Impact of environment on timber structures, bois duramhen 971, the case of Guadeloupe (F.W.I.)

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IMPACT OF ENVIRONMENT ON TIMBER STRUCTURES, BOIS DURAMHEN 971, THE CASE OF GUADELOUPE (FWI)

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ABSTRACT: Wooden house is a traditional mode of construction in the Caribbean Islands. The buildings have to resist to multiple situations: earthquakes and hurricanes are the most impressive. Nevertheless, humidity and temperature conduct to a sever climate for these constructions. The impact of these environmental conditions is the aim of this paper. Eurocode 5 defines the requirements for serviceability and ultimate limit states for European timber structures. The impact of environment can be defined by two parameters. One is about durability considerations, the other one is about impact of environment on mechanical characteristics. The first one, employment class, the hazard classes of biological attack on the durability of wood and wood-based products is defined in EN 335 and is not in the scope of this study. The service classes and their impact on the use and the mechanical characteristics of wood and wood-based materials are defined in EN 1995-1.1. Their definition is based on the moisture content of wood or on the temperature and the relative humidity of the surrounding air; these conditions are the ones studied in this paper. A 18 month experimental campaign is described and justified. The use of Météo France meteorological data is reported. First results are discussed in terms of possibility of use for different wood and wood based materials regarding a proposed map for Guadeloupe Island.

KEYWORDS: Temperature, relative humidity**,** Service classes, soft wood, hard wood, moisture content

INTRODUCTION

Regarding Eurocode standard dedicated to timber structures, French west indies islands are often considered as a service class 3 area (the most sever environmental conditions). This decision is based on the sever climate of Caribbean islands for one part, but mainly for a lack of information on the real local climate and its consequences on timber elements of buildings. Caribbean island climate is characterized by a high level of air humidity and high temperatures. Nevertheless very few information on impact on timber, soft woods and hard tropical woods, are available. A European project, *Synergîle-Bois Duramhen971:BD971*, is devoted to the study of environmental effects on timber structures in Guadeloupe island and a French national project, *PACTE-Bois Duramhen972* proposes the same approach for Martinique island. The aim of these two programs is to build a reliable data base in order to propose a map with different service class zones (SC2 & SC3) if it is possible. The work presented here is only related to Guadeloupe island. The chosen strategy is based on:

- the identification of available meteorological data,
- the choice of different buildings or "sites" (≈ 100),
- a 18 month measurement period (temperature and relative humidity of surrounding air on the sites, and the measurement of moisture content on ≈ 240 elements (≈ 500 faces),
- a continuous analysis of data and measurements.

This paper will present successively the specificity of subtropical situation of French Caribbean islands, the chosen strategy, validation of measurements and first results.

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2 SPECIFIC SITUATION OF FRENCH CARIBBEAN ISLANDS

Guadeloupe (16-17°N, 61-62°W) is composed of a main island with two parts and few smallest islands. The climate is a subtropical marine one with a wet hot period and a slightly dryer one. Buildings are mostly located in zones with the lower altitude. European soft wood and tropical hard wood are used for these constructions.

Figure 1 presents these islands. The climate zones determined by French Meteorological Institute “Météo France” are named Météo France Zone: (MFZ). The local meteorological measurement equipment (MF)are also located on this figure. Standard year statistics for temperature are given for example on figure 2 for “Le Moule-Lauréal” MF.

Meteorological equipment for environmental parameter records are illustrated on figure 3-a.

