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Selection of damage prone area induced by a cyclone in Indian subcontinent: Dominance rule based approach in neutrosophic arena

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Abstract: In recent year, there was occurred a number of cyclonic storms in several countries adjacent to ocean and sea in Indian subcontinent resulting the devastating impact in social life and atmosphere. The basic motivation of this attempt is to set a mathematical framework to predict the severity of damage occurred by a cyclone likely to be blown over an area under this region. It will assist the administration, responsible authority and the concerned residents to be alert to make some prior manipulations to combat strongly with the post storm period. The entire work consists of two key parts. First part talks about a number of relevant parameters which affect the prediction mostly. But due to incomplete and imprecise information, this prediction may be uncertain by nature. So in second part, the possible damage of an area is characterized categorically in the parlance of the set of parameters considered here, and this characterization is explored by neutrosophic soft set in order to look after the indeterminacy and inconsistency of decision makers in setting of data more precisely. Based on the subjection and domination rule of parameters, the methodology is furnished. An efficient algorithm is designed for that, and it is demonstrated practically. A strong validation is drawn after performing the rigorous analysis of outcome on existing frames.

Key words: Neutrosophic soft set; Wind speed; Domination rule; Storm disaster.

1. Introduction

With the passage of time, there is a noteworthy advancement of human civilization with the development of science and technology. The life style of mankind has changed significantly and it goes towards in a progressive state. This situation demands a strong financial requirement and it calls upon the utilization of natural resources in unsustainable ways. Then our environment's stability is being degraded and its impact is being seen rudely. Raising emission level of carbon dioxide and other greenhouse gases in the atmosphere through the burning of fossil fuels and other human activities increase the temperature globally: the surface of land, sea, and entire environment. Thus the climate of Earth is being changed, and this may call a possibility to alter the numbers, intensity, or paths of tropical cyclones worldwide. Also different kinds of natural calamities occur frequently in recent time, and it is till out of capability of human beings to control and resist these. We can only take the precautions and build up the post disaster management in a proficient manner from our past experiences.

Several studies in that concern have been conducted by the researchers. The natural disasters caused by severe winds and related events may result around 80% of economic losses [38]. Tropical cyclones in the period 2000-2017 led to an approximate loss of 946 billion US dollars across the world and it was the one-third of all natural hazard-induced damages [24]. Regarding the spoil of economy, personnel, infrastructure and ecosystems caused by storm related disaster, numerous discussions have been explored in the studies [15, 16, 37]. Studies

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regarding the wind-induced physical damage, infrastructure damage have considered in the works [13, 19, 20]. Along with the housing smash up, subjects like casualties, resettlement, and post-disaster reconstruction are also great concern [7, 42]. According to Olsen et al. [27], the improper management in post disaster state may call an unstable impact in a country's political and social structure, and then its international relationship and security may be volatile. The role of three distinct subjects: hazards, exposure and vulnerability have been examined in topical cyclone risk assessment by researchers [12, 22, 26, 28, 32, 43]. Topical cyclone hazards, in majority of research papers [11, 25, 34] are characterized by high wind speed. But some recent investigations [2, 41] and more have found a significant role of cyclone induced rainfall for that. In the present time, global warming is a burning issue and mainstream subject to be considered greatly while discussing the nature of cyclonic storm. It has a massive impact on the frequency of occurrence, hazards and track migration of cyclone in a region. Several research and findings [14, 17, 18, 36] have come up to that intensity, and variations of cyclone will increase worldwide whatever its frequency will be (it may be decreased or remain constant). Changnon et al. [5], Pielke [29], Schmidt et al. [33, 34], Geiger et al. [11] and more others have focused on the detection and attribution of cyclone damage of socioeconomic development.

Majority of the relevant literatures have been built up on crisp data setting. Once the fact (here natural disaster) occurs, we can have in hand the clear picture of calamities. The subsequent demolition is then assessed by inspecting the affected area. But decision making in advance in that context is always based on the observed data gathered from the multiple number of past events and these may not be exact. So, usually there appears inconsistencies and indeterminacies in setting of experimental data i.e., the subject is completely uncertain. But there does not exist any framework or tool that can integrate all facets of humanitarian need while measuring various natural disasters [44]. Hence on quantifying the disaster, it is a challenge to deal the inconsistencies to stake holders by formulating legislation and policies responding to the disaster [44]. Probability theory, a constructive mathematical tool, may be used in that concern, but it is an age old, applied on random process and is based on crisp set theory. Also Zadeh's Fuzzy set (FS) [45] theory and Attanasov's Intuitionistic fuzzy set (IFS) [1] theory dealing this fact have some limitations by their structural features. Both FS and IFS only tell about the incomplete information, not indeterminate independently. That is why, the real facts like sport event, decision making, casting of poll by an elector etc directing tri-components outcome can not be duly explored by FS, IFS. In realistic approach, between acceptance and rejection, there may be a neutral state. Comprehending this reality and to overcome the barrier of previous developments, Smarandache [35] brought the notion of Neutrosophic set theory (briefly, NtS theory) which describes an phenomenon by three independent directions *viz.* truth, indeterminacy and falsity. But characterization of an object or a decision in real application by applying crisp, FS, IFS, NtS theory etc undergoes to the parametrization inadequacy syndrome. This problem can be efficiently handled by use of Soft set theory [23]. The Neutrosophic soft set (briefly, Nss) theory was appeared when Maji [21] has initially combined NtS and Soft set theory, and it was later redefined by Deli and Broumi [8]. Linear programming based decision making approaches over NtS and FS were built up in the literatures [3, 4, 30].

The countries belonging to ASEAN (The Association of Southeast Asian Nations) and SAARC (South Asian Association for Regional Committee) have suffered severely from a number of tropical storms and cyclones in recent years. India, in its geographical situation, suffers much from that. The states West Bengal, Odisha, etc located in the coast of Bay of Bengal and Kerala, Gujarat, etc in the coast of Arabian sea are mostly vulnerable to cyclonic impact. A list of cyclonic storms, not limited, Aila (super cyclone in the year 2009), Bulbul (very severe cyclone in 2019), Amphan (extremely severe cyclone in 2020), Yaas (very severe cyclone in 2021), Mandous (very severe cyclone in 2022), Dana (very severe cyclone in 2024) generated from Bay of Bengal and Hikka (very severe cyclone in 2019), Nisarga (severe cyclone in 2020), Tauktae (extremely severe cyclone in 2021), Biparjoy (extremely severe cyclone in 2023) born from Arabian sea caused the impact to a severe extent like damages to infrastructure and houses, uproots trees, unprecedented floods, spoil of vegetation and casualties, and thus made an immense beat to the overall economy of India very often. Bangladesh, the neighbour country of India, also suffers much from the tropical storms and cyclones born from Bay of Bengal almost throughout the year. Hence if it is possible to assess the damage or to develop the effect of cyclone after landfall on an area in advance, then it will help the administration, responsible authority and concerned residents to be prepared or to arrange the management group properly to rescue, control and overcome the post disaster situation in a fast hand.

