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Scaling the pressure and release model to address climate shock hazards and disaster risk reduction approaches in northeast *haor* basin of Bangladesh

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ABSTRACT

The *haor* basin at northeast Bangladesh covers almost one fifth of its total land area, produces about 20 percent of country's total staple food grain (rice) and supports livelihood for twenty million people. However, the areas are regularly affected by flood hits with enormous loss of crops, fodders, and other food commodities, and earning sources that make the people live therein vulnerable. Proper attention is not paid yet to explain the disaster occurs in the areas and overcome from the hazard risks with a holistic model. Therefore, the aim of the study is to explain the progression of vulnerability and hazards situation due to flood shocks in *haor* areas with a popular conceptual framework like the Pressure and Release (PAR) model. Important drivers of the root causes, dynamic pressures and unsafe conditions responsible to progress the vulnerability (Pressure model) are identified through collecting both secondary and primary sources of data from published, unpublished and grey literatures, consulting with various categories of stakeholders, and focus group discussion meeting with flood victim's farmers. The possible determinants (relief drivers) towards the progression of safety and disaster mitigation as a whole are pinpointed in the Release model which can be utilized in the Disaster Risk Reduction (DRR) or Management (DRM) programmes. The geo-morphological setting of *haor* areas and early heavy rain especially in the highly elevated upstream catchments like Cherrapunji, Meghalaya of India, and poor and un-time management of embankment are identified as proximal drivers for early flash flood hit which lead to inundate and damage of pre-matured *Boro* paddy. Early transplantation of *Boro* seedling with cool-tolerant and short life span cultivar which is trying to develop could assist to minimize the disaster risk to a great extent. The determinants can be categorized for performing immediate actions, short and medium term measures and long term planning. The analysis integrates the entire package of both social and physical components, and the results of the study can be utilized in government or policy planning.

Keywords: Cherrapunji, Disaster, Emergency response, Flash flood, Hazard, Pressure model, Rainfall, Release model, Risk, Upstream catchment, Vulnerability

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1. INTRODUCTION

The *haor* basin is located in the northeastern region of Bangladesh and consisted with Sylhet, Sunamganj, Moulvibazar, Habiganj, Netrokona, Keshoreganj and Brahmanbaria districts (Map 1). There are 373 *haors* comprised about 0.859 million hectares of land which is around 43 percent of the total area of those seven districts (CEGIS, 2012). *Haors* are the large bowl or saucer shaped tectonic depressions normally inundated by water during the monsoon season from May to September or sometimes up to October. Thus at this season, the areas remain crop less except some *Aman* paddy which is usually grown in the somewhat elevated periphery places of the *haors*. Within the longer time monsoon inundation, flood thrusts each of two to three week's duration occurs almost every year in many *haor* areas (Awal, 2021). The crop loss, mainly *Aman* paddy due to monsoon flood or inundation is not largely occurred but people's movement and alternative livelihood activities would become increasingly difficult. Thus during the period of monsoon inundation, *haor* farmers, in limited scale serve as fishers to support livelihood.

Map 1. Seven *haor* districts at northeastern region of Bangladesh

Due to a longer season's inundation during monsoon, the time for crop production in the *haor* land is much squeezed and largely utilized with a sole or mono crop with cultivation of *Boro* paddy during the months from December to May (Photograph 1). The cultivation of this crop needs a two-tier of work. The seedlings should have to prepare first in the seedbed. Then the seedlings of 30-40 days old are needed to transplant in the well prepared puddle land. Thereafter, the crop depending on the variety takes about 110 to 130 days to mature the grain for harvest. As a whole, the harvesting period of the *Boro* paddy falls in the month of April and May – the time is specified for a flash flood hit in most years. Consequently, the *Boro* harvest is remained at risk and the farmers consider it as a chance harvest. Loss of harvest of *Boro* paddy with various magnitudes is a common phenomenon every year and the highest loss of paddy and fodder about 80-90 percent is occurred in March-April of 2017 when a large scale early flash

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flood hit the *haor* areas (Haque, 2022). Loss of other lives like fish, livestock, cattle's, duck, poultry etc are also common if the flood hit is occurred rigorously as that occurred in 2017 (DDM, 2017). The vulnerable people are fallen to a disaster in 2017 as they lost their main staple crop *Boro* paddy along with other food commodities and earning sources. To support livelihood, the alternate income sources are very limited in the *haor* areas as no industry is established yet in nearby areas. Therefore, most of the people are needy and hence living at risk or vulnerable situation.

