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ESTUDO DA VARIABILIDADE DO REGIME DE VENTOS NO AMBIENTE MICRO URBANO DAS CIDADES DE ARRAIAL DO CABO E SÃO PEDRO DA ALDEIA DO ESTADO DO RIO DE JANEIRO COM USO DA LÓGICA FUZZY

ROBERTO ROSENHAIM

MACAÉ/RJ

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Dissertação apresentada ao Programa de Pós-Graduação em Engenharia Ambiental do Instituto Federal Fluminense de Macaé, como requisito para obtenção do título de Mestre em Engenharia Ambiental, área de Fontes Renováveis, Conservação e Uso Eficiente de Energia, linha de pesquisa Desenvolvimento e Sustentabilidade.

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Marvin Minsky

RESUMO

O objetivo deste trabalho é o estudo da variabilidade dos ventos em ambiente micro urbano para microgeração de energia elétrica que possa ser produzida com uso de aerogeradores que utilizam rotores de eixo vertical, sendo utilizada lógica *fuzzy* para aferição dos locais. O local de estudo foram as cidades de Arraial do Cabo e de São Pedro da Aldeia localizadas na Região dos Lagos do estado do Rio de Janeiro. Para Amarante (2002), é historicamente inegável o potencial eólico do Estado do Rio de Janeiro sendo este já aproveitado no passado pelo uso de cata-ventos para bombeamento de água nas salinas da Região, dentre os principais centros de consumo destacam-se os municípios de São Pedro da Aldeia com capacidade de geração eólica em torno de 82 GWh e Arraial do Cabo com 44 GWh. Segundo Wagner Granja Victer (2002), no Atlas Eólico do estado do Rio de Janeiro, tanto o Norte Fluminense quanto a Região dos Lagos apresentam os melhores potenciais eólicos para geração de energia eólica. Para realização do trabalho foram realizadas pesquisas de campo e coleta de dados, procurando-se obter diferentes perfis do ambiente urbano afim de determinar quais os melhores locais para instalação de aerogeradores de eixo vertical em áreas residenciais ou comerciais para microgeração de energia no ambiente urbano. O estudo está dividido em três partes: uma apresentação com revisão bibliográfica sobre a importância e o crescimento do uso de fontes de energias renováveis, seguido do primeiro artigo que teve uma versão preliminar publicada no *International Workshop on Simulation for Energy, Sustainable Development & Environment* (SESDE2015) e sua versão definitiva, a qual é apresentada nessa documentação, publicada no Boletim do Observatório Ambiental Alberto Ribeiro Lamego, Campos dos Goytacazes/RJ, v.9 n.2 , neste artigo é apresentado o processo de construção do sistema fuzzy, cujas variáveis foram determinadas por pesquisas bibliográficas de outros trabalhos já publicados; no segundo artigo, submetido a ICEBESE 2016 : 18th *International Conference on Environmental, Biological, Ecological Sciences and Engineering*, foram coletados dados de diferentes locais dentro das cidades foco do estudo e apresentados os melhores pontos com o uso do algoritmo criado, tendo como produto um mapa gerado por um aplicativo para smartphones. Todos os pontos marcados possuem coordenadas geográficas e as características físicas ao seu redor, variáveis *fuzzy* criadas nesse estudo, gravadas em um banco de dados. Todas as variáveis de cada ponto foram processadas pelo algoritmo *fuzzy* apresentando como resultado final o perfil de adequabilidade eólica de cada ponto.

Palavras-Chave: Potencial eólico. Variáveis linguísticas. Sistema *Fuzzy*.