The present study designs a decision making approach to predict the severity of damage to be occurred by a storm disaster in a certain area. The study initially seeks the relevant parameters affecting the prediction mostly. Then an area to be affected by the storm is characterised in the parlance of described parameters. The corresponding data capture is based on the multiple number of previous experiences, and so these may be incomplete and imprecise information. As a whole, the prediction is uncertain by nature. The experimental data are designed using Nss in order to take care of the indeterminacy and inconsistency of a decision properly along with the reflection of parametrization competence. The methodology is based on the subjection and domination rule of parameters adopted for decision making. An efficient algorithm is furnished for that, and the proposed method is demonstrated practically. The study is organised as follows:
After remembering some existing definitions in Section 2, the study moves to Section 3 to define relevant parameters, its features to be integrated in the present decision making approach. Then some necessary definitions, mathematical formulation and a suitable decision making algorithm are developed in Section 4. Section 5 brings a practical demonstration of the proposed methodology. Its outcome is also analyzed rigorously and the validity of proposed work is sought after comparing the outcome with the existing techniques. Finally, a summary of entire study along with its limitation, future aspects are stated in Section 6.

2. Preliminary results

Here, we shall recall some existing definitions to buildup the present study.

Definition 2.1. [35] An NtS M defined over the universe X characterises an object x by three independent components: truth T_M, indeterminant I_M and falsity F_M for $T_M, I_M, F_M : X \to]^-0, 1^+[$. The representation of M is: $\{< x, (T_M(x), I_M(x), F_M(x)) >: x \in X\}$ with $^-0 \leq \sup T_M(x) + \sup I_M(x) + \sup F_M(x) \leq 3^+$. The non-standard set $]^-0, 1^+[$ is used in philosophical subjective. But as it has no domain in real life state, so the standard subset [0,1] of $]^-0, 1^+[$ is used in real neutrosophic environment.

If three components T_M, I_M and F_M of an NtS M are members of $[0, 1]$ only, then M is called a single valued NtS. Then the above inequality is relaxed to the form $0 \leq T_M(x) + I_M(x) + F_M(x) \leq 3$.

Definition 2.2. [23] Let X be a universal set and E be a set of parameters. Let $\wp(X)$ be the power set of X. Then the pair (F, A) is called a soft set over X for $A \subseteq E$ and $F : A \to \wp(X)$.

Definition 2.3. [8] An Nss is denoted by a pair (f_M, A) or simply by M_A and is defined by a mapping $f_M : A \to NS(X)$ for $A \subseteq E$ (E being the set of parameters) and $NS(X)$ be the set of all NtSs over X. The set theoretic design of an Nss is given by:

$$\begin{aligned} & \{(e, f_M(e)) : e \in A\} \\ = \quad & \{(e, \{< x, T_{f_M(e)}(x), I_{f_M(e)}(x), F_{f_M(e)}(x) >: x \in X\}) : e \in A\} \end{aligned}$$

for $T_{f_M(e)}(x), I_{f_M(e)}(x), F_{f_M(e)}(x) \in [0,1]$, respectively called the truth, indeterminacy, falsity membership function of $f_M(e)$ with holding the inequality $0 \leq T_{f_M(e)}(x) + I_{f_M(e)}(x) + F_{f_M(e)}(x) \leq 3$. Each $f_M(e)$ is called an NtS over X.

Definition 2.4. [3] Let P be an NtS over the universal set X. Then (α, β, γ) -cut of P is denoted by $P_{(\alpha,\beta,\gamma)}$ and it is defined as: $P_{(\alpha,\beta,\gamma)} = \{x \in X : T_P(x) \geq \alpha, I_P(x) \leq \beta, F_P(x) \leq \gamma\}$ for $\alpha, \beta, \gamma \in [0,1]$ with $0 \leq \alpha + \beta + \gamma \leq 3$. Clearly, it is a crisp subset X. Here $P_{(\alpha,\beta,\gamma)}$ is called (α, β, γ)-level set or (α, β, γ)-cut set of the NtS P.

Definition 2.5. [8] Let, P_A and Q_A be two Nss over the pair of universe (X, A) for $A \subseteq E$, E being the set of parameters. Then P is a neutrosophic soft subset of Q, if $T_{f_P(e)}(x) \leq T_{f_Q(e)}(x)$, $I_{f_P(e)}(x) \geq I_{f_Q(e)}(x)$, $F_{f_P(e)}(x) \geq F_{f_Q(e)}(x)$; $\forall e \in A$ and $x \in X$. It is executed by $P_A \widetilde{\subseteq} Q_A$ and then Q_A is the neutrosophic soft superset of P_A.

3. Parameters used for prediction

In this section, a number of relevant parameters are taken into consideration to carry out the decision making approach proposed in the present study and their categorical effects regarding that are talked about.

Wind speed (e_1): When the atmospheric pressure between two areas differs, then wind flows from high pressure to low pressure areas to make a balance between them. The greater the pressure difference is, faster the wind is. And there is always a risk of severe damages of life and property from a peak wind speed. Following Table 1 provides a classification of storm along with their impacts on landfall formulated by Indian Meteorological Department (IMD) and it is also adopted by World Meteorological Organization (WMO). Sometimes a storm having lower scale of wind speed may cause a bad effect beyond belief and it depends over which area the storm blows.

Table 1. Classification of storm & their impacts.

Wind speed	Category	Wind speed	Damage at landfall
31-49 km/h	Depression	119-153 km/h	Minimal
49-61 km/h	Deep depression	154-177 km/h	Moderate
61-88 km/h	Cyclonic storm	178-210 km/h	Extensive
88-117 km/h	Severe cyclone	211-250 km/h	Extreme
118-165 km/h	Very severe cyclone	> 250 km/h	Catastrophic
166-220 km/h	Extremely severe cyclone		
> 221 km/h	Super cyclone		

There are two important subjects *viz.* atmospheric temperature and percentage of humidity in an area depending on which the possibility of storm to be blown across that. Areas where the air is warmed often have lower pressure because the warm air rises. Further the humidity is higher in low pressure because lower pressure allows the air mass to hold more amount of water in high altitudes. Before occurring of storm, existing wind speed in a low pressure area is lower, and it causes maximum evaporation of water and so high humidity occurs. Reverse situation is seen in an area with high pressure. Thus in order to measure the degree of probable wind speed and its effect on damage, experts will have to follow the atmospheric temperature and percentage of humidity in a concerned area based on past records.

Duration of strong wind (e_2): The damage is caused by a storm not only depending on the peak wind speed, but the duration of strong wind blown also plays an active role in that. For an extended period of time, if the wind blows in a peak level, then fluctuating wind pressure, flying debris, wind-driven rain, falling trees contribute to damage when properties and life are exposed to the storm. Any building or any structure is made with the connection of different building components, for instance roof to wall link, connection of window frame to lineton of a house, standing of electric pole on earth or tie of trees' root in soil etc. Fluctuating wind load over a long period in continuous way may cause fatigue in these links. Wind storm persists in long duration because of two basic reasons: (1) high atmospheric pressure difference across a region and (2) blowing of strong jet-stream winds overhead. Like a vacuum cleaner, the jet stream sucks air out of the top and causes it to become more intense, lowering the pressure system for an area. Then wind becomes stronger due to low pressure within a system. So to predict the possible damage to be caused by a storm in a region, experts have to cultivate these two factors from the past evidence.

Accumulated rainfall during and after landfall (e_3): It is natural to occur rain fall during and after landfall of storm blown over a region. Heavy and prolonged rains cause floods in rivers and in low land area which cause submergence of the nearby locality and residential area, erosion of agricultural field, destruction of properties and loss of lives, prevalence of vector and water born diseases. Hence we need to study the mean height of land's surface in the region as well as the past data concerning the damage caused by a storm.