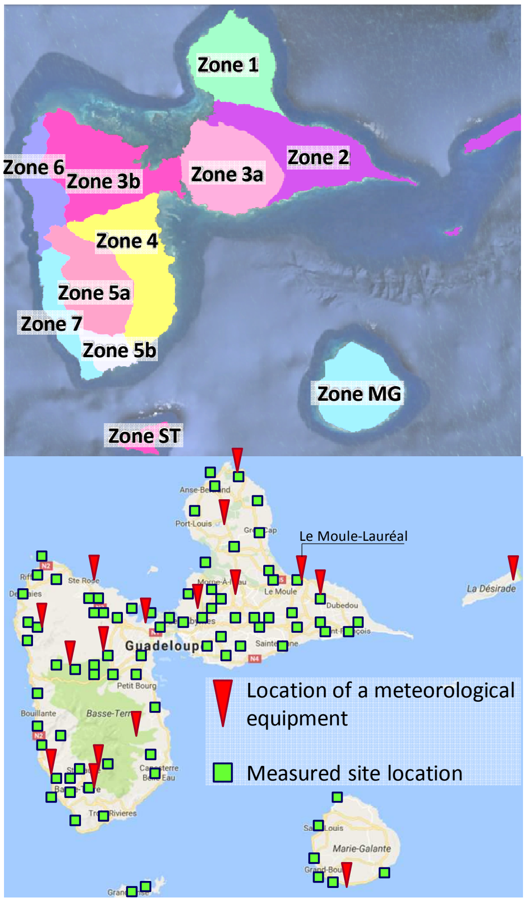

Figure 1: *Guadeloupe meteorological zones and location of studied buildings*

For *BD971*project, various buildings have been chosen. The results obtained on these studied building are defined as site measurements results (SMR). Some of the (SMR) are also plotted on figure 1.
Chosen parameters for these buildings are:

- Location in the different ZMF
- Proximity or not with MF
- Proximity or not with urban zone
- Altitude and gradient of altitude
- Soft wood and tropical hard wood elements
- Similitude or not between buildings

Some buildings or timber elements taken into account in these study are presented in figure 3-b.The cross section of these elements on site varies from 33x97 to 150x150 mm². The studied timber elements are sheltered wood beams. The structure illustrated in the right low picture of figure 3-b is a bus stop which is a standardized tropical wood structure implanted in all the Guadeloupe Island; a same timber structure with a same species (AngelimVermelho), in different sites, is an interesting parameter for our study.
A listing of wood species communly used is created; table 1 give an idea of these species. The origin of soft wood is mainly Europe and the major part of tropical wood comes from South America (French Guyana and Brazil). In order to complete this list, a species identification work is integrated in this project. Some mechanical, physical (dry density d_0, moisture content *MC*) test are also performed.

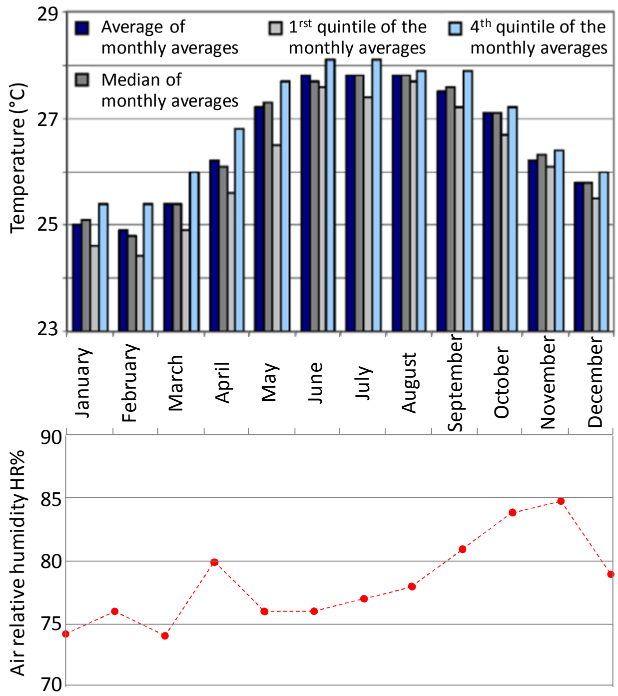

Figure 2: *Monthly MF statistics for a usual year, Le Moule-Lauréal station (ZMF 2) [7]*

Figure 3: *Examples of MF equipment and examples of buildings SMR*

Table 1: *Wood species most usual in Guadeloupe Island for buildings*

category	Species	Density (kg/m^3)

Soft wood	Pin(*Pinus*)	520
	Douglas	530
	Mélèze	600
	Epicéa	460
Tropical hard wood	Jatoba(*Hymeneasp*)	900
	Cumaru (*Dipterixsp*)	1100
	AngélimVermelho (*DiniziaExcelsa*)	1000
	Basralocus (*Dycoryniaguiannensi*)	800

3 METHODOLOGY OF THE STUDY

The study is separated in three main phases: the data acquistion, data analysis and finally the service class zones determination [1]. Figure 4 gives an overview of this methodology and folowing sections give precision on the objectives of each step and substep[2] [3].