Photograph 1: A *haor* area with pure (single) or mono cropped (*Boro* rice-Fallow-Fallow) *Boro* paddy. Photo Credit: Author.

The nature dependant people in *haor* areas could not manage the situation anyway if the flood hit arrives as havoc. Historical flood trend analysis shows that large scale early flash flood occurred in the years 1964, 1982, 1996, 2003, 2010, 2017 and 2022 with a great loss of growing paddy and other food commodities and earning sources (Rashid and Yasmeen, 2017; Abedin and Khatun, 2019; Tasnim, 2022). Climate change may aggravate the situation further and future flash flood would not only hit intensely but also with frequently, as per expert's opinion. Thus the protection of livelihood of vulnerable *haor* communities is of prime importance with find out the causal drivers of hazard (i.e. trigger event) occurred and means to overcome from disasters more holistically. Although a few studies were undertaken to the point but the efforts seem scale down as the observations devoid a suitable model (Kamruzzaman and Shaw, 2018; Ferdushi et al., 2019; Fahim and Sikder, 2022).

The Pressure and Release model (shortly PAR model) is a popular conceptual model that is utilized to understand the risk in terms of vulnerability study in the particular circumstances (Awal, 2015). The PAR model is a device that expresses how disasters take place when natural threats affect the population at risk (Wisner et al., 2003). Many workers successfully utilize the PAR model to explain how the progression of vulnerability and hazard situations turned to a disaster (Pressure model). The concept of Disaster Risk Reduction (DRR) or Management (DRM) that utilizes the progression of safety and hazard mitigation approaches is also embedded in PAR model as in the Release part (i.e. Release model). The supremacy of the PAR model is that it explicitly calls attention to the vulnerability by taking into account the full package of both social and physical elements. The PAR model is used to analyze the vulnerability and hazard situations, and possible means to overcome from the risks for almost all kind of disasters like drought risk (Schilderinck, 2009), landslide hazard (Santha and Sreedharan, 2010), river flood vulnerability (Rauken and Kelman, 2010), cyclone risk (Asgary and Halim, 2011), public health hazards and emergency response (Hammer et al., 2019) and so on (Blaikie et al., 2004; Wilder, 2018). The flood hazards and consequent disaster in *haor* areas of Bangladesh can be scaled-up with a PAR model to assist the DRR or DRM but yet to figure it out. Therefore, the aim of the study is to analyze the vulnerability and hazard risk due to flood shocks in *haor* areas at the northeast Bangladesh and suggest the possible means to overcome from the disaster with the PAR model.

2. MATERIALS AND METHODS

The study was conducted in the Laboratory of Plant Ecology, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, during the period from 2018 to 2021. Both primary and secondary sources of data were collected. Primary data were