Distance from landfall (e_4): By nature, coastal areas are greatly exposed to landfall of storm. When a storm makes landfall, it becomes weaken over land as it is cut off from its primary energy source (i.e., supply of evaporated water from oceans). As the storm moves towards inland, its velocity gradually decreases due to frictional differences between water and land with the free atmosphere. Moreover bushes, trees, buildings, any natural altitude etc also make some obstacles in the progressive movement of storm. Thus coastal areas are vulnerable to maximum damage from a storm as compared to inland. As the distance of a region from landfall increases, it is expected to occur a lesser damage.

Population density (e_5): Areas with dense population are at a high risk for damage from a storm to be blown across that. Because of crowd residence, electric line and poll, different construction, there may be always a chance to occur an accidental damage. In rural area, it will be more severe for the huge presence of trees, earthen hut, agricultural field etc.

Development of area (e_6): The degree of damage caused by a storm in a region also depends on the areal development materialised so far. In rural areas, light structures of house such as wooden frame, aged structures, and buildings with low quality materials are generally seen. These types of housing are likely to be damaged by tropical storm, cyclone etc. Height and area of buildings are another two important factors as severe damage occurs mostly in case of larger or taller houses. Furthermore, it is seen to have big trees nearby houses or on the road side in village area. There is always a high risk of falling either its branches or the full tree on the house or on the vehicles and pedestrians passed by the road, and thus a serious damage of house and injury of residents, even the casuality occurs. But in a village surrounded by larger water area, houses suffer less damage therein.

In urban areas, though good quality housing generally exists, but high building density and active electric posts are mostly seen. These structures obstruct the natural flow of wind. It calls spoil on different structures of houses exposed to storm e.g., window, temporary roof setting by light materials etc along with its interior portion. Moreover, due to lack of good water drainage system, accumulated rainfall during and after landfall of storm results in a tough impact in social life. Disruption of essential subjects like health care, power supply, water supply, sanitation, transportation and communication services are terribly impacted. High-speed wind also often destroy deadly flying projects, key bridges, overpasses etc. Then there is always a high risk of happening accident, loss of life, collapse of transportation system.

Communication links and health care (e_7): The calamity of a storm is greatly seen in post disaster period. It causes the damage of houses, buildings, and various infrastructures like key bridges, overpasses, and roads. These may disrupt transportation, power, and communication services. Then society suffers a vital communication gap. In coastal area and hill region, there is a high possibility to be flooding and landslides. Rescue efforts are hampered greatly. Transportation and supply of food, drinking water, medicine, cloths etc needed to the residential of affected area in earliest mode becomes very complicate. As a result health and hygiene system is lost. Also, disruption of power supply brings a collapse on tape water supply. People are forced to use pond water for bathing, cleaning of kitchen utensils and other concerns. Pond water becomes blackish and polluted due to fallen trees and leaves. All these lead to water contamination and spread of diseases. Moreover medical facility may be out of reach to the people. So experts should consider the existing status of communication links and health care system of the respective area.

Agricultural area (e_8): When the storm is blown over an area covering agriculture fields, it makes a damage to a great extent to seasonal crops, vegetables, flowers etc. This leads to loss of investment on agriculture, shortages in food supply and thus push back the overall economy of respective society significantly. In coastal area, if seawater enters in the low-lying fields, then it hammers the life and property severely. Moreover the fertility of soil by that is reduced too much, and it results a long term challenging issue in agriculture and farming. Hence decision makers should be sincere in that respect while pre-quantifying the damage of an area by storm disaster.

Proposition 3.1. *(Categorical effect of individual parameter in disaster)*
The parameters taken here to measure the disaster at a spot are interrelated by nature as studied above. Hence it is tough to determine the impact of parameter individually on a disaster. But to bring a flexibility in the development of methodology for finding the entire impact of a disaster, a categorical representation of individual parameter and its post cyclonic effect is outlined in the Table 1,2,3,4,5,6. The scale set here bears the mean degree of devastation in term of NtS following some previous happenings in Indian subcontinent (pointed out in Introduction).

Table 2. Category and average effect of parameter e_1.

< 50km/h	50-70	70-90	90-110	110-130	130-150	150-170	> 170km/h
(.28,.72,.75)	(.42,.58,.57)	(.55,.50,.52)	(.62,.48,.44)	(.70,.40,.39)	(.75,.35,.36)	(.87,.28,.30)	(.93,.20,.25)

Table 3. Category and average effect of parameter e_2.

Speed ↓	< 20mins	20-45	45-60	60-75	75-100	100-120	> 120mins
< 60km/h	(.15,.80,.85)	(.25,.75,.78)	(.30,.70,.70)	(.35,.65,.62)	(.46,.58,.56)	(.52,.50,.50)	(.58,.42,.48)
60 − 90	(.25,.75,.80)	(.30,.70,.72)	(.35,.65,.66)	(.40,.60,.58)	(.50,.53,.52)	(.57,.44,.47)	(.65,.38,.42)
90 − 120	(.35,.72,.75)	(.40,.64,.62)	(.45,.58,.56)	(.50,.55,.50)	(.60,.50,.46)	(.65,.42,.40)	(.75,.32,.37)
120 − 150	(.45,.68,.60)	(.50,.62,.55)	(.55,.52,.50)	(.60,.48,.46)	(.65,.42,.40)	(.75,.35,.36)	(.82,.25,.32)
> 150km/h	(.55,.58,.54)	(.60,.52,.50)	(.65,.48,.43)	(.70,.44,.40)	(.77,.40,.38)	(.85,.30,.33)	(.92,.20,.25)

VL(Very Low), L(Low), M(Moderate), H(High), VH(Very High), BW(Backward), AV(Average), G(Good),

Table 4. Category and average effect of parameter e_4.

< 15km	15-30	30-50	50-80	80-110	110-150	150-200	> 200km
(.92,.18,.24)	(.86,.25,.30)	(.78,.30,.35)	(.66,.35,.40)	(.52,.48,.57)	(.45,.60,.68)	(.30,.70,.75)	(.20,.80,.85)

Table 5. Category and average effect of parameter e_5.

$< 200/km^2$	200-300	300-450	450-650	650-850	850-1100	$> 1100/km^2$
(.20,.80,.75)	(.30,.75,.70)	(.40,.70,.65)	(.45,.65,.60)	(.55,.60,.55)	(.65,.55,.50)	(.70,.50,.45)

Table 6. Category and mean effect of parameters e_3, e_6, e_7, e_8.

Land's surface (e_3)	e_6	e_7	e_8
VL (.80,.25,.30)	BW (.88,.28,.30)	MG (.90,.30,.30)	VL (.28,.50,.80)
L (.65,.30,.45)	AV (.74,.38,.42)	AV (.80,.40,.38)	L (.35,.46,.75)
M (.50,.45,.55)	M (.62,.44,.53)	M (.60,.50,.48)	M (.45,.40,.60)
H (.30,.60,.70)	G (.45,.52,.62)	G (.48,.60,.65)	H (.70,.32,.40)
VH (.20,.70,.85)	VG (.36,.60,.68)	VG (.38,.70,.74)	VH (.82,.25,.30)

VG(Very Good), MG(Meager).

4. Proposed methodology

Here a methodology to reckon the state of damage by a cyclone disaster in an area is build up mathematically. The approach to be proposed is driven over neutrosophic atmosphere to look after the data handling in a complete manner.