ABSTRACT

The objective of this work is the study of the variability of wind in urban environment microgeneration of electricity which can be produced with the use of wind turbines using vertical axis rotors, being used fuzzy logic to scouting locations. The study site were the cities of Arraial do Cabo and São Pedro da Aldeia located in the Lakes Region of the state of Rio de Janeiro. To Amarante (2002), is historically undeniable the wind potential of the state of Rio de Janeiro which is already exploited in the past by the use of windmills for pumping water in the salt mines of the region, from the main consumption centers stand out municipalities São Pedro da Aldeia with wind generation capacity of about 82 GWh and Arraial do Cabo with 44 GWh. According to Wagner Victer Granja (2002),in the Wind Atlas of the state of Rio de Janeiro, both the North Fluminense as the Lakes Region have the best wind potential for wind power generation. To carry out the work were carried out field research and data collection, seeking to obtain different profiles of the urban environment in order to determine the best locations for vertical axis wind turbine installation in residential or commercial areas for microgeneration in the urban environment. The study is divided into three parts: a presentation with literature review on the importance and growing use of renewable energy sources, followed by the first article that had a preliminary version published in the International Workshop on Simulation for Energy, Sustainable Development & Environment (SESDE2015) and its final version, which is presented in this documentation, published Bulletin of Environmental Observatory Alberto Ribeiro Lamego, Campos dos Goytacazes / RJ, v.9 n.2, this article shows the construction process of the fuzzy system, whose variables wich were determined by literature searches of other studies published; on the second article submitted to Renewable Energy journal and ICEBESE 2016: 18th International Conference on Environmental, Biological, Ecological Sciences and Engineering, data were collected from different locations within the cities focus of the study and presented the best spots using the created algorithm , as a result a map was generated by an application for smartphones. All points scored have geographic coordinates and physical characteristics around, fuzzy variables created in this study, recorded in a database. All variables of each point were processed by the fuzzy algorithm presenting as a final result the wind suitability profile of each point.

Keywords: Wind potential. Linguistic variables. Fuzzy system.

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ABEEólica - Associação Brasileira de Energia Eólica

AIE - Agência Internacional de Energia.

Aneel - Agência Nacional de Energia Elétrica.

GNU - General Public License.

ICEBESE - International Conference on Environmental, Biological, Ecological Sciences and Engineering

LIDAR - *Light Detection and Ranging.*

MME – Ministério de Minas e Energia

PCH - Pequenas Centrais Hidrelétricas.

PROELICA - Programa Emergencial de Energia Eólica

ProGD - Programa de Desenvolvimento da Geração. Distribuída de Energia Elétrica

PROINFA - Programa de Incentivo às Fontes Alternativas de Energia Elétrica .

SESDE - *Simulation for Energy, Sustainable Development & Environment*

SUMÁRIO

APRESENTAÇÃO

A crise do petróleo no final dos anos sessenta e início da década de setenta intensificou questionamentos quanto a participação do homem no planeta além da reflexão acerca das futuras gerações, tal preocupação define-se como um dos conceitos de desenvolvimento sustentável segundo Brundtland apud Scharf, (2004). Esse fato permitiu o aumento das pesquisas quanto a pensamentos políticos, sociais e filosóficos.

Conforme Barbosa (2008) cita em seu trabalho, o relatório de Brundtland chamou a atenção do mundo sobre a necessidade de se encontrar novas formas de desenvolvimento econômico, sem a redução dos recursos naturais e sem danos ao meio ambiente. Seguindo essa linha que é apresentado o estudo do potencial energético do vento, gerado no interior das cidades e com isso as possibilidades do uso de torres eólicas verticais em áreas urbanas, as quais devido a inúmeras dificuldades, tem seu potencial inúmeras vezes mal utilizado de acordo com pesquisa de Millward-Hopkins (2013).

Há necessidade do crescimento econômico das nações para o aumento do bem-estar das pessoas, embasado nesse fato, foi assinado em 21 abril de 2016, o tratado da Convenção-Quadro das Nações Unidas sobre a Mudança do Clima (UNFCCC - sigla em inglês), negociado durante a 21ª Conferência das Partes (COP21) que rege medidas de redução de emissão dióxido de carbono a partir de 2020 (AMORIM, 2015). Para tanto há um esforço mundial entre as nações, incluindo programas e projetos de redução da emissão de CO^2 na atmosfera incentivado pelo uso cada vez maior das energias limpas.

Para que o PIB possa aumentar nos países em desenvolvimento, existe a necessidade da produção de mais energias, tendo em vista que países subdesenvolvidos produzem menos energia que os países desenvolvidos, ainda nesse cenário existe a necessidade do compromisso dos Governos e o interesse do poder público através de incentivos governamentais. No Brasil programas como o Programa de Desenvolvimento da Geração Distribuída de Energia Elétrica de 15 de dezembro de 2015 (Progd), tem como objetivo incentivar à geração de energia pelos próprios consumidores com base em fontes renováveis outro programa é o Programa de Incentivo às Fontes Alternativas de Energia Elétrica (Proinfa), o qual incentivou o uso cada vez maior de fontes alternativas de energias limpas como a solar e a eólica.