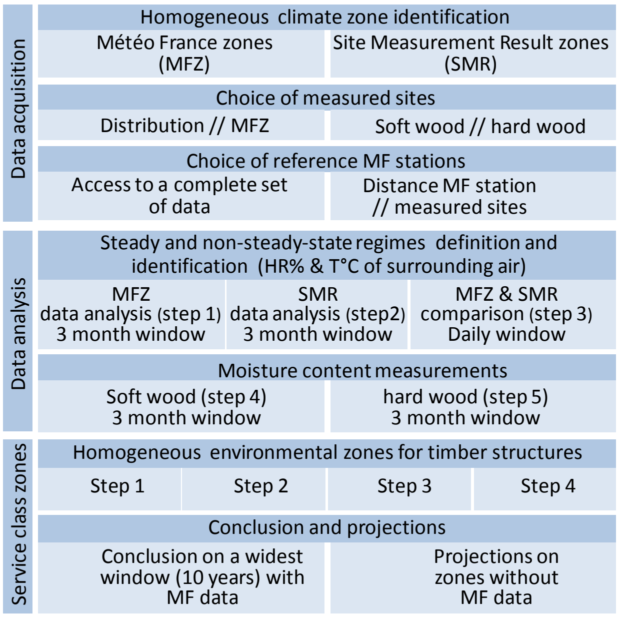

Figure 4: *Experimental methodology*

3.1 DATA ACQUISTION

The acquistion of data is based on two sources:
- the set of measurement given by Meteo France stations (principaly Relative Humidity*HR%* and temperature θ of surrounding air, some other parameters are available but not studied here),
- measurements on sites of the same parameters and also wood moisture content.

Some of the sites are chosen to be very close to MF (less than 800 m) in order to compare *HR%* and θ coming from MF measurements and *BD971* records.

In order to cover all these sites, regarding the duration and the financial envelop of the *BD971* project, the choice is made to investigate each site twice a month during 13 months with a manual measurement equipement. This equipment is presented on figure 5.

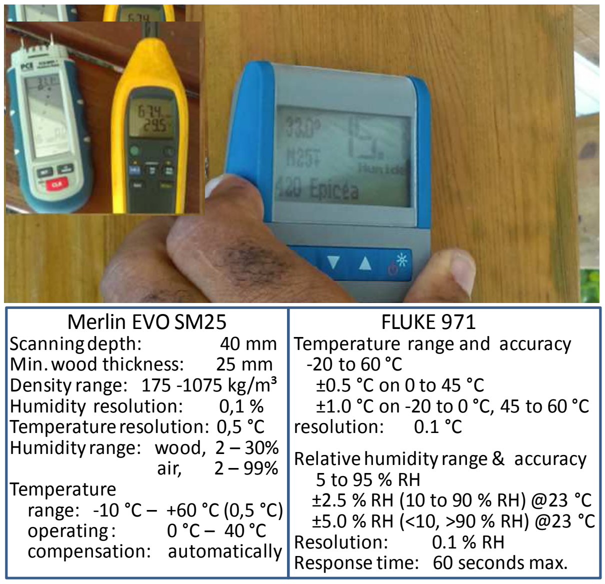

Figure 5: *Measurement equipment for HR%,* θ *and MC*

3.2 DATA ANALYSIS

The Data analysis is divided in few steps. The step 1 consist to determine the wood moisture content regarding (*HR%* and θ°*C* of air) obtained by MF. The aim of step 2 is the same regarding *HR%* and θ°*C* obtained by measurments on sites. The moisture content is calculated with the equilibrium moisture content diagram integrated in NF EN1995-1.1/NA [8]; this diagram is reported in figure 6. Step 3 is devoted to the comparison and the compatibility (or consistency) of these two approaches.