Proposition 4.1. *(Domination and subjection rule)*
For a pair of objects, these two rules evaluate how an object dominates over another with respect to an attribute. Suppose the neutrosophic assessment of two objects x, y with respect to an attribute e are:

$$< x, T_{f_{M(e)}}(x), I_{f_{M(e)}}(x), F_{f_{M(e)}}(x) > \text{ and } < y, T_{f_{M(e)}}(y), I_{f_{M(e)}}(y), F_{f_{M(e)}}(y) >$$

Then the dominating and subjective functions for the object x over y with respect to e are respectively denoted by $\overline{\lambda}(x,y)$, $\underline{\lambda}(x,y)$ and are defined as:

$$\overline{\lambda}(x,y) = \{e : T_{f_{M(e)}}(x) \geq T_{f_{M(e)}}(y), I_{f_{M(e)}}(x) \leq I_{f_{M(e)}}(y), F_{f_{M(e)}}(x) \leq F_{f_{M(e)}}(y)\}$$
$$\underline{\lambda}(x,y) = \{e : T_{f_{M(e)}}(x) \leq T_{f_{M(e)}}(y), I_{f_{M(e)}}(x) \geq I_{f_{M(e)}}(y), F_{f_{M(e)}}(x) \geq F_{f_{M(e)}}(y)\}$$

Proposition 4.2. *(Mathematical formulations)*
Suppose a region consisting k number areas $x_1, x_2, \cdots, x_k$ will be hit by a cyclonic storm as per the weather office's forecast. The administration then takes some initiatives at once to protect the residents, and get ready to arrange the rescue teams and other respective professionals to overcome the post disaster troubles in a rapid hand. But it will be helpful to administrate the entire operation by gathering the responsible team in a specific area if the possible effect corresponding to that area is well-informed. To accomplish this job, the possible damage of each area $x_i : 1 \leq i \leq k$ is personified in virtue of eight parameters stated above. Thus the planned configuration is a multi attribute decision making (MADM) framework. Each entry corresponding to an area and its attributes are taken as NtS. These are built from the information regarding categorical effect of parameters (see Table 1-6)

by an expert appointed. Now it may happen that either a specific attribute remains undecided or for it, no any information could be collected whatsoever. In such situation, this attribute has to be done away with. Suppose Table 7 represents the analogous MADM frame.

Table 7. MADM frame of decision making approach.

	e_1	e_2	$\cdots$	e_8
x_1	(T_{11}, I_{11}, F_{11})	(T_{12}, I_{12}, F_{12})	$\cdots$	(T_{18}, I_{18}, F_{18})
x_2	(T_{21}, I_{21}, F_{21})	(T_{22}, I_{22}, F_{22})	$\cdots$	(T_{28}, I_{28}, F_{28})
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
x_k	(T_{k1}, I_{k1}, F_{k1})	(T_{k2}, I_{k2}, F_{k2})	$\cdots$	(T_{k8}, I_{k8}, F_{k8})

where $(T_{k8}, I_{k8}, F_{k8}) = \{T_{f_M(e_8)}(x_k), I_{f_M(e_8)}(x_k), F_{f_M(e_8)}(x_k)\}$ *and others for the Nss* M. *Let us now extend the concept of dominating and subjective function for a pair of areas* $(x_i, x_j), i \neq j$ *with respect to the attributes* $e_m, 1 \leq m \leq 8$ *as follows:*

$$\overline{\lambda}(x_i, x_j) = \{e_m : T_{f_M(e_m)}(x_i) \geq T_{f_M(e_m)}(x_j), I_{f_M(e_m)}(x_i) \leq I_{f_M(e_m)}(x_j), F_{f_M(e_m)}(x_i) \leq F_{f_M(e_m)}(x_j)\}$$

$$\underline{\lambda}(x_i, x_j) = \{e_m : T_{f_M(e_m)}(x_i) \leq T_{f_M(e_m)}(x_j), I_{f_M(e_m)}(x_i) \geq I_{f_M(e_m)}(x_j), F_{f_M(e_m)}(x_i) \geq F_{f_M(e_m)}(x_j)\}$$

Thus the functions for a pair of areas x_i, x_j *are clearly a collection of attributes satisfying the specified inequalities. Or in other words, the area* x_i *executes supremacy and inferiority over the area* x_j *for which of attributes. Now for a definite area, say* x_k, *we shall find the cardinality* $|,|$ *of* $\overline{\lambda}$ *for all* $x_i : 1 \leq i \leq k$ *and then take their sum* $\overline{\zeta}$. *Similar approach will be taken for* $\underline{\lambda}$ *and also their sum* $\underline{\zeta}$ *for* x_k. *Sometimes, it may happen that the nature of any two areas is almost equal concerning to one or more attributes. To emphasize this in the present decision making, we shall take the intersection of* $\overline{\lambda}$ *and* $\underline{\lambda}$. *Then we shall calculate for each area* $x_i : 1 \leq i \leq k$,

$$\overline{\zeta}(x_i) = \sum_{x_j} |\, \overline{\lambda}(x_i, x_j) \,|, \quad \underline{\zeta}(x_i) = \sum_{x_j} |\, \underline{\lambda}(x_i, x_j) \,|,$$

$$\xi(x_i) = \sum_{x_j} |\, \overline{\lambda}(x_i, x_j) \cap \underline{\lambda}(x_i, x_j) \,|$$

Finally, the degree of damage of each area from a storm cyclone is evaluated as:

$$\Upsilon(x_i) = \frac{\overline{\zeta}(x_i)}{\underline{\zeta}(x_i)} \times \xi(x_i) \quad for \quad 1 \leq i \leq k$$

Proposition 4.3. *(Decision making algorithm)*
The proposed methodology is now sketched by the following steps.
Step 1: Fix the areas for which the prediction of damage will be done.
Step 2: Design the Nss table by the opinion of an expert based on the data appearing in the Table 1-6.
Step 3: Apply domination rule for parameters to calculate $\overline{\lambda}(x_i, x_j)$ *for all areas.*
Step 4: Apply subjection rule for parameters to calculate $\underline{\lambda}(x_i, x_j)$ *for all areas.*

Step 5: Find $\overline{\zeta}(x_i)$ *for all areas i.e., the sum of cardinality of all* $\overline{\lambda}(x_i, x_j)$.

Step 6: Find $\underline{\zeta}(x_i)$ *for all areas i.e., the sum of cardinality of all* $\underline{\lambda}(x_i, x_j)$.

Step 7: Find $\xi(x_i)$ *for all areas i.e., the sum of cardinality of all* $\overline{\lambda}(x_i, x_j) \cap \underline{\lambda}(x_i, x_j)$.

Step 8: Calculate $\Upsilon(x_i) = \frac{\overline{\zeta}(x_i)}{\underline{\zeta}(x_i)} \times \xi(x_i)$ *and find the final score of each area.*

Step 9: The maximum score indicates the major disaster and the least score indicates the lowest disaster.

Step 10: If tie occurs in the score of some areas, then these areas have same disaster.

5. Demonstration of proposed methodology

This section provides a demonstration of planned technique for decision making to find its efficiency.

Example 5.1. *A study is conducted to find the impact of a severe cyclonic storm to be arisen from an ocean over some areas in a country of Indian subcontinent adjacent to that ocean. Let us consider five areas* x_1, x_2, x_3, x_4, x_5 *likely to be affected from that cyclone. Following Table 8 provides the damage prediction level of five areas in term of NtS with respect to the eight attributes stated in Section 3. All the entries of Table 8 are adopted from the information of Table 2-6 and is bearing to uncertain state to perform a prediction based on a number of previous happenings.*

Table 8. Prediction of damage in term of Nss.

