**XXVIII INTERNATIONAL SYMPOSIUM ON
MODERN TECHNOLOGIES, EDUCATION AND PROFESSIONAL PRACTICE
IN GEODESY AND RELATED FIELDS**

Sofia, 08 - 09 November 2018

NATURAL HAZARDS AND FRACTAL PROPERTIES OF MALDIVES

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ABSTRACT

The Maldives are a vulnerable country to different natural hazards. After the Indian Ocean tsunami of 26th December 2004 generated by a powerful earthquake with a magnitude 9.1, many people lost their lives, some remained homeless and the losses reach 170 billions dollars. After this gigantic catastrophe (the most victims in the human history have been ever recorded) an Indian Ocean tsunami early warning system has been established. In parallel way many local systems have been developed to monitor their local hazards and to exchange data with other countries and to warn the local coastal population. Several other natural hazards threaten Maldives and most of them have nonlinear behavior in their generation, development and possible negative effects. The fractal nature of the Maldives archipelago is investigated. The areas of the main atolls are measured and presented as fractal graphics and the fractal dimension is calculated. The result obtained show the strong nonlinearity for the sizes of the atolls visible areas. The links between the different nonlinearities are noticed.

INTRODUCTION

The present study is focused to present the potential natural hazards to Maldives, the reaction of the government authorities related to the function of the multihazard early warning system. It is important to mention that the Maldives are islands country, surrounded and isolated by the ocean and consists of many separate atolls, attracting a lot of tourists every year. The archipelago is extended to about 1200 km in N-S direction in the Indian Ocean. Maldives enjoys a warm and humid tropical climate, with two monsoon periods known as the southwest monsoon (the wet period from May to November) and the northeast monsoon (the dry period from January to March) [3]. The most common forms of hazards experience in the Maldives are ocean waves of different types such as storm surges, tidal waves in combination with wind waves known as “udha”. There are also droughts, heavy rains, salt water intrusions, erosion, wind storms, etc. After 26th December 2004, Indian Ocean Tsunami, which affected strongly the lowland country, a multihazard early warning system was developed, which operates in every day practice.

NATURAL HAZARDS IN MALDIVES

The Maldives frequently experiences high frequency low impact events such as monsoonal flooding, coastal erosion and salt water intrusion. According to United Nation Development Program [4] there are four categories of natural hazards in the Maldives. They are geological hazards which involves earthquakes and coastal erosions, meteorological hazards which involves tropical cyclones and thunder storms, hydrological hazards which involves flooding and storm surges and climate related hazards which involves sea level rise and sea surface temperature rise. Among the categories mentioned, floods induced by tsunamis, abnormal swell waves, heavy rainfall, windstorms, droughts and earthquakes are considered as major natural hazards in the Maldives [4].

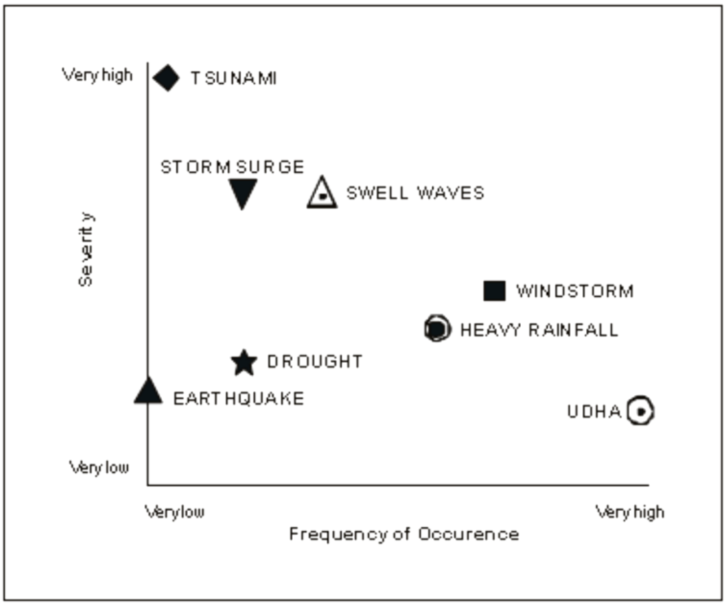

Fig.1. General patterns of the major natural hazards prevealing in the Maldives (UNDP, 2008)

The distribution pattern of natural hazards is strictly controlled by their geophysical properties and climatic peculiarities.