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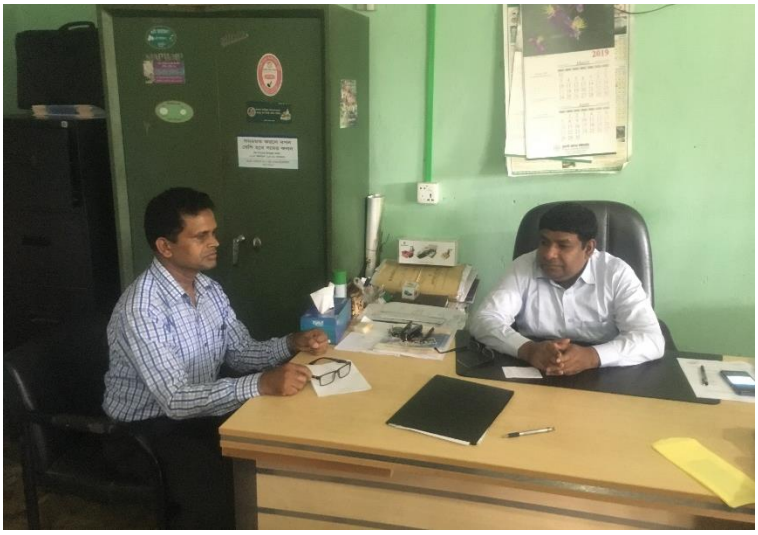
collected from flood affected *haor* farmers with focus group discussion (FGD) meeting (Photographs 1 and 2). Stakeholder consultation meeting was conducted with chief scientist in the research institutes and chief officials of the Ministry of Agriculture and Ministry of Water resources working in the *haor* areas (Photograph 3).

Photograph 2: FGD meeting with some flood victim's farmers in *haor* area. Photo Credit: Author.

Photograph 3: Some flash flood victim's farmers, at risk to cultivate *Boro* paddy in *haor* area. Photo Credit: Author.

Chief scientists of plant breeding programmes working in the research organizations were also consulted to understand the up to date information on innovation of agricultural technology especially crop cultivars capable to withstands the emerging threats of abiotic stresses including climate change (Photograph 4). The secondary information were collected with analysis of reviews from books, published, unpublished and grey literatures. Climate information especially rain and flood data, collapse of flood protecting embankments were gathered from maps, scientific articles and newspapers published in webs. All collected information were grouped and regrouped to fit theses in to a conceptual model like the Pressure and Release (PAR) model (Wisner et al., 2003). The PAR model pursues to elucidate how the junction of exposed (or unsafe) conditions and dangers turns out to a public vulnerability (Blaikie et al., 2004). The PAR is a device which exhibits that disaster occurs when hazards affect unprotected (or vulnerable) population or people at risk. The PAR model has major two parts: the Pressure model and the Release model. The pressure part is responsible to focus the progression of vulnerability that includes the root causes, dynamic pressure and unsafe conditions to form a disaster in combination with a hazard or trigger event.



Photograph 4: Consulting with a key DAE (Department of Agricultural Extension) Official in *haor* area. Photo Credit: Author.

Photograph 5. Discussing with a key rice breeder working at Bangladesh Rice Research Institute (BRRI) for developing cool-tolerant *Boro* paddy cultivar with short duration characteristics. Photo Credit: Author.

The Disaster (D) or Disaster Risk (DR) can be explained with the following foundational equation (Blaikie et al., 2004):

$$DR = H \times V \qquad \text{Eq [1]}$$

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where, H and V respectively represent the hazard (potential threat to people and their welfare) and vulnerability (exposure and susceptibility to losses) of the impact area of the disaster occurred.

Disaster occurs when a Hazard event in an impact area (i.e. environment) intercepts to the Exposures of vulnerability (Fig. 1).

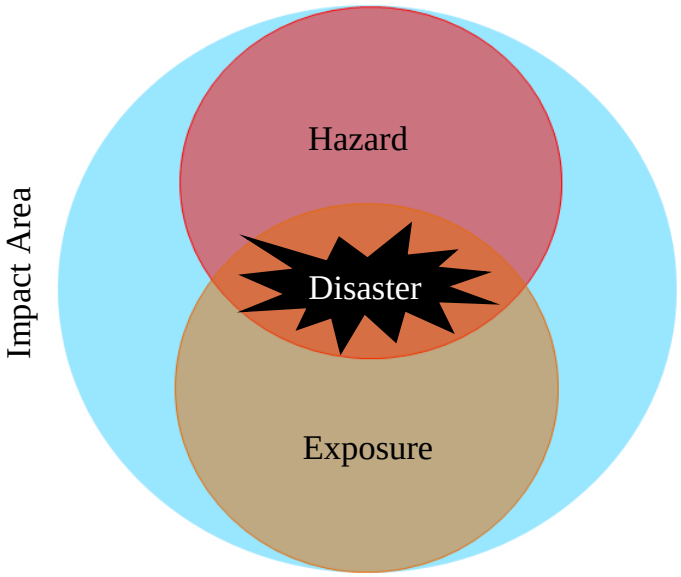

Figure 1. The Disaster System model. Modified from Shi and Kasperson (2014).