X	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8
x_1	(.55,.50,.52)	(.65,.38,.42)	(.80,.25,.30)	(.52,.48,.57)	(.55,.60,.55)	(.45,.52,.62)	(.38,.70,.74)	(.82,.25,.30)
x_2	(.87,.28,.30)	(.55,.58,.54)	(.65,.30,.45)	(.86,.25,.30)	(.30,.75,.70)	(.74,.38,.42)	(.90,.30,.30)	(.28,.50,.80)
x_3	(.42,.58,.57)	(.57,.44,.47)	(.30,.60,.70)	(.45,.60,.68)	(.65,.55,.50)	(.36,.60,.68)	(.48,.60,.65)	(.45,.40,.60)
x_4	(.70,.40,.39)	(.50,.62,.55)	(.80,.25,.30)	(.78,.30,.35)	(.40,.70,.65)	(.88,.28,.30)	(.80,.40,.38)	(.35,.46,.75)
x_5	(.62,.48,.44)	(.50,.55,.50)	(.20,.70,.85)	(.66,.35,.40)	(.70,.50,.45)	(.45,.52,.62)	(.60,.50,.48)	(.70,.32,.40)

Table 9 represents the domination of an area over remaining four others in perspective of eight parameters and its sum of cardinality.

Table 9. $\overline{\lambda}(x_i, x_j)$.

$\overline{\lambda}$	x_1	x_2	x_3	x_4	x_5	$\overline{\zeta}(x_i)$
x_1	A	$\{e_2, e_3, e_5, e_8\}$	$\{e_1, e_2, e_3, e_4, e_6, e_8\}$	$\{e_2, e_3, e_5, e_8\}$	$\{e_2, e_3, e_6, e_8\}$	26
x_2	$\{e_1, e_4, e_6, e_7\}$	A	$\{e_1, e_3, e_4, e_6, e_7\}$	$\{e_1, e_2, e_4, e_7\}$	$\{e_1, e_2, e_3, e_4, e_6, e_7\}$	27
x_3	$\{e_5, e_7\}$	$\{e_2, e_5, e_8\}$	A	$\{e_2, e_5, e_8\}$	$\{e_2, e_3\}$	18
x_4	$\{e_1, e_3, e_4, e_6, e_7\}$	$\{e_3, e_5, e_6, e_8\}$	$\{e_1, e_3, e_4, e_6, e_7\}$	A	$\{e_1, e_3, e_4, e_6, e_7\}$	27
x_5	$\{e_1, e_4, e_5, e_6, e_7\}$	$\{e_5, e_8\}$	$\{e_1, e_4, e_5, e_6, e_7, e_8\}$	$\{e_2, e_5, e_8\}$	A	24

Table 10 represents the subjection of an area over others in perspective of deciding parameters and its sum of cardinality.

Table 10. $\underline{\lambda}(x_i, x_j)$.

$\underline{\lambda}$	x_1	x_2	x_3	x_4	x_5	$\underline{\zeta}(x_i)$
x_1	A	$\{e_1, e_4, e_6, e_7\}$	$\{e_5, e_7\}$	$\{e_1, e_3, e_4, e_6, e_7\}$	$\{e_1, e_4, e_5, e_6, e_7\}$	24
x_2	$\{e_2, e_3, e_5, e_8\}$	A	$\{e_2, e_5, e_8\}$	$\{e_3, e_5, e_6, e_8\}$	$\{e_5, e_8\}$	21
x_3	$\{e_1, e_2, e_3, e_4, e_6, e_8\}$	$\{e_1, e_3, e_4, e_6, e_7\}$	A	$\{e_1, e_3, e_4, e_6, e_7\}$	$\{e_1, e_4, e_5, e_6, e_7, e_8\}$	30
x_4	$\{e_2, e_3, e_5, e_8\}$	$\{e_1, e_2, e_4, e_7\}$	$\{e_2, e_5, e_8\}$	A	$\{e_2, e_5, e_8\}$	22
x_5	$\{e_2, e_3, e_6, e_8\}$	$\{e_1, e_2, e_3, e_4, e_6, e_7\}$	$\{e_2, e_3\}$	$\{e_1, e_3, e_4, e_6, e_7\}$	A	25

Table 11 represents the intersection of domination and subjection of an area over others in perspective of deciding parameters and its sum of cardinality.

Table 12 provides the final score (taking upto two decimal places) of different areas susceptible to the damage on storm disaster.

Table 11. $(\overline{\lambda} \cap \underline{\lambda})(x_i, x_j)$.

$(\overline{\lambda} \cap \underline{\lambda})(x_i, x_j)$	x_1	x_2	x_3	x_4	x_5	$\xi(x_i)$
x_1	A	$\{\phi\}$	$\{\phi\}$	$\{e_3\}$	$\{e_6\}$	10
x_2	$\{\phi\}$	A	$\{\phi\}$	$\{\phi\}$	$\{\phi\}$	8
x_3	$\{\phi\}$	$\{\phi\}$	A	$\{\phi\}$	$\{\phi\}$	8
x_4	$\{e_3\}$	$\{\phi\}$	$\{\phi\}$	A	$\{\phi\}$	9
x_5	$\{e_6\}$	$\{\phi\}$	$\{\phi\}$	$\{\phi\}$	A	9

Table 12. Final score $\Upsilon(x_i) = \frac{\overline{\zeta}(x_i)}{\underline{\zeta}(x_i)} \times \xi(x_i)$.

	x_1	x_2	x_3	x_4	x_5
$\Upsilon(x_i)$	10.83	10.29	4.8	11.05	8.64

Hence the order of area susceptible to damage is: $x_3 < x_5 < x_2 < x_1 < x_4$ *and so the supreme attention and management should have to be paid on the area* x_4.

Proposition 5.1. *(Analysis of outcome)*
We have viewed multiple points in the numerical execution part.
(i) *The Table 8 does not support Intuitionistic fuzzy atmosphere. Because the sum of truth and falsity values arisen in almost every pairs* (x_k, e_m) *are greater than 1. Thus data setting in NtS is reliable, flexible and generalisation than IFS.*
(ii) *If the proposed approach is run over FS, it is seen at a glance that the area* x_4 *dominates over the area* x_5 *based on the parameter* $\{e_1, e_2, e_3, e_4, e_6, e_7\}$. *But* e_2 *has been excluded in Table 4 and so the entire outcome over NtS may be a refinement of FS. A detail comparison regarding that issue is performed in Section 5.3.*
(iii) *The nature of area* x_1 *is similar to the area* x_4, x_5 *with respect to the parameter* e_3, e_6 *respectively as seen in Table 11. The matter is obvious also from the data setting appears in the Table 8.*

Proposition 5.2. *(Comparison with existing techniques)*
Here, we shall apply the proposed technique in fuzzy environment and also evaluate its supremacy over existing techniques.
(i) Outcome in fuzzy environment: *The reduced form of Table 8 by taking only fuzzy membership values is presented by Table 13.*

Table 13. Prediction of damage in fuzzy.