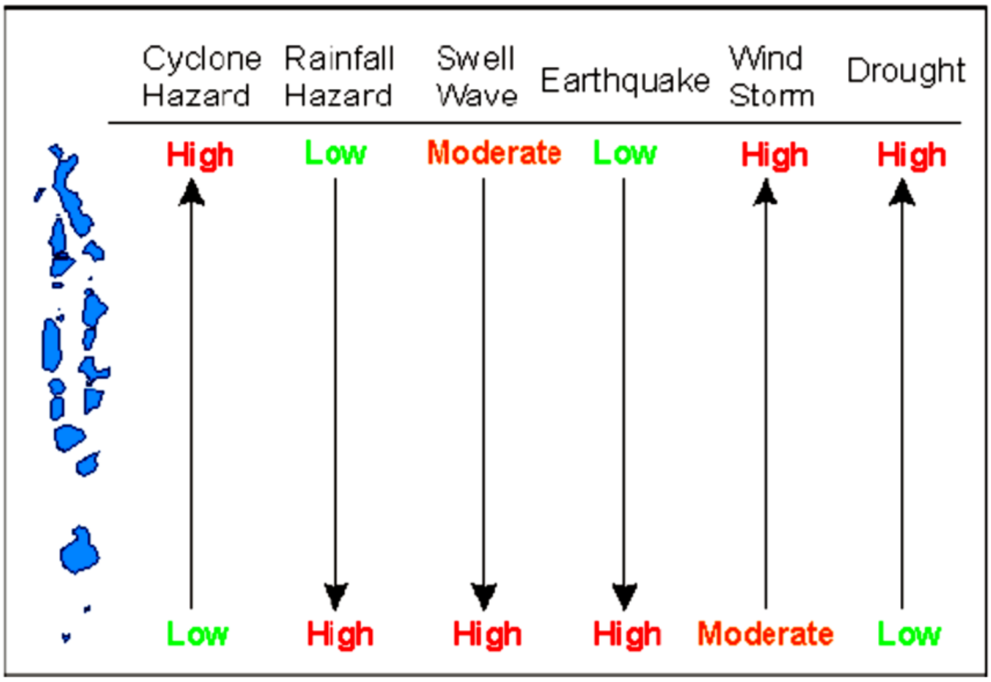

Fig. 2. Latitudinal variations of major natural hazards across the Maldives (UNDP, 2008 [4])

The cyclone hazard, wind storms and drought are more frequent in the northern region of the Maldives, while rainfall hazards, swell waves and earthquakes are more frequent in the southern regions of the Maldives. The eastern rim islands are subjected to tsunamis and waves of higher intensity compared to islands in the western rim which are protected from high intensity waves. The island morphology and size also plays an important role in protection against coastal hazards [4].