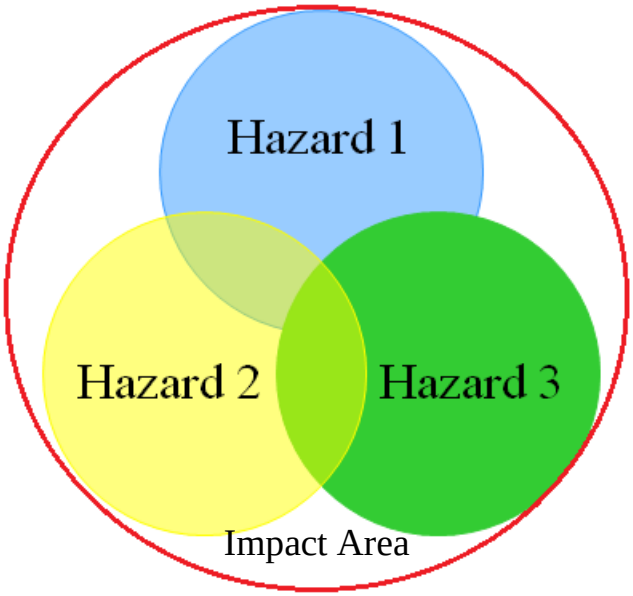

Figure 2. The concept of a multiple hazard. Sketch Credit: Author.

The DR can also be expressed as (UNISDR, 2009):

$$DR = (H \times V)/CC \qquad \text{Ed [2]}$$

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where, CC means Coping Capacity by which institutions or society use available abilities and/or resources to face the adverse consequences which could lead to a disaster.

The Progression of Vulnerability can be shown as:

Root Causes>Dynamic Pressures>Unsafe Conditions

Overall, the Disaster Risk can be outlined as:

Root Causes>Dynamic Pressures>Unsafe Conditions>**Disaster Risk**<Hazard

When a region (i.e. impact area) is unmasked to more than one threat or hazard, it is called multiple hazards. For example, a widespread flood shock causes famine, spread of infectious diseases (e.g. diarrhea), destruction of infrastructures, and so on (Fig. 2) which are very common in Bangladesh including the *haor* areas where the study is carried out.

The Release model would help to reverse the situation named as the Disaster Risk Reduction (DRR) or Management (DRM). The DRR or DRM is based on the approaches regarding the Progression of Safety and Hazard Mitigation which could help to overcome the disaster as:

Address Root Causes<Reduce Pressures<Achieve Safe Conditions<**DRR**>Hazard Mitigation

3. RESULTS AND DISCUSSION

The premise of the PAR model is that a disaster is the bridging episode between two major opposing drivers. These contrasting drivers are what give rise to vulnerability and the natural incidence i.e. hazard event, which are part of the Pressure model. The release part of the PAR model (i.e. the Release model) considers the giveback or reduction or management of the disaster. The impact of the disaster has to be kickback or reduced if any programme(s) could relieve the pressure (Wisner et al., 2003).

3.1 The Pressure model

The Pressure model shows how root causes, dynamic pressures and unsafe conditions combine with a natural hazard event create a disaster. The socio-economic context of a hazard is very important. In poor or badly governed (root causes) places with rapid change and poor capacity (dynamic pressures) and poor coping capacity (exposed or unsafe conditions), disasters are likely occurred.