A indústria brasileira ainda é baseada em comoddities, agricultura, e quando há necessidade de crescimento usa-se mais energia, um problema encontrado quando se fala das novas metas de redução de emissão de gases do efeito estufa o que tornasse um grande desafio.

Outro ponto a ser levado em consideração é a necessidade do consumo consciente, sustentável também pelas pessoas.

O Brasil tem um importante papel no processo do acordo climático internacional, não só pelas suas dimensões continentais ou sua população, mas principalmente pelos recursos que possui e que podem vir a substituir a utilização dos combustíveis fósseis num prazo relativamente curto, pois tem condições para utilização de diversas fontes de energia como: eólica, solar, bioenergia entre outras tornando a sua matriz energética tão diversificada que não o torna dependente de um só recurso como ocorre atualmente em relação aos combustíveis fósseis ou a dependência em relação à energia obtida das hidrelétricas (EPE, 2016).

Segundo o Ministério de Minas e Energia o Brasil apresenta situação privilegiada em termos de utilização de fontes renováveis de energia. No país, 43,9% da Oferta Interna de Energia (OIE) é renovável, enquanto a média mundial é de 14% e nos países desenvolvidos, de apenas 6%. A OIE, também denominada de matriz energética, representa toda a energia disponibilizada para ser transformada, distribuída e consumida nos processos produtivos do País.

Nesse contexto encontra-se o uso de energia proveniente dos ventos e são recentes os estudos referentes ao regime de ventos em microclimas como os dos centros urbanos e topo de edificações.

Existe um grande número de parâmetros de incertezas gerados pela grande dificuldade de se estimar a real eficiência eólica dos ventos no regime micro urbano (J.T. MILLWARD-HOPKINS, 2013). Fontes de energia descentralizadas, como energia eólica em pequena escala, têm um número conhecido de vantagens, porém, em áreas urbanas, o potencial de geração de energia proveniente dos ventos não é completamente utilizado, sendo que uma das razões para isso é a complexidade dos fluxos de ar no interior da camada limite urbana as quais dificultam uma previsão precisa do recurso eólico.

Este estudo busca auxiliar na agilidade da avaliação das áreas urbanas para uso de fontes de energia eólica através do uso da lógica *fuzzy*.

Decisões humanas são de alguma forma baseadas nas expectativas, geradas a partir das vivências. Tanto os estímulos quanto as sensações catalisadas no mundo concreto, via verbalizações, podem ser operacionalizadas pela lógica *Fuzzy*, uma vez que são entes ambíguos (LANZILLOTTI,1999).

Para suprir as diferenças sutis no ambiente urbano e as incertezas dos modelos matemáticos comuns, foi utilizada a lógica *fuzzy* proposta por Loft Zadeh em 1965, modelo que pode gerar respostas a diversas questões considerando dados imprecisos e contraditórios, auxiliando na tomada de decisão.

Ainda segundo Arruda (2013) a lógica *fuzzy* permite modelar matematicamente a tomada de decisão humana de forma a incorporar as imprecisões características da linguagem natural e os aspectos subjetivos e qualitativos inerentes ao processo decisório em problemas reais.

Este método já foi utilizado em outros trabalhos como método de apoio a decisão conforme cita Malutta et al (2004) em sua tese de doutorado sobre adequação de aterros sanitários: A aplicação do Sistema de Gestão Ambiental em muito se simplifica com a implementação de um controle inteligente, através da lógica *fuzzy*, que vai contemplar aspectos imprecisos no raciocínio lógico utilizado pelos seres humanos, além disso Ganga et al (2011) em seu artigo sobre o uso da lógica *fuzzy* aplica à gestão do desempenho em cadeias de suprimentos: O emprego da lógica *fuzzy* na modelagem do mundo, atua como um mecanismo de predição de desempenho das variáveis de resposta (lagging), em função de determinados valores de entrada (leading), que são determinados por meio de estimação ou dados disponíveis.

Este trabalho está dividido em dois artigos o primeiro foi a criação do sistema baseado em lógica fuzzy através do uso da uma ferramenta XFUZZY de licença pública GNU desenvolvido pelo Instituto de Microeletrônica de Sevilha e possui integração com diversas ferramentas permitindo inclusive a exportação do código do sistema criado para uma linguagem de programação de alto nível como JAVA, segundo Golsing (2000) Java é uma linguagem de vários propósitos, baseada em classes e orientada a objetos e foi desenhada para ser simples o suficiente para que se possa programar com fluência, além de ser uma linguagem de alto nível , a mesma foi a base para integração com o aplicativo criado através da IDE *Android Studio* para desenvolvimento de aplicativos para smartphones que utilizam Android.