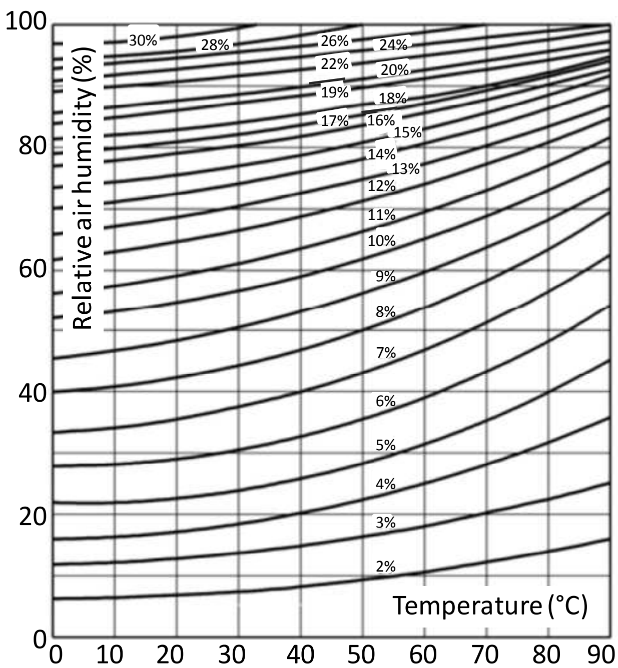

Figure 6: *Equilibrium Moisture Content EMC of wood [8]*

In steps 4 and 5, wood moisture content, respectively on soft woods and hard woods, are measured on sites and analysed.

Finally, The results of these different steps of sudy are compared and synthetised in order to obtain homogeneous environmental parameter zones for timber constructions.

3.3 SERVICE CLASS ZONES

This stage is the final objectif of the project. In order to have a wide set of data, different axis of information are investigated. MF data covers a large period, few decades but they are limited to the number of MF available station. BD971 data covers a narow period (12 months for the different sites) but a wide area with a large number of sites and buildings. They integrate environmental data but also Moisture Content.
To complete these measurements, two other main actions are conducted:
- one site is equiped with three monitoring sensors (HR%, θ °C, MC) for 10 months .
- specimens of wood are sawn on sites and studied for species analysis and physical parameters determination on one hand and for the other hand, specimens are placed in an environmental test chamber to have adsorption-desorption caracterisics of these wood to valid (or not) the equilibrium moisture content (EMC) diagram presented in figure 6. This EMC diagram is mainly related to soft wood. Figure 7 gives an illustration of the complementarity of these investigations.

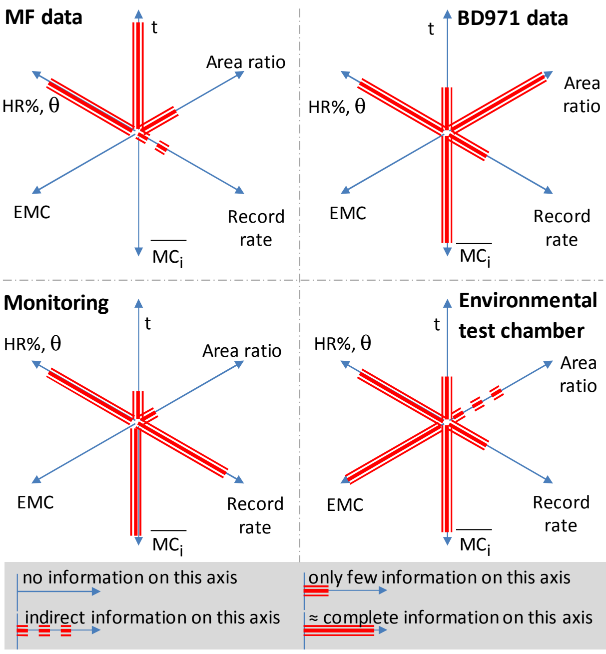

Figure 7: Complementarity of investigations

4 FIRST RESULTS

4.1 DATA ACQUISITION RESULTS

4.1.1 Measurement equipment calibration

Relative humidity and temperature of surrounding air are measured with Temperature Humidity meter FLUKE 971. Moisture content, capacity non destructive measurement, is obtained by a MERLIN EVO SM 25. The calibration of Fluke apparatus is obtained by comparison with MF values and MF Pattern ships. The calibration of Merlin Apparatus is based on comparison between Merlin values and direct MC measurement on specimens sawn on few sites [4].