X	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8
x_1	0.55	0.65	0.80	0.52	0.55	0.45	0.38	0.82
x_2	0.87	0.55	0.65	0.86	0.30	0.74	0.90	0.28
x_3	0.42	0.57	0.30	0.45	0.65	0.36	0.48	0.45
x_4	0.70	0.50	0.80	0.78	0.40	0.88	0.80	0.35
x_5	0.62	0.50	0.20	0.66	0.70	0.45	0.60	0.70

Table 14 represents the domination and subjection of an area together over remaining and its sum of cardinality.

Then $\xi(x_i) = |\overline{\lambda}(x_i, x_j) \cap \underline{\lambda}(x_i, x_j)|$ *and the final score of different area in fuzzy atmosphere are given by Table 15.*

Table 14. $\overline{\lambda}(x_i, x_j)$ and $\underline{\lambda}(x_i, x_j)$.

$\overline{\lambda}$	x_1	x_2	x_3	x_4	x_5	$\overline{\zeta}(x_i)$
x_1	A	$\{e_2, e_3, e_5, e_8\}$	$\{e_1, e_2, e_3, e_4, e_6, e_8\}$	$\{e_2, e_3, e_5, e_8\}$	$\{e_2, e_3, e_6, e_8\}$	26
x_2	$\{e_1, e_4, e_6, e_7\}$	A	$\{e_1, e_3, e_4, e_6, e_7\}$	$\{e_1, e_2, e_4, e_7\}$	$\{e_1, e_2, e_3, e_4, e_6, e_7\}$	27
x_3	$\{e_5, e_7\}$	$\{e_2, e_5, e_8\}$	A	$\{e_2, e_5, e_8\}$	$\{e_2, e_3\}$	18
x_4	$\{e_1, e_3, e_4, e_6, e_7\}$	$\{e_3, e_5, e_6, e_8\}$	$\{e_1, e_3, e_4, e_6, e_7\}$	A	$\{e_1, e_2, e_3, e_4, e_6, e_7\}$	28
x_5	$\{e_1, e_4, e_5, e_6, e_7\}$	$\{e_5, e_8\}$	$\{e_1, e_4, e_5, e_6, e_7, e_8\}$	$\{e_2, e_5, e_8\}$	A	24
$\underline{\zeta}(x_i)$	24	21	30	22	26	

Table 15. Table for $\xi(x_i)$ and final score.

Area $\rightarrow$	x_1	x_2	x_3	x_4	x_5
$\xi(x_i)$	10	8	8	10	10
$\Upsilon(x_i)$	10.83	10.29	4.8	12.73	9.23

Hence the order of area is: $x_3 < x_5 < x_2 < x_1 < x_4$. *It is seen that the final score of* x_4 *and* x_5 *have been raised keeping intact the order of devastation of alternatives as compared to Table 12.*

(ii) Comparison with Dinda et al. *[10]: We shall now extend the mid-level decision rule in neutrosophic atmosphere. The mid-level thresholds of Table 8 is:*

$$\{(e_1, .632, .448, .444), (e_2, .554, .514, .496), (e_3, .550, .420, .520), (e_4, .654, .396, .460),$$

$$(e_5, .520, .620, .570), (e_6, .576, .460, .528), (e_7, .632, .500, .510), (e_8, .520, .386, .570)\}.$$

The revised form of Table 8 with respect to these thresholds and following the Definition 2.5 is given by Table 16.

Table 16. Revision of Table 8 using mid-level rule.

X	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8	Choice value
x_1	0	1	1	0	1	0	0	1	4
x_2	1	0	1	1	0	1	1	0	5
x_3	0	1	0	0	1	0	0	0	2
x_4	1	0	1	1	0	1	1	0	5
x_5	0	0	0	1	1	0	0	1	3

The order is $x_3 < x_5 < x_1 < x_2$ *or* x_4 *i.e., the maximum damage prone area is undecided (i.e.,* x_2 *and* x_4*). The full order of area prone to damage may be obtained or it may be changed, if preference of attribute is applied. But since the natural calamity is beyond the hand of human being, so the detection of its dimension should not be restricted while measuring the disaster. It is intelligent to keep a focus on all attributes equally in the current study, more specifically when there is an inter-relation between the attributes in a decision making. So, neither we put any restriction to attributes nor discard any of attributes.*

(iii) Comparison with Das et al. *[6]: Das et al. furnished a group decision making approach using neutrosophic soft matrix and having a scope to make the choice of parameter (/parameters) from a relevant set for each expert. But we shall here calculate the order of area based on all eight parameters because of the ground stated in 2nd comparison. The matrix form* $(\widetilde{a}_{ij})_{5\times 8}$ *of Table 3, the neutrosophic choice matrix* $(\widetilde{\xi}_{ij})_{8\times 8}$ *and their product* $(\widetilde{a}_{ij}) \otimes (\widetilde{\xi}_{ij})$ *are put respectively as follows:*

$$\begin{array}{c} \\ x_1 \\ \vdots \\ x_5 \end{array}\begin{array}{c} \begin{array}{ccc} e_1 & \cdots & e_8 \end{array} \\ \begin{pmatrix} (.55,.50,.52) & \cdots & (.82,.25,.30) \\ \vdots & \ddots & \vdots \\ (.62,.48,.44) & \cdots & (.70,.32,.40) \end{pmatrix} \end{array}, \quad \begin{array}{c} \\ e_1 \\ \vdots \\ e_8 \end{array}\begin{array}{c} \begin{array}{ccc} e_1 & \cdots & e_8 \end{array} \\ \begin{pmatrix} (1,0.5,0) & \cdots & (1,0.5,0) \\ \vdots & \ddots & \vdots \\ (1,0.5,0) & \cdots & (1,0.5,0) \end{pmatrix} \end{array}$$

$$\begin{pmatrix} (.82,.5,.30) & (.82,.5,.30) & (.82,.5,.30) & (.82,.5,.30) & (.82,.5,.30) & (.82,.5,.30) & (.82,.5,.30) & (.82,.5,.30) \\ (.90,.5,.30) & (.90,.5,.30) & (.90,.5,.30) & (.90,.5,.30) & (.90,.5,.30) & (.90,.5,.30) & (.90,.5,.30) & (.90,.5,.30) \\ (.65,.5,.47) & (.65,.5,.47) & (.65,.5,.47) & (.65,.5,.47) & (.65,.5,.47) & (.65,.5,.47) & (.65,.5,.47) & (.65,.5,.47) \\ (.88,.5,.30) & (.88,.5,.30) & (.88,.5,.30) & (.88,.5,.30) & (.88,.5,.30) & (.88,.5,.30) & (.88,.5,.30) & (.88,.5,.30) \\ (.70,.5,.40) & (.70,.5,.40) & (.70,.5,.40) & (.70,.5,.40) & (.70,.5,.40) & (.70,.5,.40) & (.70,.5,.40) & (.70,.5,.40) \end{pmatrix}$$