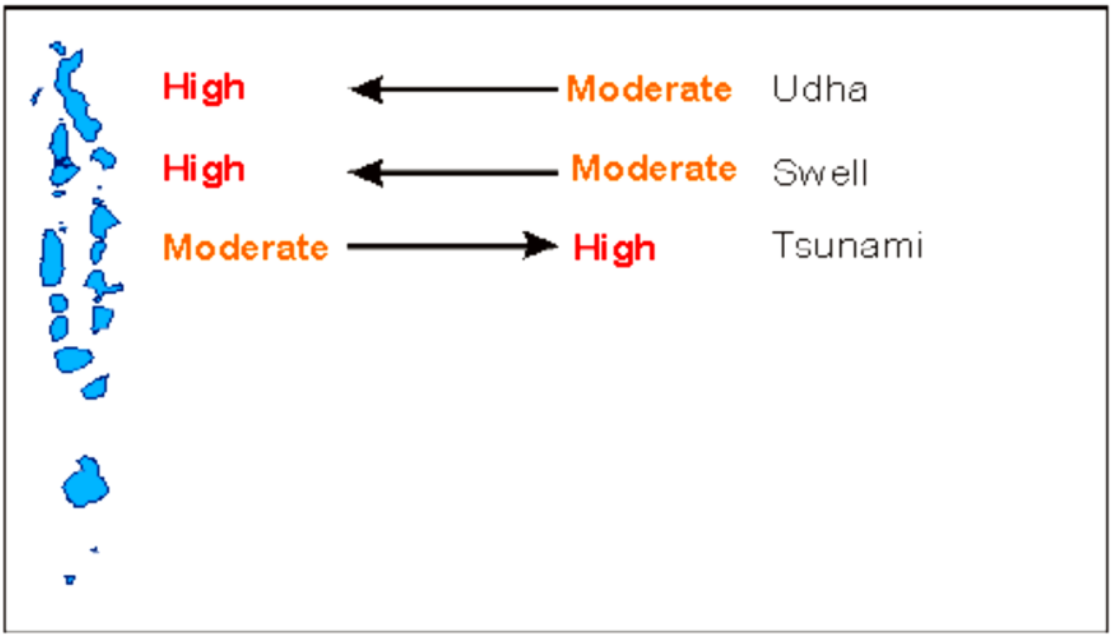

Fig. 3. Longitudinal variations of the major natural hazards across the Maldives (UNDP, 2008[4])

According to Ministry of Environment and Energy [5], three major types of swells exist in the Maldives, they are 1) “Udha” waves, which are known as gravity waves caused by high tides and strong winds; 2) swell waves, which are known as tidal waves and 3) Tsunami waves, which are low frequency high impact waves caused by earthquakes and other bottom phenomena.

Wave swells can cause significant flooding that can damage key infrastructures such as homes, harbors, schools, mosques, and jetties in the islands. Other hazards such as monsoon strong winds can cause high tides, which can increase coastal flooding events.

In 2008, strong surface winds, combined with heavy rainfall, caused significant damage to roofs and the uprooting of trees in many islands of the Maldives.

Hazardous weather events which regularly affect Maldives include tropical cyclones and sever local storms. Tropical cyclones are considered destructive if they are associated with strong winds exceeding 150 km per hour with rain fall above 30 to 40 centimeters within a 24-hour period and storm tides exceed four to five meters.

Northern atolls have a greater risk of cyclonic winds and storm surges compared to the southern atolls however, the cyclones that affect northern islands of the country are weak cyclones that are formed in the southern part of the Bay of Bengal and the Arabian Sea.(UNDP, 2008). Islands located within close proximity to the equator, are largely free from storms.

The northern region of the Maldives is more prone to wind hazards from cyclones compared to southern region of the Maldives. Strong winds can damage vegetation, houses, communication systems, roads, while heavy rainfall can cause flooding and cyclonic winds sometimes can cause sudden rise in the sea-level along the coast leading to storm surges [4].

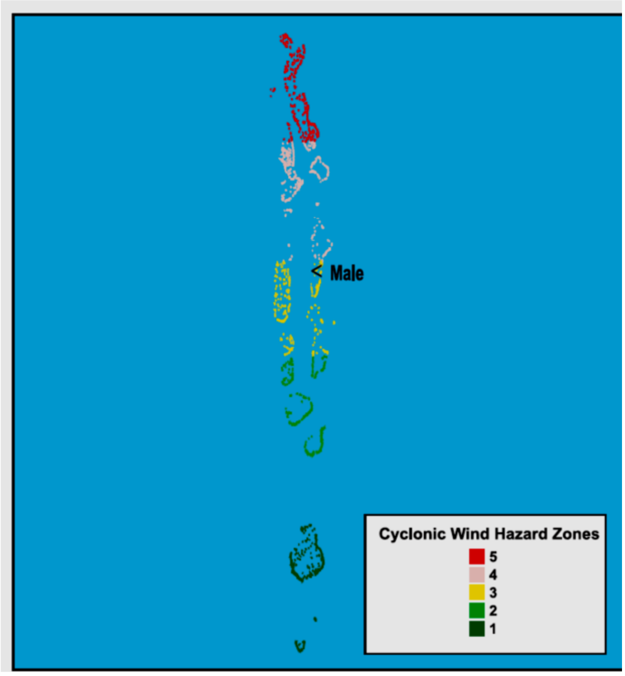

Fig. 4. Cyclonic wind hazards map of the Maldives (UNDP, 2008 [4])

Seismic hazard is low and only few expectations are related to the south. The threats from sea level rise due to climate change are a uniform hazard throughout the whole country.