For temperature and relative humidity of air, the calibration is performed by comparison between MF and BD971 sets of data for close sites and MF stations (distance less than 800 m and difference of altitude less than 30 m). Figure 8 gives an example of this comparison. Figure 8-a presents the raw results; some results (≈26/03 and ≈25/07) give temperature above the MF maximum value for the day. If we take into account the period of BD971 measurements (AM or PM), a corrected value of temperature (difference of average MF and BD971 values) can be defined. This correction for this example is -3.6 °C. Corrected results are plotted on figure 8-b. BD971 values of temperature are strictly included between minimum and maximum MF temperatures and they are above average temperature when BD971 measurements are performed post meridiem, and blow for AM measures.
These calibrations (temperature and relative humidity) will be finalized at the end of the program with all the data.

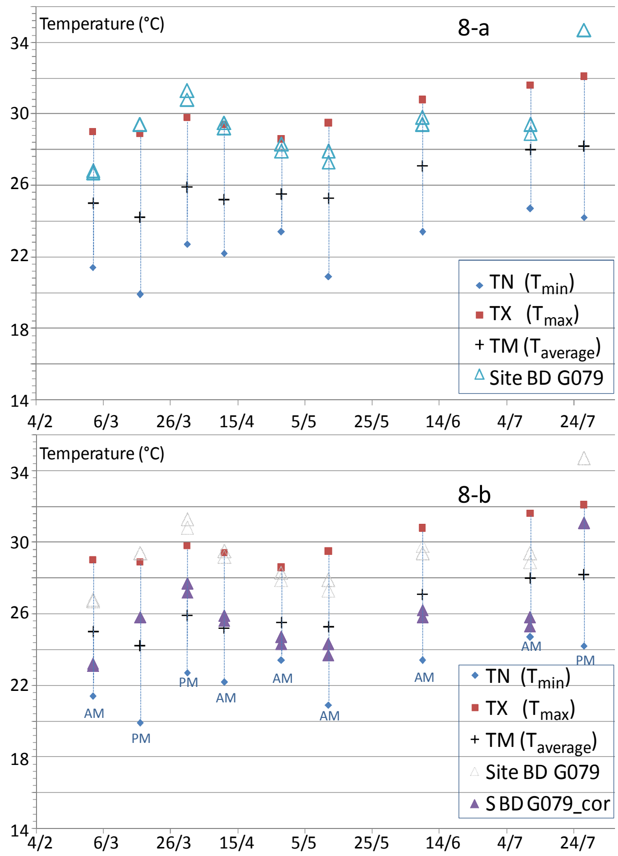

Figure 8: Example of temperature measured by MF and BD971 during 6 months for G079 & MF015 LeRaizet Aero (distance ≈ 800 m, ≠ altitude 30 m) - 8-a row results - 8-b values after calibration

4.1.2 Measurement results

There are a lot of singular parameters who can studied in this project and can influence the final result.
We noted five principal parameters:

- Wood species
- Maritime location : influence of the sea wind
- Mountains location and valley back ground (forest and river)
- Coating of elements: painting or not
- Massiveness of elements measured

One of the main parameters affecting our results is the location of the site: mountain or maritime environment. We based our study on the "bus stop" located in different sites and made with same timber structure and species (Angelim Vermelho).

