# Forecast based Financing ( FbF)

# Menu of Triggers for Tropical cyclone

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# Contents

## 1. Scope

Mozambique Red Cross (CVM) in cooperation with the National Institute for Disaster Management (INGC) and other international actors developed and implements innovative tools for forecast based financing (FbF) and improved prevention and disaster preparedness actions. The Red Cross Red Crescent Climate Centre and German Red Cross supports National organizations implementing this new approach on disaster preparedness.

Forecast based Financing (FbF) is mechanism to use climate, weather and/or hydrologic forecasts to automatically disburse funding for preparedness actions before a possible extreme event occurs.

In FbF approach pre-selected actions should be carried out in the window between forecast (warning) and weather event. Thus, the National Institute of Meteorology (INAM) assisted by RCCC defined danger level for tropical storms to trigger preparedness actions before cyclone hit the area. In other side, CVM and INGC are working together selecting appropriate early actions aiming in reducing impact of hydro-hazards.

## 2. Background

Tropical cyclones are one of hydro-meteorological hazards that causes big damages in Mozambique, particularly along coastal districts where impacts related to cyclone activity are often reported. (et. WMO 2000).

The Research of tropical cyclone dated from 1969-2015 (Annex 1), identified 115 tropical storms (Disturbances, depressions and cyclones) that conditioned weather along the Mozambique channel. Furthermore, is verified that 32 of these storms developed in Mozambique Channel and the rest developed at east coast of Madagascar and moved westward crossing or circumventing Madagascar before entering in the channel by north or south "gate".

The average life time of tropical storm impacting the continent is about 4 days (Annex 2). However, some storms can take more days particularly when a storm forms from a persistent (stationary) low pressure system, in this situation high amount of rainfall is observed while, the mean accumulated precipitation during storm lifetime ranges from 200-300 mm.

Analyses show that every 10 years about 7 storms affect the country. Furthermore, it was observed that 21 corresponding 65% of total reported made landfall over inland, what is equivalent to say that every 10 years about 5 tropical storms made landfall in Mozambique.

Zambezia Province is cyclically hit by storms, about 15 storms, equivalent to 47% of total storms recorded in whole country were reported there. Furthermore, the analysis shows that 8 storms of these 15, made landfall in the interior of the province, what is equivalent to 38% of total cyclones which makes landfall in Mozambique. These features make Zambezia province the most affected by tropical cyclones in the country and making deep analysis is noted that total number of storms affecting the province, about 53% devastated interior districts.

## 3. Tropical Cyclone forecasting

This section describes thresholds for tropical cyclones based on existing operational procedures and EWS in use. The table1 shows official classification of tropical storms, which

is based on wind intensity, considering only storms with wind speed above 63 km/h. Tropical disturbance and depression are not included in this classification because their winds are below the threshold (63km/h). However, they are considered stormy weather and warnings are issued whenever these storms develop.

| Category | classification | Max wind speed (Km/h) | Wind gusts (Km/h) |
|---|---|---|---|
| 1 | Moderate tropical storm | 63-88 | 90-124 |
| 2 | Severe tropical storm | 89-117 | 125-165 |
| **3** | **Tropical cyclone** | **118-165** | **166-233** |
| **4** | **Intense tropical** | **166-212** | **234-299** |
| **5** | **Very intense** | **>212** | **>300** |

*Table 1: Classification of tropical cyclone*

Additionally, INAM classify precipitation in 3 categories (thresholds) for warnings/alerts, using the following color code [1]:

| Warning code | Threshold (mm/24h) | Qualitative classification |
|---|---|---|
| Yellow | 30-50 | Moderate to heavy |
| Orange | 50-75 | Heavy rainfall |
| Red | > 75 | Very heavy rainfall |

*Table 2: Rainfall Thresholds-INAM*

The warning color code described in table2, was recently introduced in INAM to categorize alert/warnings. The most used threshold is yellow code as in many location 30-50 mm/24h causes flash flood with significant impacts (disruption of normal activities, including transport system, electricity and water supply).

The menu of trigger under FbF scope introduces other elements such as direction to the target and strike probability map. Full description of tropical cyclone allows the practitioners to take appropriate actions before an event strike .

4.  **Danger level selection**

By combining wind intensity described in table 1, rainfall thresholds in table 2 and taking into consideration storm direction to the target (full or partial hit), and vulnerability studies based in past events (1970-2015), two danger levels were determined. Additionally, the analysis of tropical cyclone frequency in Mozambique indicates that Zambezia province is the most affected by tropical storms and Nicoadala district which is situated 60 km from the coast is highly exposed to multi hazards, the vulnerable communities are particularly exposed to floods, cyclones and erosion. Here too climate Change is likely to aggravate the situation and increase flood and cyclone occurrences [2].