Then the cross entropy value for the alternative x_k is determined by:

$$\begin{aligned} & D(A^*, x_k) \\ = & \sum_{j=1}^{8}[\log_2 \frac{1}{0.5(1+T_{kj})} + T_{kj}\log_2 \frac{T_{kj}}{0.5(1+T_{kj})} + (1-T_{kj})\log_2 \frac{1-T_{kj}}{1-0.5(1+T_{kj})}] \\ + & \sum_{j=1}^{8}[\log_2 \frac{1}{1-0.5(I_{kj})} + I_{kj} + (1-I_{kj})\log_2 \frac{1-I_{kj}}{1-0.5(I_{kj})}] \\ + & \sum_{j=1}^{8}[\log_2 \frac{1}{1-0.5(F_{kj})} + F_{kj} + (1-F_{kj})\log_2 \frac{1-F_{kj}}{1-0.5(F_{kj})}] \end{aligned}$$

and is calculated as: $D(A^*, x_1) = 9.244, D(A^*, x_2) = 8.526, D(A^*, x_3) = 13.129,\ D(A^*, x_4) = 8.712, D(A^*, x_5) = 11.489$ *for* $A^* = (T, I, F) = (1, 0, 0)$ *being the ideal alternative (here it is greatest damage prone area) in neutrosophic concept. Thus the order is:* $x_3 < x_5 < x_1 < x_4 < x_2$ *having some deviations in the outcome of the proposed methodology (*$x_3 < x_5 < x_2 < x_1 < x_4$*). For normalized neutrosophic matrix also, the order remains same. It is clearly seen that the order of area follows the order of truth component corresponding to the column of product matrix. Moreover the existence of ideal alternative is quite impossible in real state.*

(iv) Comparison with Dey et al. *[9]: Dey et al. found aggregated decision matrix based on the choice parameters and then constructed the weighted decision matrix by determining the weight of the choice parameters. Finally, the order of alternatives was evaluated using TOPSIS technique. Let us apply it on Table 8.*

The entropy value H_j for j-th parameter e_j ($1 \leq j \leq 8$, respectively) are: 0.8833, 0.8865, 0.7300, 0.79755, 0.843125, 0.8636, 0.82625, 0.84325; Their respective weights (w_j) are: 0.0880, 0.0856, 0.2036, 0.1526, 0.1183, 0.1028, 0.1309, 0.1182 with $\sum_{j=1}^{8} w_j = 1$. The tabular form (Table 17) of weighted decision matrix is obtained by use of the operation $w \otimes <T, I, F> = <1-(1-T)^w, I^w, F^w>$ as:

When the attributes are considered as benefit type, the positive and negative ideal solutions are respectively found as:

Table 17. Tabular form of weighted decision matrix.

X	e_1	e_2	e_3	e_4
x_1	(0.0679,0.9408,0.9441)	(0.0859,0.9205,0.9284)	(0.2794,0.7541,0.7826)	(0.1060,0.8940,0.9178)
x_2	(0.1643,0.8940,0.8995)	(0.0661,0.9544,0.9486)	(0.1924,0.7826,0.8499)	(0.2592,0.8093,0.8322)
x_3	(0.0468,0.9532,0.9517)	(0.0697,0.9321,0.9374)	(0.0700,0.9012,0.9299)	(0.0872,0.9250,0.9428)
x_4	(0.1005,0.9225,0.9205)	(0.0576,0.9599,0.9501)	(0.2794,0.7541,0.7826)	(0.2063,0.8322,0.8520)
x_5	(0.0816,0.9375,0.9303)	(0.0576,0.9501,0.9424)	(0.0444,0.9299,0.9675)	(0.1518,0.8520,0.8695)
X	e_5	e_6	e_7	e_8
x_1	(0.0901,0.9414,0.9317)	(0.0596,0.9350,0.9520)	(0.0607,0.9544,0.9614)	(0.1835,0.8489,0.8674)
x_2	(0.0413,0.9665,0.9587)	(0.1293,0.9053,0.9147)	(0.2602,0.8542,0.8542)	(0.0381,0.9213,0.9740)
x_3	(0.1168,0.9317,0.9213)	(0.0448,0.9488,0.9611)	(0.0820,0.9353,0.9452)	(0.0682,0.8974,0.9414)
x_4	(0.0586,0.9587,0.9503)	(0.1958,0.8773,0.8836)	(0.1899,0.8870,0.8810)	(0.0496,0.9123,0.9666)
x_5	(0.1328,0.9213,0.9099)	(0.0596,0.9350,0.9520)	(0.1130,0.9133,0.9084)	(0.1326,0.8740,0.8974)

$$\begin{aligned} R_G^+ &= <(0.1643, 0.8940, 0.8995)_1, (0.0859, 0.9205, 0.9284)_2, (0.2794, 0.7541, 0.7826)_3, (0.2592, 0.8093, 0.8322)_4, \\ &\quad (0.1328, 0.9213, 0.9099)_5, (0.1958, 0.8773, 0.8836)_6, (0.2602, 0.8542, 0.8542)_7, (0.1835, 0.8489, 0.8674)_8 > \\ R_G^- &= <(0.0468, 0.9532, 0.9517)_1, (0.0576, 0.9599, 0.9501)_2, (0.0444, 0.9299, 0.9675)_3, (0.0872, 0.9250, 0.9428)_4, \\ &\quad (0.0413, 0.9665, 0.9587)_5, (0.0448, 0.9488, 0.9611)_6, (0.0607, 0.9544, 0.9614)_7, (0.0381, 0.9213, 0.9740)_8 > \end{aligned}$$

The distance measure of alternatives from R_G^+, R_G^- and closeness coefficient ρ are presented by Table 18.

Table 18. Distance of x_i from R_G^+, R_G^- and closeness coefficient ρ.

dx_1^+	dx_2^+	dx_3^+	dx_4^+	dx_5^+
0.0769280	0.0546123	0.1050853	0.0495480	0.0925113
dx_1^-	dx_2^-	dx_3^-	dx_4^-	dx_5^-
0.0835963	0.0924865	0.0326726	0.0954114	0.0476620
ρ_1	ρ_2	ρ_3	ρ_4	ρ_5
0.5207704	0.6287373	0.2371741	0.6581939	0.3400220

The order of area is: $x_3 < x_5 < x_1 < x_2 < x_4$ which is distinct from the outcome ($x_3 < x_5 < x_2 < x_1 < x_4$) of Section 5.1. This order remains same when attributes are taken as cost type. Moreover the TOPSIS method is time consuming and takes laborious calculations until having any related software based algorithm.

Proposition 5.3. *(Damage measurement of a previously occurred cyclonic storm in view of projected method and its validity)*
On 9th November, 2019, the very severe cyclone 'Bulbul' hit a large area of West Bengal (W.B.), Odisha state in India and some regions of Bangladesh. Originated from Bay of Bengal, it made a landfall in W.B. coast (near Lat. 21.55° N, Long. 88.5° E) close to Sunderban Dhanchi forest (across Sunderban delta, South 24 Parganas) by late evening on 9th November and crossed Samshernagar (near 22.19° N, 89.06° E) of Hingalganj Block (North 24 Parganas, W.B.) on 10th November 2019 around 2 a.m. To follow up the efficiency of the technique presented here, we only take a small sample of three spots in W.B. affected by 'Bulbul': (i) Digha (DGH) surrounds (21.63° N, 87.51° E, East Medinipur district) (ii) Namkhana (NMK) surrounds (21.77° N, 88.23° E, South 24 Parganas district), (iii) Hingalganj (HNG) surrounds (22.23° N, 88.99° E, North 24 Parganas district). Now, regarding 'Bulbul' cyclone, a comparative study of the three chosen areas is placed in Table 19 based on the adopted parameters.

The information on e_1, e_2 are referred to [39, 40]. The attribute e_3 is stated from the past weather bulletins [46–48]. For e_4, the areal distance has been measured with respect to corresponding latitude and

Table 19. Parametric assessment of DGH, NMK, HNG.