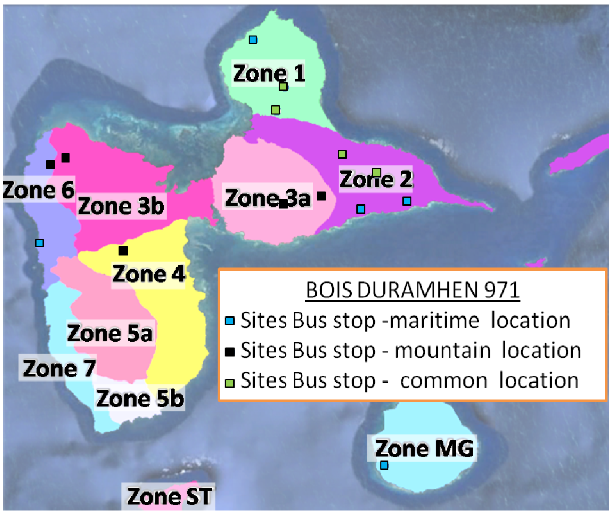

Figure 9: *Locations of some studied Sites Bus stop*

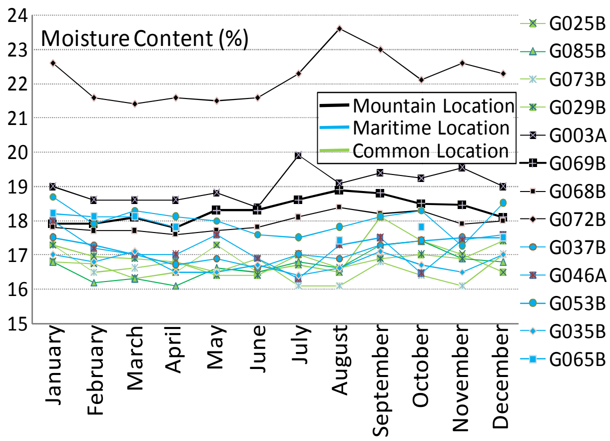

Figure 10: *Experimental measured Hard wood moisture content for Bus stop sites (cf. fig 9 for locations)*

The Bus stop sites located on Mountains or valley back ground are wetter than those located in common location. As shown on figure 10, for hard wood, the consequences of maritime wind do not drive to lower MC than for common location.

4.2 DATA ANALYSIS

For each MFZ, wood moisture content is calculated (EMC) – Equilibrium Moisture Content – and measured (MC) – instantaneous Moisture Content –. A month average value is firstly considered; figure 11 gives an example of results for MFZ 7 and MFZ 2. In MFZ 4, the coast is oriented on Atlantic Ocean, the altitude varies in a wide scale; MFZ 4 is the one where quite different values of MC are obtained [5] (figure 12); all these parameters can explain the different obtained values. The MFZ 4 in this area should be separated in two or three homogeneous environmental parameter zones. Actually twelve month of measurements are available only for sites and final results needs the complete results to conclude [6].

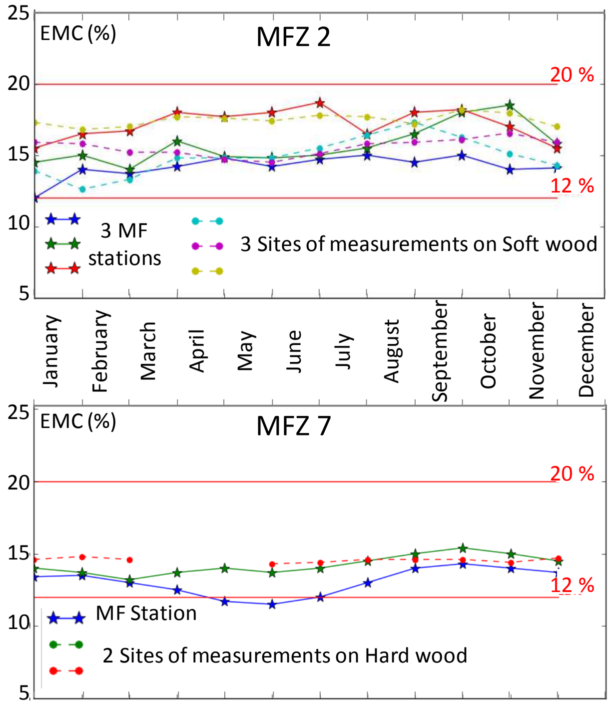

Figure 11: *Experimental calculated and measured wood moisture content for stations and sites in MFZ 2and MFZ7*

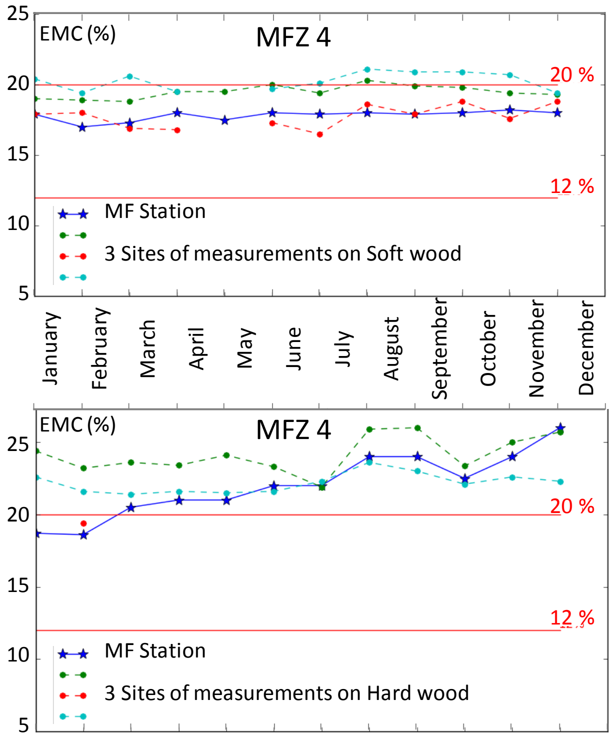

Figure 12 *Experimental Calculated and measured wood moisture content for stations and sites in MFZ 4*