O artigo de Arruda et al (2013) fez uma análise comparativa de ferramentas computacionais para modelagem de lógica *fuzzy* e foi fundamental para escolha do *XFUZZY*, no seu artigo são avaliados diversos parâmetros que ranqueiam diversas ferramentas *fuzzy* e demonstram que a preferência pela ferramenta de Sevilha por se tratar de um software livre.

Foram criadas variáveis linguísticas para uso como entradas do sistema permitindo que o mesmo se aproximasse cada vez mais da linguagem natural do ser humano conforme Arruda et al (2013):

> Associados às **variáveis linguísticas** são usados **modificadores** na modelagem com o objetivo de conseguir maior semelhança com a linguagem natural. Sua função equivale àquela que os adjetivos e advérbios assumem na linguagem. Ou seja, da

> mesma forma que estes mudam as características de substantivos e verbos, os modificadores, na teoria dos conjuntos nebulosos, alteram a forma das funções de pertinência, transformando um conjunto nebuloso em um novo conjunto.

Para determinação e calibração das variáveis linguísticas foram utilizados diversos artigos de análises anteriores referente à aspectos que podem influenciar o regime de ventos no ambiente urbano dentre eles Brazel (1987) e Oke (1988).

Brazel (1987) cita que as condições do vento na camada interurbana são muito complexas e dependem de barreiras físicas, tamanho e orientação de prédios, densidades de ocupação e padrões gerais de uso do solo. Os fortes ventos regionais predominantes e a rugosidade aerodinâmica da cidade são importantes para geradores de turbulências, enquanto que, os ventos fracos, as diferenças de pressão e efeitos de estabilidade atmosférica, em adição à rugosidade, são críticas na determinação de ventos urbanos de local para local.

Para Oke (1988), o parâmetro superficial crítico que governa a produção de turbulência do fluxo perpendicular a vales urbanos é a rugosidade da superfície. Quanto maior a rugosidade, maior a intensidade da interferência e a influência do atrito como, por exemplo, a adição de prédios que pode interferir de acordo com a proximidade das edificações.

No segundo artigo foi utilizado o sistema de inferência *fuzzy*, criado e integrado a um aplicativo de mapeamento para *smartphones* que utilizam *Android* com intuito de permitir a gravação e exportação dos dados de um banco de dados como o *SQLITE* o qual permitiu a avaliação dos pontos observados pelo algoritmo criado com as variáveis linguísticas e suas diversas regras de inferência *fuzzy*.

O estudo apresentado pode gerar dúvidas a respeito de outras variáveis que não foram consideradas as quais são também encontradas no ambiente tais como: umidade relativa do ar, temperatura, aspectos sazonais, medição da velocidade dos ventos em diferentes altitudes, assim como aspectos relativos ao problema do limite de aproveitamento da energia cinética dos ventos, conhecido como lei de Betz. Esses aspectos podem ser considerados como entradas para outros trabalhos, inclusive no sistema *fuzzy* criado, dando continuidade à pesquisa aqui iniciada podendo gerar outros resultados que podem ser comparados com o estudo atual.

ARTIGO CIENTÍFICO 1

Fuzzy Inference About Wind Resources in Urban Environment[1]

Inferência Fuzzy para Identificar recursos eólicos em ambiente urbano

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Thaiane Fagundes de Araújo Holanda[****]

Abstract

Technological advances allow the use of small wind towers within urban areas. It is difficult to choose the best place to set up such facilities because wind regime in micro regions suffers many influences of the surrounding environment. A wind tower may be installed and will not work properly. A fuzzy inference system dealing with this issue needs to pick up the factors that most impact the wind regime in micro urban environment. Also it uses data from the wind regime of a larger region surrounding the site. The system outputs an adequacy rank for sitting the wind tower.

Keywords: Wind energy. Artificial intelligence. Renewables.

Resumo

Os avanços tecnológicos permitem o uso de pequenas torres eólicas em áreas urbanas. É difícil escolher o melhor local para montar esse tipo de estrutura porque o regime de vento em microrregiões sofrem muitas influências do entorno ambiental. Uma torre eólica pode ser instalada e não funcionar de forma adequada. Um sistema de inferência difusa que lida com essa questão precisa captar os fatores que causam maior impacto no regime de ventos no microambiente urbano. O sistema também usa dados do regime de ventos de uma região mais ampla em torno do local. O sistema produz uma classificação para localização da torre.