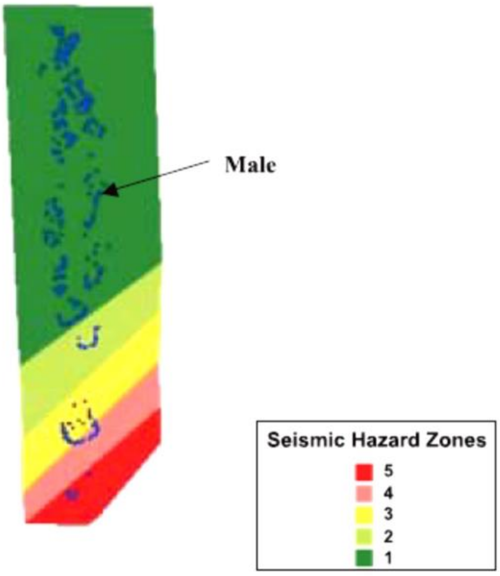

Fig. 5. Maldives seismic hazards zones (UNDP, 2008 [4])

The most devastating natural event affected Maldives is the tsunami in Indian Ocean of 26 December 2004. This unexpected event affected 3 continents, 11 countries and was the most deadly natural disaster occurred during the human history. More then 300 000 deaths, 1.5 million homeless and damages over 100 billions US$ were reported. Significant damages were registered as well as in Maldives. After this disastrous event an extensive program of tsunami hazard investigations and measures about people protection have been developed.

Hazard Zone	Range of Probable Maximum Wave Height (centimeters)
1	less than 30
2	30-80
3	80-250
4	250-320
5	320-450

