groups (high betweenness centrality) through indirect contacts. Seemingly, micro-pioneer adopters simultaneously disseminated the information through direct and indirect networks.

## 5. Conclusions

This study examined how the information on an innovative disaster-preventive technology, such as the rainwater-harvesting tank as an alternative drinking-water source, disseminated through hearing from person to person at the regional (macro) and local (micro) level and the role of pioneer adopters in this process. We found that social networks played the most critical role in this process, and the role of change agents (e.g., NGOs) and mass media was negligible. As the innovation was very new in this region, there was no information available from mass media. The NGO, as a change agent, worked initially to disseminate the awareness knowledge of the innovation, but its impact faded away after the first phase of the diffusion of innovation, and the impact of social networks started to appear.

In contrast to the existing study findings, our study showed that not all pioneer adopters played a critical role in the information dissemination for innovative technology. Our primary argument is that the pioneer adopters are not unidimensional; instead, there are several types of pioneer adopters, depending on their adoption timing respective to macro (regional)- and micro (village)-community dimensions. Those who adopted at the beginning of the diffusion in the regional context but were actually late adopters in the village or neighborhood context were not active in disseminating the information within and outside their community. Those who adopted early at both the regional (macro) and village (micro) levels played an instrumental role in encouraging new members within their local communities and, thereafter, disseminating information on the innovation to larger communities such as new villages and neighborhoods. Therefore, they played a critical role in spreading awareness knowledge that innovation does exist and *principles knowledge*, including the merits, functions, and usefulness of the innovative disaster-preventive technology.

However, the macro-pioneer adopters faced limitations to hastening the information dissemination in new micro-communities, including villages and neighborhoods. Their information was critical for obtaining new adopters in a new place where the innovation did not occur, but they could not penetrate further among the general population in a new area. Then, the pioneer adopters in these new areas played an instrumental role in disseminating the information and encouraging the rest of the village population to adopt the innovation. The conventional diffusion studies consider them late adopters and inactive in information dissemination. However, our studies showed that they are late adopters at the regional or macro-scale, but they are pioneer adopters in their local areas such as villages and neighborhoods and played the most critical role in disseminating the information.

We found that the information traveled more through direct and local social networks. People wanted to receive information more from their local area, instead of outsiders and indirect context. Potential adopters relied on information from local and direct contacts because it helped them to understand the local and culture-specific issues and benefits of the tank installation. However, the local pioneer adopters also played a critical role in disseminating information through indirect networks (e.g., high betweenness centrality).

The vital role that the pioneer adopters at the regional level (macro) played in this diffusion process was creating awareness of the tank among the people at the regional and local levels. The local pioneer adopters, such as village or neighborhood leaders, provided *principles knowledge* and *how-to knowledge*. Hence, potential adopters understood the merits, demerits, functions, and usefulness of the tank from their subjective perspective, as the information came through direct contacts and from their own area.

This study draws the following policy and planning implications for disseminating innovative disaster-preventive technologies.

- In the conventional approach, planners and disaster-management authorities generally target early adopters at the regional level to effectively disseminate disaster-preventive technologies. However, our study found that not all regional early adopters play an instrumental role in information dissemination, nor are they the only catalyst for information dissemination. This study suggests that, along with early regional

adopters, planners should target local or village-level pioneer adopters for the fast and effective dissemination of disaster-preventive technologies. Local pioneer adopters are not necessarily early adopters at the regional level. Hence, planners should also identify local pioneer adopters among the late adopters at a regional scale, who are generally ignored in the conventional approach.

- This study suggests that planners should identify regional-level early adopters for disseminating awareness knowledge that "the technology exists". The major role of the regional-level early adopters is to pass the information about the disaster-preventive technology to the potential pioneer adopters at the local or village level. Planners should identify regional-level pioneer adopters not concentrated in one place but sparsely distributed, to disseminate the awareness knowledge of the innovation to all corners of the region. Using regional-level early adopters can reduce the campaigning cost.
- However, regional-level early adopters would not be beneficial for the dissemination of the information at the local level. For that, planners should target pioneer adopters at the village and neighborhood levels. The individuals in close contact with local-level pioneer adopters would be considered the most potential adopters of the innovative disaster-prevention technology.
- Local-level pioneer adopters' close network data should be collected because those network partners have the highest propensity to adopt the tank. Local-level adopters should be involved in village meetings, neighborhood meetings, and focus-group meetings to promote innovative disaster-preventive technologies. The success cases of local pioneer adopters should be displayed and propagated in each village and neighborhood. Planners should be in close contact with local pioneer adopters to identify the potential adopters and understand the dynamics of the innovation dissemination. Local pioneer adopters can also be involved in technology dissemination planning and technologies.
- Incentives should be given to local pioneer adopters so that they would be motivated to more intensively disseminate the information of the innovation. The incentives could be economical and in-kind or social recognition. This would also create a culture of having new local pioneer adopters in new villages and neighborhoods.

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