Palavras-chave: Energia eólica. Inteligência artificial. Recursos renováveis.

1. Introduction

Wind energy extraction possibilities within cities are a challenging but promising research issue. It features opposite scenery to large wind farms. In the last quoted, the required great investment and the power extracted from the plant justify long-term measurement seasons, usually two or three years. As mentioned by Lange et al. (2006), in the urban environment with the prevalence of stand-alone, small turbines and custom installations for few users, a rather different approach is required. Shorter

[1] Artigo publicado no Boletim do Observatório Ambiental Alberto Ribeiro Lamego, Campos dos Goytacazes/RJ, v.9 n.2, p. 107-123, jul./dez. 2015 (http://www.essentiaeditora.iff.edu.br/index.php/boletim/article/view/5926/5236)
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measurement sessions and faster investing / equipment installation decisions are necessary, notwithstanding being essential to take into account several.

Among these factors one can quote not only an obvious macroclimatic characterization of the wind regime but also a series of uncertain, fuzzy parameters hard to define accurately in an analytical way. Considering a single building where a wind turbine is supposed to be set up, the area surrounding it has many influencing factors according to Caldas (2010): nearby buildings concentration or scattering, height and shape variation of the constructions, changing of wind directions, displacement heights etc.

Taking into account the importance of knowing wind potential for urban planners, turbine manufactures, as well as for potential consumers, this research investigates a possible simpler approach for in-site wind resource estimation. It resembles the 'measure-correlate-predict' approach described by Landberg et al. (2003) but expects to replace the statistical correlation tools by a fuzzy inference one.

When traditional logical concepts are not able to assess adequately the desired parameters, fuzzy logic allows the use of vague concepts, expressing qualitative information form. To address these questions in the environment of uncertainties inherent in the mathematical models, the use of fuzzy logic proposed by Loft Zadeh in 1965 (ZADEH, 1965) fits well. It may be used to generate answers to several questions considering imprecise and contradictory data.

A recent study in the United Kingdom (MILLWARD-HOPKINS, 2013) has determined some parameters that influence the wind regime in the environment of large cities. This was done through the use of a complex data modeling with detailed geometric description of buildings and vegetation. Calculations of aerodynamic characteristics of wind regimes were performed and integrated to LIDAR (light detection and ranging) system that allowed describing and predicting the wind efficiency of the studied sites. In another research concerning urban sites, Caldas (2010) used the WindPro and WaSP software for modeling the wind regime. In this study it was noticed the need of using input data such as terrain models, roughness and buildings characteristics, which may be fuzzyficated for possible use in fuzzy systems. In the results of Millward-Hopkins studies (2013), it was suggested that the possible locations of wind turbines within a city can differ greatly concerning suitability:

> The results suggest that there are viable sites distributed thought the city, including within the complex city centre, where at the most suitable locations above-roof Wind speeds may be comparable to those observed at well exposed rural sites. However, in residential areas, consisting of groups of buildings of similar Heights, it is likely that the majority of properties will be unsuitable turbine locations. (MILLWARD- HOPKINS, 2013).

For the calibration of the fuzzy inference model using XFUZZY tool, it was necessary to create variables that could be transformed into linguistic variables, based on those that are most likely to influence the wind regime within the urban environment. The second part of this paper describes the methodology for designing the system and its outputs. Using wind data from weather station of Arraial do Cabo (Rio de Janeiro / Brazil), one may determine that according to the statistical techniques that region has an adequate potential for installing wind towers. A portable anemometer was used and measurements were taken in a short period of time at three different sites (points 1, 2 and 3 further described). These measurements were compared with those from an automatic anemometer nearby installed. It was sought to demonstrate how the variables may have some influence on the suitability for installation of wind towers and subsequent calibration of the system. In the last part of the paper the measurements are shown, as well as tables' inserts and system outputs so in the subsequent section a pre-completion of recently done studies in the region can be presented.