Hence, damages caused by strong cyclones (category 3 above) are designed as **Danger level1** and medium damages (storm below category 3) are defined as **Danger level 2**

### 4.1 Rationale for Danger Levels selection

Tropical cyclone data analysis shows that 65% of total storms with huge impacts in Mozambique made landfall over continent, causing damages along its path (Annex3). In the "menu of choice for trigger", when a tropical storm crosses or makes landfall in the area of interest will be designed "**full hit**". In other side when storm is not moving directly to the location but, strong winds and heavy rains are expected to cause damages in that area, this will be called "**partial hit",** because impacts are relatively less than in other situation.

### 4.2 Danger level 1

When a tropical storm is expected to cause huge impacts on assets and the risk of deaths related to storm is high. For these damages storm should be classified as category 3 or greater with the following descriptions:

a) Winds greater than 118 km/h AND
b) Winds greater than 118 km/h and rainfall more than 75mm of rain in 24 hours OR
c) Winds greater than 118 km/h more than 250mm of rain in 4 days.

Tropical cyclone with landfall over continent are very destructive along its path. Benedicte and Bonita are some examples of Tropical cyclone which made landfall over Zambézia causing floods and many infrastructures were destroyed in some districts included Nicoadala. These damages are already standardized in tropical cyclone early warning system as following:

- Houses built with local material (low cost) are destructed
- Roofs are snatched away by strong winds
- Crops are destroyed and trees downed
- High risk of human lives.

### 4.3 Danger Level 2:

When tropical cyclone is impacting the area of interest but storm is not hitting directly. The critical thresholds defined are:

**a)** Winds greater than 75 km/h and
**b)** more than 50mm of rain in 24 hours OR
**c)** more than 200mm of rain in 4 days.

Coastal districts are frequently affected by active storms in Mozambique channel, depending on its intensity and approximation to continent, heavy rainfall with moderate or strong winds are more likely to occur. The Mozambican coastline is very long (2700Km) and the most populated area, big cities and infrastructures are all along the coast and the low area is used for rain-fed agriculture. When a tropical storm hits this area, damages are always reported, tropical cyclone Funso-2012 in Zambézia and Helen-2014 in Cabo Delgado are examples of intense storms near the coast with severe impacts. The thresholds proposed in this section are adequate when storms are predicted to hit partially the area of interest. Nicoadala which is 60 km far from the coast is also affected by storms passing near the coast, heavy rainfalls are the main cause of impacts. Damages can be considered as "medium" if taking into account that storms in this case are slightly far from the zone of impact. However, overall the damages related to storms are almost similar with described in danger level 1, the slightly difference is in number of assets or fatalities associated to the storm.

## 5. Triggers for action

Trigger is a forecast issuance for action when the danger level is forecasted at a high enough probability. The probability is agreed upon beforehand amongst all stakeholders. In FbF, the trigger will be defined based on attributes of a scientific forecast of likely extreme event. It is the moment when the forecast is informed to enable the implementation of actions. Trigger is to say yes to take early action (i.e. act activate the SOP) based on Early warning. Therefore, in order to help practitioners and decision makers to select appropriate action, three choices/options of triggers in each category (danger level) are presented below.

### 5.1. Section 1: Tropical Cyclone making landfall-Danger level 1

Here, the focus is for cyclones that hit the area full-on doing major damage. Select which of the following trigger levels you will use for your action for huge damages. You have choices A, B, or C.

**Choice A1**:

| | lead time: 24 hours |
|---|---|

| hazard | Storm description | Direction to the target | Affected area | Danger level | Strike probability map[2] |
|---|---|---|---|---|---|
| Tropical cyclone | Category 3 | full hit | Ex. Quelimane, Namacurra e **Nicoadala** | Level 1 | >80 % |

*Table 3: Trigger 1*

### 5.1.2 Rationale for why choice A1 was selected

When Forecasting tropical cyclone, there are several elements to look at: Magnitude, storm speed, wind intensity, rainfall, track map and storm surge.