4.3 SERVICE CLASS ZONES

In order to define service classes, all the results, as shown for example on figures 11 and 12 are analyzed now. The average values of MC and the difference between the minimum and the maximum during one year are taken into account. First results can be illustrated on figure 13. The altitude is an important parameter, such as forest environment. The biggest zone identified as service class 3 is the principal mountain of the island. The smallest, corresponds to an area with brittle and significant variations of altitude; the bottoms of valleys are particularly wet and wood MC is higher than in other zones.

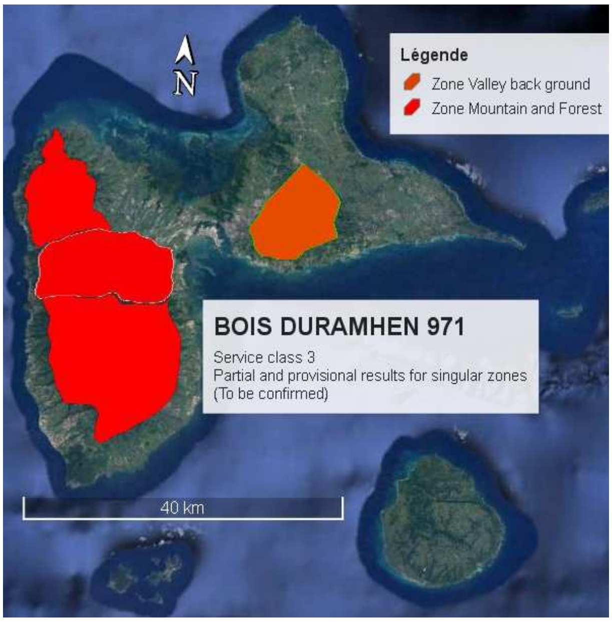

Figure 13 *First proposal for geographic zones to be classified as Service Class 3*

5 CONCLUSIONS

The results obtained by the different approaches, the comparison of measurements, the calibration of measurement equipments conduct to a wide data base and give interesting projections. On most of the MF stations and the different sites, the calculated and measured moisture content values fit well inside a MFZ. In this case, service class zone might be clearly defined. In other zone(s), the service class determination have to be more detailed and deepened in order to propose a more precise map. The variation of MC during the year should be determinant for that. The work presented here will be continued until the end of 2018. Parameters such as Wind could be taken in account and its influence can be more or less important regarding softwood or hardwood. Equilibrium Moisture content diagram should be also modified for hardwood; the actual test on environmental chamber might produce this kind of information. It will be also completed by a similar work for Martinique island.

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REFERENCES

[1] Quistin P. et al: Bois Duramhen 972 - Technical report, methodology of study, Août 2017,

[2] Bargy J.-M.: Etude de l'humidité du bois mis en œuvre dans son environnement - application et expérimentation dans la Région Guadeloupe 971. Master thesis: civil engineering. Clermont-Ferrand: Polytech, 2017.

[3] Quistin P. et al: Présentation Bois Duramhen 971 - GDR 3544 Wood Sciences meeting - Bordeaux, november, 2016

[4] Peterson, C.: Hand Held Moisture Meters . Symposium Report, Fort Lauderlale, 2008.

[5] Christian Brévignon: Atlas climatique, l'environnement atmosphérique de la Guadeloupe, de Saint-Barthélemy et Saint-Martin. Météo France, 92 pages, 2005.

[6] Lamadon Th.: Taux d'humidité et panneaux dérivés en service, Note de cadrage-Bois Duramhen 971, 5 pages, 2017

[7] Météo France :Fiche climatologique ZMF 2-station Lauréal Moule

[8] CEN TC 250 / P21 A. Eurocode 5.1.1 French national annex. 10 pages, April 2007