2. Methodology

The methodology relies on three cornerstones. At first, wind regime of a given region, obtained from large scale wind atlas is taken into account through the extraction of Weibull distribution. A simpler and faster gathering of wind regime corresponding to data acquired from an anemometer inside urban area is also considered, producing its own Weibull distribution. At a second step, the anemometer installation site, which is also a candidate location for turbine placement, is described through fuzzy sets that express the location adequacy. Finally rules relating macro and local wind distribution along with location adequacy are established for fuzzy inference purpose and processed by fuzzy inference toolkits.

2.1 Weibull Distribution from Wind Dataset

In order to describe wind potential in a given region, a well-established procedure is the use of Weibull probability distribution (DAL MONTE et al., 2012). In this work the R statistical software package 'bReeze' (GRAUL and POPPINGA, 2014) was used. Data were obtained from the automatic weather station Arraial do Cabo in the state of Rio de Janeiro, Brazil (Arraial do Cabo-A606 Code OMM: 86892 Latitude: -22.975468º Longitude: -42.021450º Height:
3 meters. Register: 23 UTC) (Figure 1). The data are based on the year 2014 from January to December. The results are shown in Figure 2 below, extracted from the data series of case study region, the resulting Weibull distribution characterizes the wind regime on the site and can directly be used for the calculation of the potential energy production of a wind turbine (GRAUL, 2015).

Figure 1 - Automatic weather station Arraial do Cabo
Source: authors (2015)

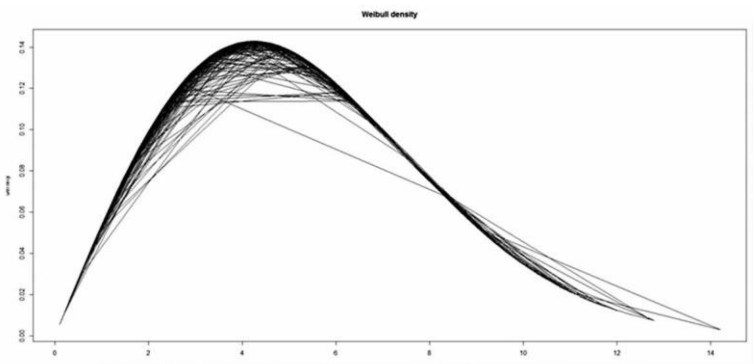

Figure 2 - Weibull density from study region dataset using bReeze package functions for wind resource assessment
Source: authors (2015)

2.2 Fuzzy Inference Rules

One of the major differences of using fuzzy inference systems is the possibility of using linguistic terms to demonstrate what one sees in reality.

> A linguistic variable u in the universe of discourse U is defined in a set of terms (or terminology), names or label, T (u), with each value being a fuzzy number set in U. For example, if u is speed, then its set of terms T (u) could be: T (speed) = {low, medium, fast} on the universe of discourse U = [0.100], where low, medium, fast, are terms or language of greatness variable speed. (SIMÕES; SHAW, 2007).

Barriga et al. (2006) show that the specification of the system can be obtained from the knowledge expressed by an expert or it can be provided by a set of numerical data, for this a possible design flow is depicted in Figure 3.

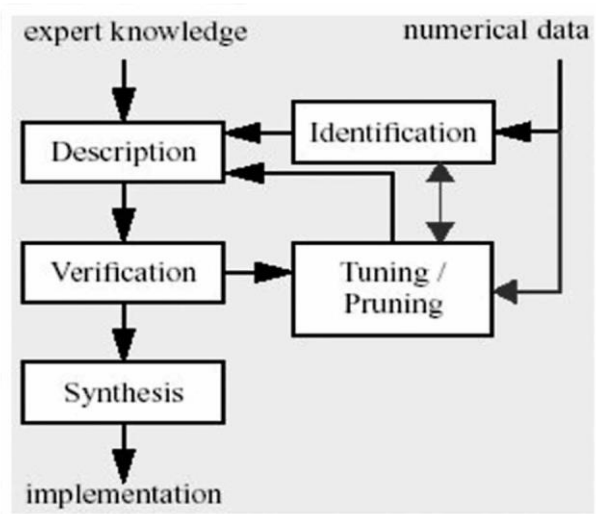

Figure 3 - Design methodology for Xfuzzy system
Source: Barriga et al., 2007

According to Barriga et al. (2006), the development environment for fuzzy system, Xfuzzy, does not impose any design methodology but it allows adapting the needs of the designer for a particular purpose. Also according to the author, the specification of the system can be obtained from the knowledge expressed by an expert or it can be provided by a set of numerical data to design the system for suitability for use vertical wind towers in urban areas was necessary to build sets of variables as follows.