(a) Root causes

Vulnerability has 3 major drivers which are located separately from people impacted upon the disaster. The population at risk is rooted in social affairs and underlying sources that may be detached from the disaster. Thus, root causes are the distant drivers that are profoundly bound up with cultural assumptions, ideology, beliefs etc. The root causes are tied-up to the functionality of a country and the command it has as like as laws, regulations and governance. These may include poor or limited access to influence, institutions, and capital, as well as exposures of both the political and economic systems (Hammer et al., 2019). These root cause factors may lead to forceful (dynamic) pressures, including a lack of preparedness and local funding (Fig. 3). Vulnerable groups at risk live under pressure where their access to basic services such as education, healthcare and secure livelihood options are very limited as mostly found in the *haor* areas of Bangladesh.

(b) Dynamic Pressures

Dynamic pressures are on-site threats specific both to local ecological and social processes, analyzed at the regional or country level. These are the aspects which are missing within a state/society/area or the aspects that inflame the underlying root causes. For *haor* areas of Bangladesh, a large number of items are exemplified such as lack of proper education, training, skill, employment opportunities and so on as dynamic pressure in the pressure model (Fig. 3). Macro-forces may also pressure to invite vulnerability. For example, rapid population growth and urbanization, unemployment, poor cropping intensity (e.g. *Boro* paddy-Fallow-Fallow), soil and embankment erosion etc are very common in the area studied.

Dynamic pressure is also invited from the farmer's end. *Haor* farmers are usually advised to cultivate BRRI Dhan28 variety in *Boro* season whose grain yield is 5.5-6.0 t/ha and life span is 140 days. But to obtain higher yield, farmers usually cultivate BRRI Dhan29 variety (grain yield 7.5 t/ha) whose life duration is 160 days. Thus, additional 20 days for growing of *Boro* crop with BRRI Dhan29 variety are intercepted to an early flash flood hit in some years.

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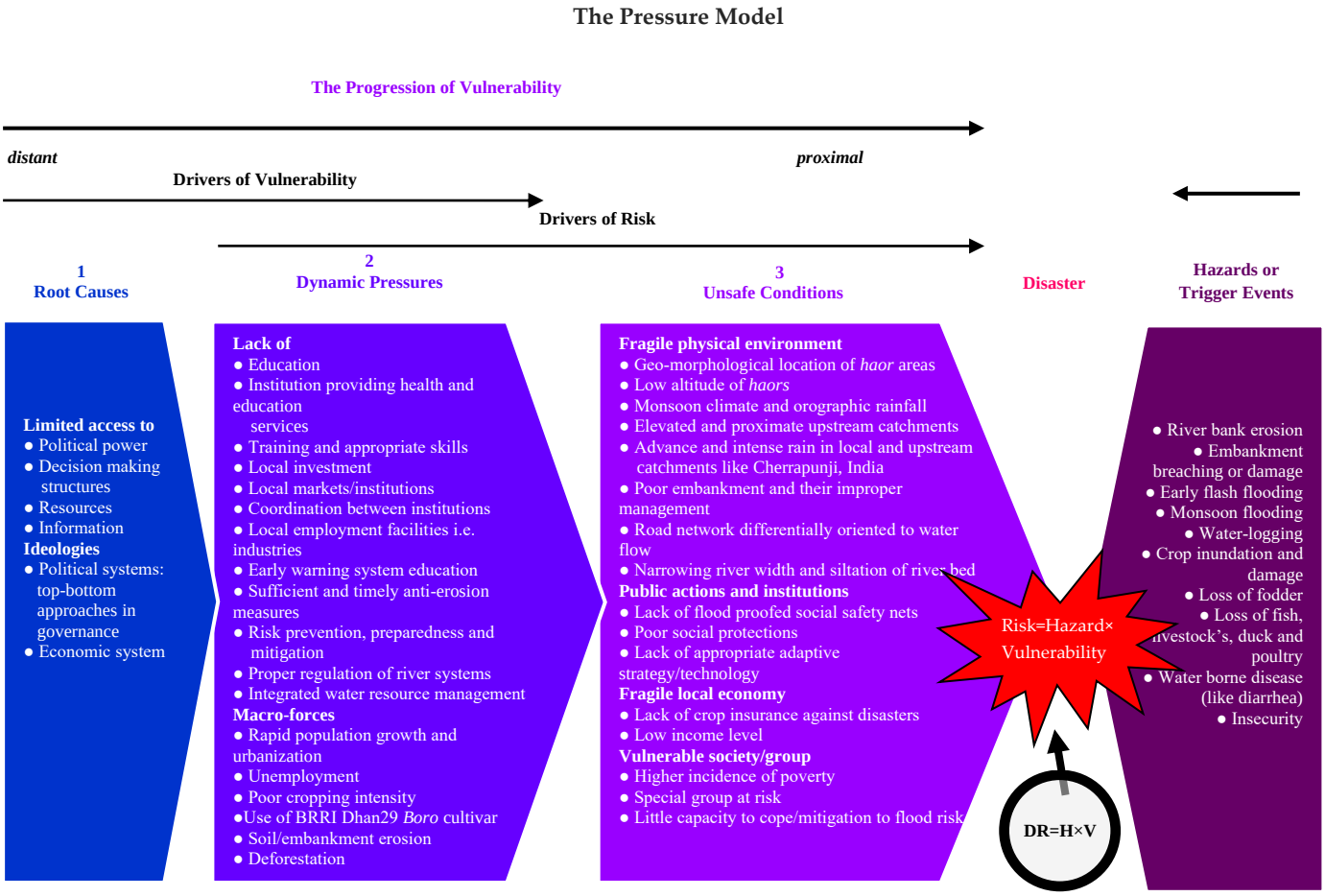