Historical analysis shows that Zambézia (case study area) was affected by 15 tropical storms in the last 47 years (1970-2015), 8 storms of these 15, made landfall in interior districts. In other words, this means that in every 10 years approximately 2 storms make landfall (full hit) over Zambézia districts including Nicoadala (FbF pilot district).
Tropical cyclone Benedicte and Electre both in 1980, Nadia 1994 and Filão in 1998 are examples of strong tropical cyclone making landfall over Zambezia, causing huge damages in interior districts including Nicoadala. Re-tracking tropical cyclone of the last 5 seasons (2011-2016) by visiting http://www.ecmwf.int/en/forecasts/charts/tcyclone/, as well as analyzing tropical cyclone warnings disseminated by INAM over time can be concluded that forecasting Cyclone in short time scale, gives high change of accurately predict the right path (strike probability map).

**Choice B1**:

| | lead time: 48-72 horas | | | | |
|---|---|---|---|---|---|
| hazard | Storm description | Direction to the target | Affected area | Danger level | Strike probability map[2] |
| Tropical cyclone | Category 3 | full hit | Ex. Quelimane, Namacurra e Nicoadala | Level 1 | 50-60 % |

*Table 4: Trigger 2*

### 5.1.3 Rationale for why choice B1 was selected

The lead time of 72h proposed here is reasonable time for forecasting strike probability, particularly for strong tropical storms, because its movement is slow and it may take two or three days before landfall.

In 2000, Hudah, strong tropical cyclone category 4, intense tropical cyclone was forecasted by La-reunion (regional tropical center) four days in advance (04 April) that it could make landfall over Zambezia, but landfall was materialized on 08 April. As stated above strong

tropical cyclone moves slowly, which is "good" for preparedness activities such as: Pre-positioning of relief items, evacuation and for coping strategies.

In the Menu of Trigger this choice will allow time for humanitarian's actions, although the probability of hit or miss is 50/50 %. The actions recommended here will not be in vain because the area will somehow be affected by winds and rains regardless of full or partial hit.

**Choice C1**:

| hazard | Storm description | Direction to the target | Affected area | Danger level | Strike probability map[2] |
|---|---|---|---|---|---|
| lead time: 3-5 days | | | | | |
| Tropical Severe storm | Category 2 | full hit | Ex. Quelimane, Namacurra e Nicoadala | Level 1 | 20-30 % |

*Table 5: Trigger 3*

### 5.1.4 Rationale for why choice C1 was selected

The accuracy of forecast is influenced by lead time, long range forecast lead to low probability of detention. Additionally, the path of tropical storm in Mozambique channel is influenced by westerly systems from the southern part of the continent. The position and movement of the two semi-permanent high pressure system (St Helena and Mascarenhas) have significant influence on movement of storms. These high pressure systems shift tropical cyclone southeasterly or block its movement making it spins in the same radius. Therefore, extended lead time results in high uncertainty in storm path.

Tropical cyclone Angele, formed in Mozambique channel on 13 December 1979, initially moved northward and turned 360º degrees before touching the north coast of Zambézia and then crossed Nicoadala on 21 December.

Therefore, in the Menu of choices for Triggers, when choosing actions to implement, the probability of acting in vain should be considered high in long lead time, so is recommended to select low costs or no-regret actions.

### 5.2 SECTION 2- Tropical cyclone hitting the area partially- Danger level 2

Here, the focus is for tropical cyclone which is not expected to make landfall over continent but its power affects particular area of interest (ex. Nicoadala). Select which of the following trigger levels you will use for your action. You have choices A and B.

**Choice A2**:

| | lead time: 24 horas |
|---|---|

| hazard | Storm description | Direction to the target | Affected area | Danger level | Strike probability map[2] |
|---|---|---|---|---|---|
| Tropical cyclone | Category 3 | Partial hit | Ex. Quelimane, Namacurra e Nicoadala | Level 2 | 50-60 % |

*Table 6: Trigger 4*

### 5.2.1 Rationale for why choice A2 was selected

Zambezia coast is very vulnerable to tropical cyclone, about 47% of total tropical storm which affected Mozambique were reported there. Heavy rains and strong winds reaches interior districts when tropical storm is active near the coast. Short lead times present high probability of detention, meaning that within 24 h.

There many examples of tropical storms which devastate coast of Zambezia without making landfall. Funso, intense tropical storm category 4 in January 2012 is typical example of devastating storm near the coast, strong winds penetrated kilometers in land and based on satellite picture cloud band covered Nicoadala and 66 houses were destroyed and two persons were reported killed because of this storm. Overall, more than 5000 people were displaced by the weather conditions[2] heavy rainfall related to this system was also reported in Malawi.