	DGH surroundings	NMK surroundings	HNG surroundings
e_1	110-120kmph gusting to 135kmph	110-120kmph gusting to 135kmph	85-95kmph gusting to 105kmph
e_2	03 hrs	03 hrs	03 hrs
e_3	Coastal region Light rain (8th Nov.) Heavy (9th Nov.) -	Sundarban region (Tidal and deltaic plain) Light rain (8th Nov.) Very heavy (9th Nov.) Light (10th Nov.)	Low lying area surrounded by river on all sides Light rain (8th Nov.) Very heavy (9th Nov.) Light (10th Nov.)
e_4	103km (approx)	37km (approx)	62km (approx)
e_5	1200/km^2 (approx)	490/km^2 (approx)	740/km^2 (approx)
e_6	Semi-urban	Rural	Rural
e_7	Good	Moderate	Average
e_8	15% (approx)	80% (approx)	42% (approx)

longitude of two places. Different Wikipedia sources [49–51] have been followed to assemble the data of e_5 to e_8. The data in e_5 row is reported from the last Census conducted in the year 2011. To find out the grade of e_6 and e_7, we have visited the fields physically in recent time. The state of parameter e_6 is decided on behalf of development, education, occupations and life style of residents in the surroundings corresponding to the latitude and longitude considered. For e_7, we have noted the geographical situation, existing communication routes like train, road, water, air (both number and quality of routes) to reach at nearby urban, semi-urban, subdivisional and district head quarter, mega city Kolkata or to avail the facilities of nearest neighbour state in earliest mode and also have studied the existing health care institutes (both govt. and private), its infrastructure facilities, belonging subdivisional and district health care institutes (both govt. and private) and its features, its distances and reaching out manner from location etc. To draw the class of e_8, we only have accepted the land utilized for cultivation of 'Aman Paddy' concerning to total area because of seasonal crops in the month November for the three spots.
Now based on the information of Table 19 and making a correlation with the data of Table 2-6, the damage estimation of three spots in term of Nss is prepared in Table 20.

Table 20. Nss table for DGH, NMK, HNG.

$X \downarrow$	e_1	e_2	e_3	e_4
DGH	(.70,.40,.39)	(.75,.32,.37)	(.65,.30,.45)	(.52,.48,.57)
NMK	(.70,.40,.39)	(.75,.32,.37)	(.80,.25,.30)	(.78,.30,.35)
HNG	(.62,.48,.44)	(.75,.32,.37)	(.65,.30,.45)	(.66,.35,.40)
$X \downarrow$	e_5	e_6	e_7	e_8
DGH	(.70,.50,.45)	(.45,.52,.62)	(.48,.60,.65)	(.28,.50,.80)
NMK	(.45,.65,.60)	(.62,.44,.53)	(.60,.50,.48)	(.82,.25,.30)
HNG	(.55,.60,.55)	(.74,.38,.42)	(.80,.40,.38)	(.45,.40,.60)

Table 21 refers both the outcome of domination and subjection rule for an area over remaining.

Table 22 refers the cardinality of intersection of domination and subjection for an area over others and the final impact on DGH, NMK, HNG by cyclone 'Bulbul'.

Proposition 5.4. *(Discussion)*

Table 21. Outcome of domination and subjection rule.

$\overline{\lambda}(x_i, x_j) \rightarrow$ $\underline{\lambda}(x_i, x_j) \downarrow$	DGH	NMK	HNG	$\overline{\zeta}(x_i)$
DGH	A	$\{e_1, e_2, e_5\}$	$\{e_1, e_2, e_3, e_5\}$	15
NMK	$\{e_1, e_2, e_3, e_4, e_6, e_7, e_8\}$	A	$\{e_1, e_2, e_3, e_4, e_8\}$	20
HNG	$\{e_2, e_3, e_4, e_6, e_7, e_8\}$	$\{e_2, e_5, e_6, e_7\}$	A	18
$\underline{\zeta}(x_i)$	21	15	17	

Table 22. $\sum|\overline{\lambda} \cap \underline{\lambda}|$ & score of damage.

	DGH	NMK	HNG
$\sum|\overline{\lambda} \cap \underline{\lambda}|$	12	11	11
$\Upsilon(x_i)$	8.571	14.667	11.647

The order of area according to the evaluated impact is: DGH < HNG < NMK. Now let us follow the status of post cyclone damage as remarked in page number 11 of Report by JRNA [31] and clearly it coincides with our evaluated order. Thus the competence of the methodology proposed in the present study is clearly established in real scenario.

6. Conclusion

The present study sets up a mathematical approach to predict the scale of disaster to be occurred by a cyclonic storm in a certain area of Indian subcontinent. The damage of concerned area is estimated in the parlance of eight relevant parameters. But based on these parameters, the information on an area will have to be gathered from different past evidences, and hence these may be incomplete and imprecise by nature. So the pre-assumption of a cyclonic disaster in an area is analysed by NtS with respect to individual parameter to cultivate the indeterminacy and inconsistency of data setting more precisely. By applying the subjection and domination rule of parameters, the methodology for finding the accumulated score of damage of an area is setup. The proposed attempt is illustrated in real state, and its validity is sought after comparing with a number of existing decision making efforts. This thought will assist the administration, responsible authority and the concerned residents to be alert to make some prior manipulations to combat strongly with the post cyclone period.

The illustration in Section 5.1 is an experimental study. The data chosen may not be exact. A small diversion in considered data may bring a distinct outcome. Moreover a deviation in the order of area arisen in several comparisons studied here is found. The proposed methodology is based on single expert's opinion, it is better to enclose the multiple number of attitudes. Also the parameters affecting the prediction of disaster mostly are practiced here only, it should be added more. Because all areas, over which the study will be carried, may not have the unique geographical stand. Also a software based algorithm is very much essential to get a quick hand outcome. So, in all these angles, further co-relation is welcome.

But in the present scenario, people have to face different kinds of disaster like cyclone, earthquake, flood etc frequently almost everywhere throughout the world. So we should have to aware the possible post disaster state in advance so that it will be overcome hurriedly. In that regard, this study will bring a ray of hope, we expect. By motivating this work, the individual may adopt the following preventive measures to stay safe during cyclonic storm:
(i) to reside indoor and to stay away from electric mains.

(ii) to have an emergency kit specially a First Aid box to survive from mishap.

(iii) to be updated with the weather forecast regularly and to rely on official warning.

(iv) to shift to secure place before cyclone while feeling unsafe at residence or at present location.

(v) not to go to catch fishes in river or sea while getting the news of landfall of cyclone.

7. Declarations

• **Ethics approval and consent to participate:** Not applicable.

• **Consent for publication:** After acceptance of manuscript, authors provides the journal **Asia Mathematika** the sole right and responsibility to publish the article in printed, online or in other media formats.

• **Availability of data and material:** Data sharing is not applicable to this article as no data sets were generated or analysed during the current study.

• **Competing interests:** Both authors declare that they have no any conflict of interest or no any relevant financial or non-financial competing interest or personal relationship that could have appeared to influence the work reported in this text.

• **Funding:** No funding was received for conducting this study.

• **Authors' contributions:** This work was carried out in collaboration between both authors Bera and Mahapatra. Author Bera designed the study,performed the analysis, wrote the first draft of the manuscript and managed literature searches in consultation with the author Mahapatra. Author Mahapatra managed the analyses of the study, wrote the protocol and literature searches. Both authors read and approved the final manuscript.

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