Figure 3. The Pressure model of flood disaster in *haor* areas of Bangladesh. Modified from Wisner et al. (2003).

(c) Unsafe or Exposed Conditions

The unsafe conditions prevail in the physical environment, public actions and institutions, local economy and social relations which increase the vulnerability of a society to translate the hazards. The root causes along with dynamic pressures may contribute to severity of exposed conditions. The exposed or unsafe conditions leave a population vulnerable to various hazards. There are a lot of exposed conditions in *haor* areas of Bangladesh. Some important of those are mentioned in the pressure model (Fig. 3). Each and every exposed condition from all sectors must be taken into consideration since a condition is tied-up to the other.

Geo-physical setting favours the flood incidence in the *haor* areas. As the elevation of the Cherrapunji (the world's heaviest rainfall area) of Indian Meghalayan is too high as 1430 meter from sea level, the rainwater quickly runs-off to the *haor* areas due to proximate concern (Cherrapunji is far from only 30 km from the Bangladesh border, i.e. the border of *haor* area). But the said run-off water become sluggish to drain to the downstream catchment when it is arrived in the *haor* areas as the elevation of the area is too low as only 2.5-5 m from sea level. The rainwater in the local catchment additionally surpluses to the run-off water from upstream areas. The road network (which act as dam) to move people from one district to the other in *haor* basin is somewhat differently oriented as it needed to discharge the water to down basin. The river systems in the *haor* areas do not also rapidly pass the accumulated water as it needs to flush downward due to the narrowing of river width and siltation of river bed leads to increase the water level and eventually turn out as food.

(d) Hazards – triggering events

A hazard is a potential source of threat or harm. Hazard is an event that has the potential to cause injury to life, damage to property, environment, livelihood, and can potentially trigger to a disaster. Hazard may be natural and man-made. Natural hazards may be geophysical, hydrological, climatological, meteorological, biological etc.

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The extreme pressure of flash flood's water cracks and eventually breaches the dams and embankment. As a result flood water rapidly enters into the *haors*, and inundates the premature or semi-mature *Boro* paddy lead to damage of partially ripen *Boro* grain along with fodder (i.e. rice straw). Loss of fish, livestock's, duck and poultry also occurs, in addition.

(e) Disaster or Disaster Risks (DR) – realization of a hazard event

A disaster is the unforeseen or immediate circumstance of a hazard event that results human trouble, instability or injury or harm to a population at risk. A disaster occurs when a society is not properly expedient or arranged to resist the effect of hazard event, and whose people is exposed or unsafe because of hardship or socially underprivileged any way.