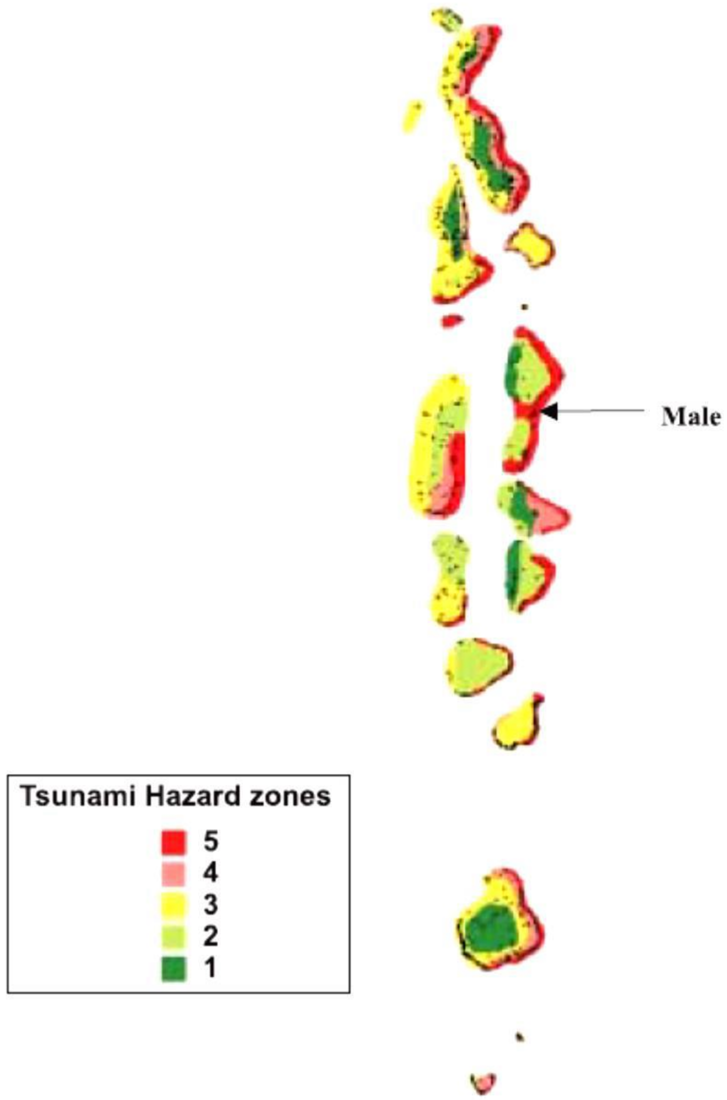

Fig. 6. Tsunami hazard map for Maldives (UNDP, 2008 [4])

Climate change is also a significant issue that needs urgent attention in the Maldives. The UN predicted maximum sea level rise of 59cm by 2100 is expected to make flooding incidents and coastal erosion events more frequent in the future. The expected increase in the sea surface temperature (according different models) will threaten the survival of the coral reef ecosystem [6]. Healthy coral reef ecosystem is a vital natural resource for tourism and fisheries industry. Damage to coral reefs such as coral bleaching due to increase in sea surface temperature will have negative impacts on tourism and fisheries industry Maldives heavily depends on for revenue.

THE FRACTAL PROPERTIES OF MALDIVES

We studied the area surfaces of the Maldives atolls and calculated the fractal dimensions for these formal areal objects.

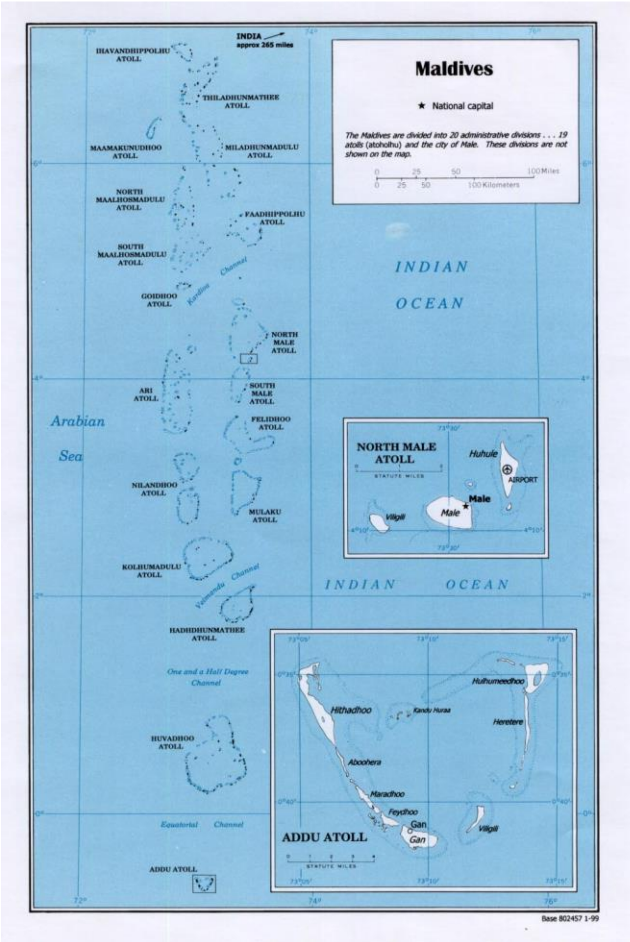

Fig.7. The studied atolls of Maldives

To calculate the fractal properties and the fractal dimension measurements of the surfaces of the Maldivian atolls on a high resolution map of Maldives (Fig.7.) have been used. The results are presented in Table 1.