Tropical storm formed in Mozambique channel are easily monitored by forecasters, because generally they develop from low pressure system and warning are produced timely before reaching a stage of Tropical cyclone. The Regional Centre (La-Reunion) and RSMC (Regional Specialized Meteorological Center- Pretoria) provide guidance of precipitation and wind intensity.

**Choice B2**:

| | lead time: 24 -48 horas | | | | |
|---|---|---|---|---|---|
| hazard | Storm description | Direction to the target | Affected area | Danger level | Strike probability map[2] |
| Tropical storm | Depression, severe storm | Partial hit | Ex. Quelimane, Namacurra e Nicoadala | Level 1 | 20-30 % |

*Table 7: Trigger 5*

### 5.2.2. Rationale for why  choice B2 was selected

The accuracy of forecast gives is a function of lead time and reliability of the models. In other side as referenced above, tropical storms below category 3 do not present well- organized synoptic configuration. Therefore, for storm in early age of development, in 72 hours lead time, storm track is quite diffuse and risk of false alarm is high. For FbF early actions is recommended to take no-regret activists in this situation.

Jokwe in 2008, after impacting Nampula and northern part of Zambézia was expected to pass near Quelimane which could produce heavy rains along surrounding area. On March 7, the National Emergency Operational Centre of Mozambique warned for coastal residents in Nampula and Zambezia provinces to be on alert. A day later, the agency issued a Red Alert for northern Nampula Province, advising potentially affected residents to seek shelter. Subsequently, the alert was extended southwestward along the coastline but no significant impacts were reported along the coast of Zambézia because Jokwe shifted southeastward to Mozambique channel where dissipated later.

## 6. Triggers for FbF actions in Nicoadala (FbF pilot district)

In this pilot phase of FbF, preparedness actions for tropical cyclone will be activated upon a short-term forecast, 3 to 5 day lead time. The actions will be taken when forecast from INAM alert that the pilot district Nicoadala is at risk of being hit by strong winds and heavy rainfalls reaching the danger levels indicated  below.

| Fenómeno | Thresholds/danger level | | | |
|---|---|---|---|---|
| | Wind speed | | Precipitation | |
| | Maximum wind speed | Wind gust | Total rainfall in 24 h | Total rainfall in 4 consecutive days |
| Severe tropical storm | >90 km/h | > 125 Km/h | > 50 mm |  > 200 mm |

*Table 8: Tropical storm thresholds*

The potential damage of tropical cyclone is estimated combining danger level and strike map. Storms moving directly to area of interest are more devastating than the others passing nearby.  INAM will monitor and send a warning message whenever a storm with characteristics above is threatening to impact Nicoadala. The figure below show an example of tropical cyclone monitoring.
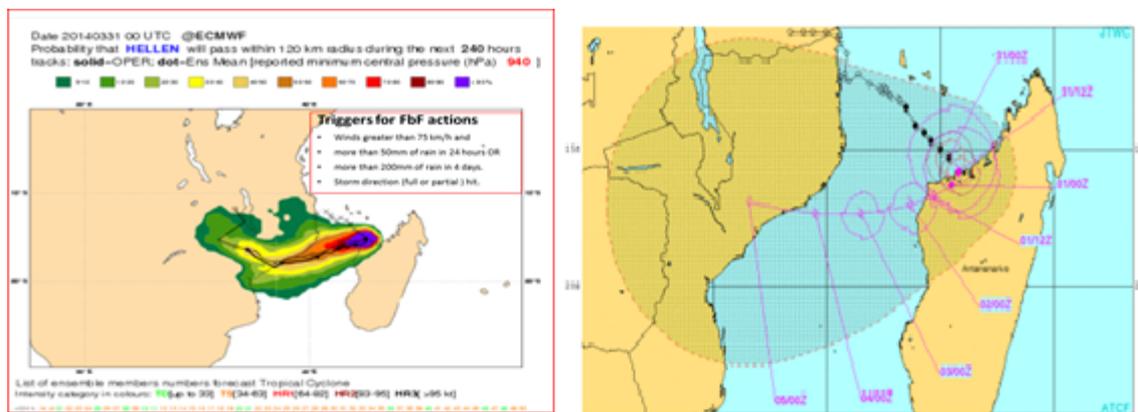