A disaster happens when a large number of people who are at risk (i.e. poor) encounter a hazard event and experience extreme harm or damage to their livelihood. The risk people rarely to restore their livelihood from the impacts of the disaster without the help of external aid (Wisner et al., 2003). For example, a disaster was noticed following an early flash flood hit due to heavy rain and breaching of flood protecting embankment in March-April of 2017 when *haor* basin of northeast Bangladesh lost about 800,000 MT of paddy and 263,808,000 person day as working labour (Nirapad, 2017; Siddique, 2017). Consequently, people sufferings became severe as a result of price hike of rice (staple food) and an acute jobless situation of labour-class people (especially poor) in *haor* areas. To buffer the havoc situation partially, a lot of aid materials in terms of food, medicine, money etc were provided to the distressed people from the GO and NGO bodies, foreign organizations, Development Partners, and so on. The footprint of that disaster is still remained in some of the impact areas.

3.2 The Release model – unfolding the disaster

The programmes from the disaster risk of the vulnerable people are also embedded in the PAR model as like in the release part. It places the blue print at the centre of mitigation and coping strategies, for all kinds of disaster. Some important approaches that address root causes, reduce pressure and achieve safe conditions towards the progression of safety are briefly mentioned in the Release model (Fig. 4).

Equitable distribution of power, wealth and resources is very important to promote the livelihood of marginal people in *haor* areas. The *Jalmahal* (refers to a public water body within a *haor*, *baor*, *beel* etc) is to be used by the real fishermen in the *haor* areas. Limited access of actual or genuine fishermen to the *Jalmahal* because of leasing system is to be widened.

Strong coordination is needed among the institutions working in *haor* areas such as Bangladesh Haor and Wetland Development Board (BHWDB), Flood Forecasting and Warning Centre (FFWC), Department of Agricultural Extension (DAE), Bangladesh Water Development Board (BWDB), Department of Disaster Management (DDM), and so on. For proper coordination, the ministries of the said institutions should prepare the legislative frameworks or work plans.

In order to release the pressures, the DRR manager must act to reduce or manage the vulnerability components of the threats. Following matters are to be complied in the work plan of vulnerability reduction or disaster recovery processes or programmes (Cutter et al., 2008; ESCAP and UNISDR, 2012; ODI, 2018):

- Understanding of antecedent conditions, value of local contexts or knowledge, beliefs, customs, traditions and solutions (ways of doing things), and local institutions;
- Ensuring full engagement or participation of all the stakeholders affected by the disaster with resolving their resource tenure issues;
- Addressing issues of politics and governance at all levels from local to regional or international;
- Investing in disaster risk reduction can reduce vulnerability;
- Fixing target can stimulate the investments in disaster risk reduction;
- Managing ecosystem, planning land-use and controlling supply chain have the potential to reduce exposure;
- Providing a clear expression of the ground for including biodiversity conservation (Photograph 6);
- Using innovative technologies that offer new possibilities to reduce the exposure of vulnerability and disaster risk, and so on.