Table 1. Areas (in km^2) of the main atolls of Maldives

No	Atolls	Area [km^2]
1	Thiladhunmathi	4000
2	Huvadhoo	3300
3	Ari	2270
4	Maalhosmadulu Uthuruburi	2000
5	Kolhumadulu	1700
6	Male' Uthuruburi	1580
7	Felidhu	1080
8	Mulaku	970

9	Maalhosmadulu Dhekunuburi	960
10	Haddhunmathi	880
11	Nilandhe Dhekunuburi	730
12	Faadhippolhu	710
13	Nilandhe Uthuruburi	605
14	Male' Dhekunuburi	530
15	Ihavandhippolhu	290
16	Addu	150
17	Fasdhūetherē (Fasdhūtherē)	140
18	Maamakunudhoo	135
19	Goidhu	107
20	Gahaafaru (Gaafaru)	86
21	Rasdhu	60
22	Vattaru (Falhu)	45
23	Kaashidhu	8
24	Fuvahmulah	5.7
25	Thoddu	3.5
26	Etthingili Alifushi	3.2

The total number of atolls taken in consideration is 26. Their surface dimensions vary between 3 and 4000 km^2. The accuracy of the area assessment varies between 1 (for the smaller elements) and 10% (for the larger ones). Thus the graphic representation of the relationship between the size and the respective number of atolls gives us the possibility to calculate the fractal dimension of 2.75. This means that the fractality is well defined and the nonlinear relationship between the size of the atolls (in semi logarithmic scale) and the respective numbers is very well expressed [8].

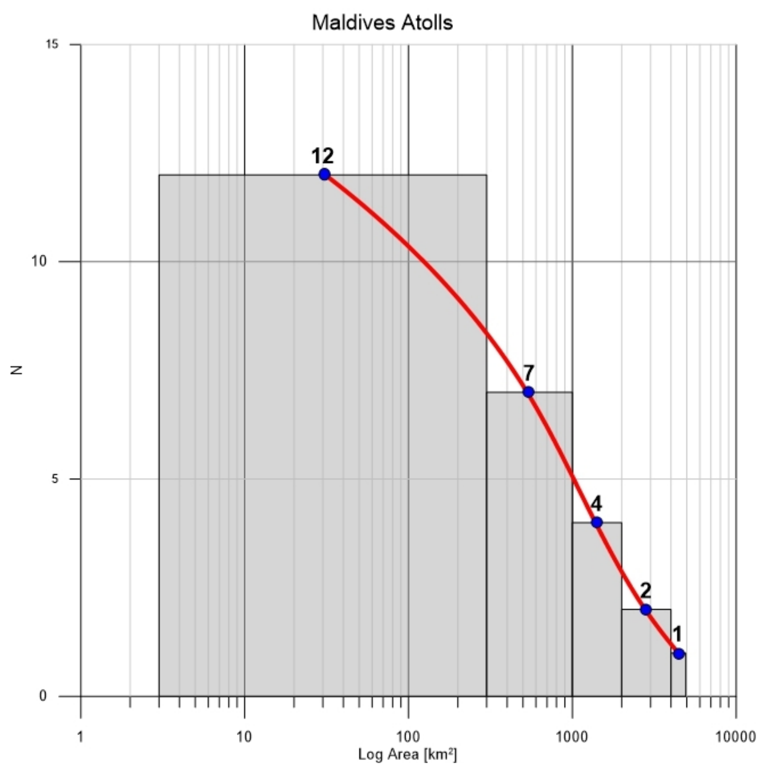

Fig.8. The semi logarithmic fractal plot of the observed areas and their number for Maldives atolls. The calculated fractal dimension is 2.75.

CONCLUSIONS

A short review of the natural hazards threatening Maldives is presented. Maps of zoning as first step of quantification the hazards are created and used as long term preventive measures. Multihazards influence is considered according to the combined action of the possible dangerous events [2].

New and sophisticated measures according to the specific conditions of Maldives are proposed. For the first time evacuation to the open sea is suggested as an effective tool for application in case of the early warning message received in advanced related to the danger from transoceanic tsunamis (similar to those of 26th December, 2004) [1].

The fractal analysis is performed to prove the strong nonlinearity concerning the geometry distributions of the areas of Maldives' atolls.

The nonlinear behavior of the surface elements of the Maldives' atolls is proved, thus way showing that the spatial distribution of the atolls could be investigated using formal approach of the fractal analysis.

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Acknowledgments: This work is supported by the CABARET Project No 573816-EPP-1-2016-1-UK-EPPKA2-CBHE-JP of EU Erasmus+ Program

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