*Figure  SEQ Figure \\* ARABIC 1: Tropical Cyclone Hellen- March 2014*

The National Met service ( INAM), operates a work stations set for receiving weather products  provided by Tropical Cyclone Regional Center ( la Reunion ) as well as from other global centers such as ECMWF, Ncep/NOAA,  JTWC, MTOTEC, etc. Once a storm is active in the South West Indian Ocean, INAM receives a message in text format, detailing storm characteristics (location, category, winds speed and pressure) and then, produce local alerts after adding all knowledge related to exposure and vulnerability of assets and people. Additionally, INAM, has access to global products through RSMC (http://rsmc.weathersa.co.za/index.php) and  the forecasting department during rainy season monitor the storm development using other open sources : http://moe.met.fsu.edu/cyclonephase/ , http://www.usno.navy.mil/JTWC/ , www.mtotec.com, http://passageweather.com/, etc.

Based on inputs from the sources listed above, INAM provides up to 3-day lead time warnings/alerts when storm is threatening to impact area of interest (Nicoadala). However, given the fact that activation phase of the SOP requires at least 5 days, INAM will produce a special forecast (Annex 4 ) with extended lead time up to 5 days ( Choice C1) which will be disseminated to all stakeholders involved in the implementation of FbF concept. To assure efficient and automatic forecast delivering and timely implementation of early actions a procotocol of comand  ilustrated in figure 1 will be set up before the tropical storms season.
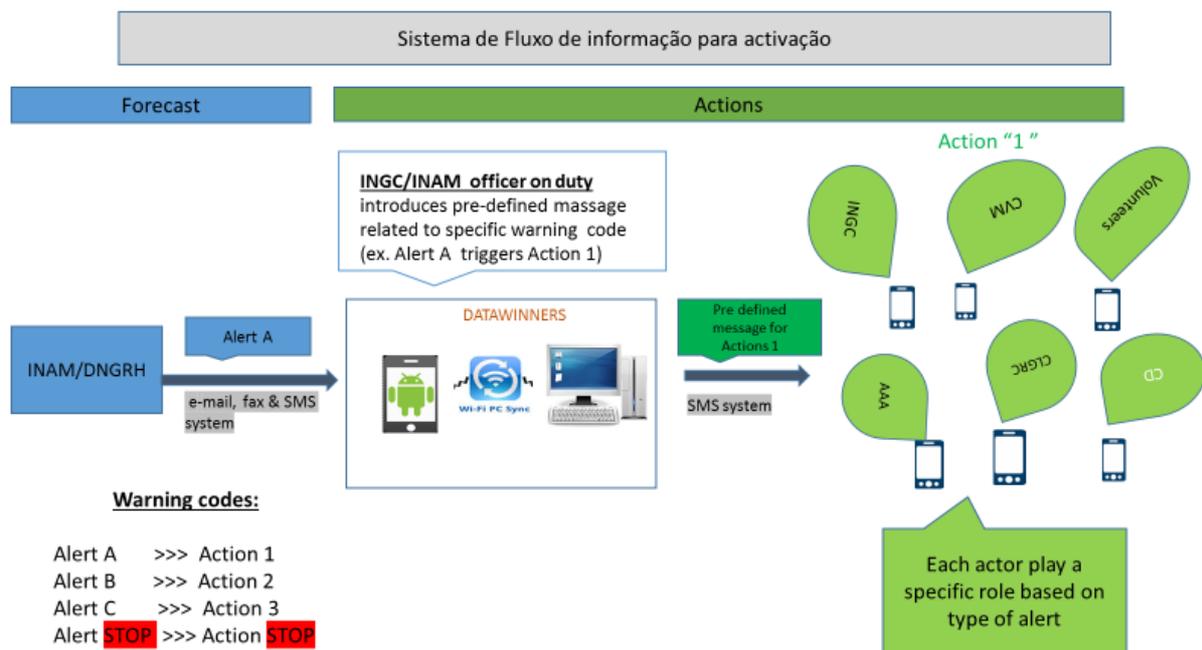


*Figure 2: Forecast flow and related actions*

The Information flow is one of main constraints when  implementing specifics action in very short time. In other side Tropical cyclone are very dinamic , it can intesify or weaken very from its initial state very quick. Therefore, in order to reduce chances of activing in vain , a

STOP mechanism (stop alert) will be activated whenever it becomes unnecessary to carry on selected activity when forecast updates and inform that the pilot area is no longer at risk.

### 7. Reference:

[1]: http://www.ecmwf.int/en/forecasts/charts/tcyclone/

[2]- http://floods.wri.org/#/state/2814/Gaza,%20Mozambique (latest-download 2013-03-13

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