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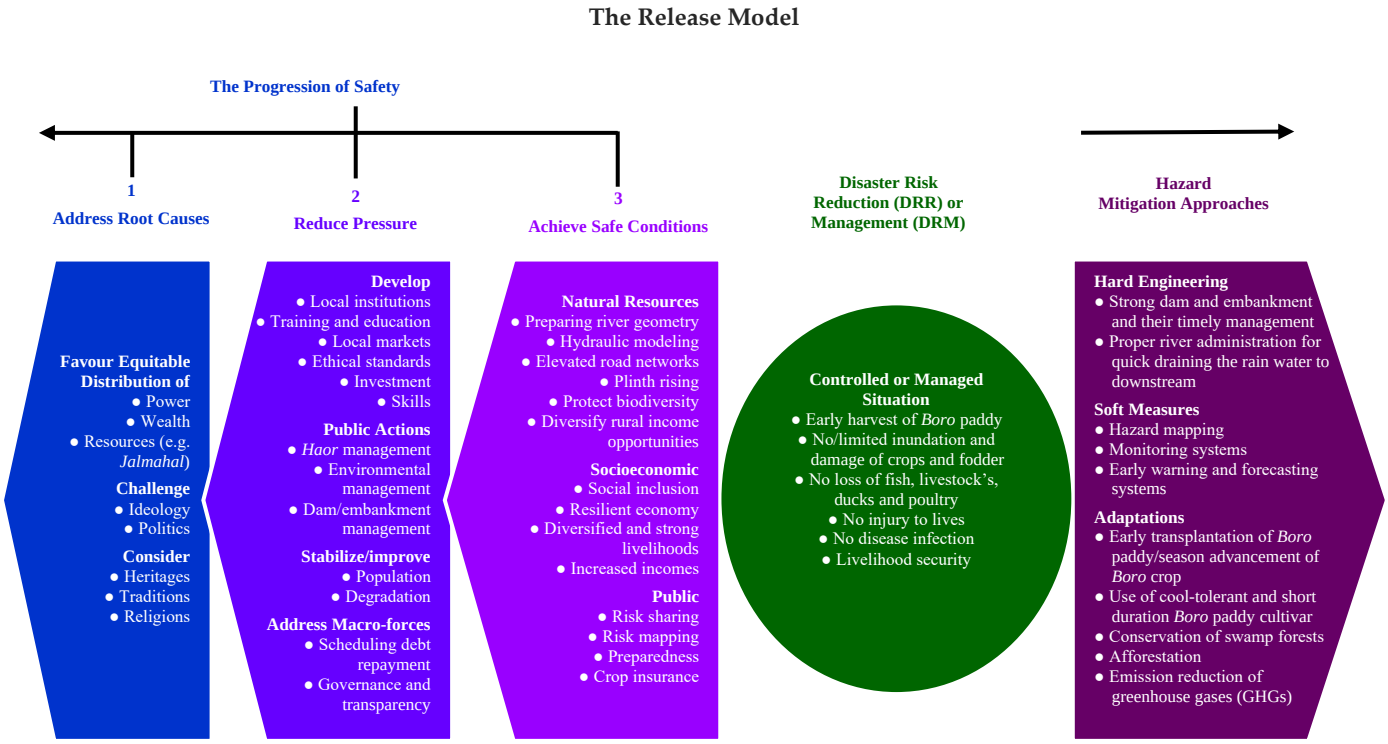

Figure 4. The Release model to escape or manage flood disaster in *haor* areas of Bangladesh. Modified from Wisner et al. (2003).

Photograph 6. A panoramic view of a swamp forest (with water tolerant trees) in *haor* area during dry season. Photo Credit: Author.

4. CONCLUSION

The pressure model for triggering a disaster risk in *haor* areas due to flood shocks has been constructed with identifying the essential causal drivers both at proximal and distant ends. Climate change may increase with time, intensifies the hazard situation further. A number of drivers have been pinpointing which act as pressure relievers for effective hazard mitigation planning. Not all drivers should have to practice right now but the planners can categorize the determinants as for perform immediate actions, short and medium term measure and long term planning. For example, hazard mapping that mostly delivers a 'snapshot' of flood risk at an impact area in time. Cultivation of existing short duration *Boro* paddy variety like BRRI Dhan28 and its early plantation can be adopted as short-term planning while innovation of cool-tolerant with short life span *Boro* cultivar can be considered as medium term planning. Early flood warning and forecasting system can be scaled to short term (within 2 to 3 days), medium term (up to 10 years) and longer term planning (up to 1000 years). Short-term risk mitigation refers to emergency response (pre-preparedness) measure aimed to minimize the consequences of a disaster. For successful management of a disaster full

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participation of all categories of stakeholders are needed. The findings can be used by the policy makers, researchers, crop growers, and so on to manage or reduce the impacts of a disaster triggered by the early flash flood shock in *haor* areas of Bangladesh.

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Ethical approval

Not applicable.

Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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