Based on Beaufort scale (LISKA et al., 2013) - shown in Table 1 – was created fuzzy type *TVelocidadeVentos* (wind speed), this type of variable is necessary for use with fuzzy system in Xfuzzy:

> A linguistic variable is defined in Xfuzzy 3 by using a type object. This definition includes the name of the type, the description of the universe of discourse (its limits and discretization), the list of associated linguistic labels, and their related membership functions. Until now, membership functions had to be "free" functions selected from a package, that is, they were defined independently and could not be explicitly related among them. (BATURONE et al., 2007).

The type *TVelocidadeVentos* has its variables defined in Table 2 and its membership function is show in Figure 4.

> A family of membership functions optimization degree obtained with free functions, due to the imposed constraints. In general, free membership functions are more appropriate to describe output variables, while families of membership functions
>
> are specially indicated to describe input variables. A good practice is to use free membership functions for variables for which no much information is available, then perform an automatic tuning or identification process to acquire some knowledge about it, and, finally, use this information to employ a suitable family if possible. (BATURONE et al., 2007).

Table 1 - Beaufort scale

Degree	Type	m/s	Ground effect
0	Calm	<0,3	Smoke rises vertically
1	Breeze	0,3 a 1,5	Smoke indicates wind direction
2	light breeze	1,6 a 3,3	The leaves move; mills start working
3	light breeze	3,4 a 5,4	Leaves flutter-and unfurl flags in the wind
4	moderate breeze	5,5 a 7,9	Dust and small raised roles; move the tree branches
5	strong breeze	8 a 10,7	Movement of large branches and small trees
6	fresh wind	10,8 a 13,8	Moving large trees; difficulty walking against the wind

Source: Liska et al., 2013

Table 2 - Fuzzy Variables based on Beaufort scale

Degree	Type	m/s	*Fuzzy variable*
0	Calm	< 0,3	mf0Calmo
1	Breeze	0,3 a 1,5	mf1Aragem
2	light breeze	1,6 a 3,3	mf2BrisaLeve
3	light breeze	3,4 a 5,4	mf3BrisaFraca
4	moderate breeze	5,5 a 7,9	mf4BrisaModerada
5	strong breeze	8 a 10,7	mf5BrisaForte
6	fresh wind	10,8 a 13,8	mf6VentoFresco

Source: authors (2015)

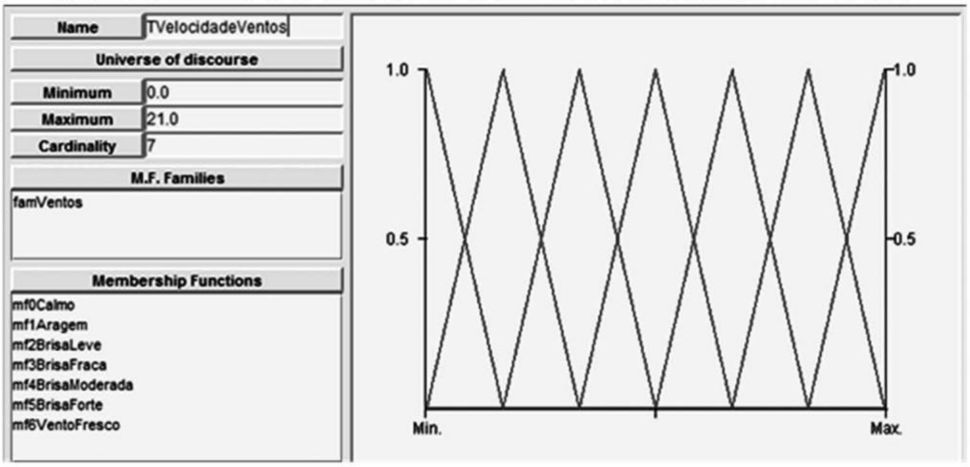

Figure 4 - A family of membership functions (BATURONE et al., 2007) for TVelocidadeVentos represented in XFUZZY based on the variables of the Beaufort scale (LISKA et al., 2013)

Source: authors, (2015)

From Troen (1989) roughness table that clusters terrain features in roughness classes (Table 3), the type Roughness' Land as *TRugosidade* was estabilished, as presented in following Table 4 and Figure 5.

Table 3 - Scale Roughness Land

z0	Terrain features	Class roughness
1,00	City	3
0,80	Forest	
0,50	outskirts	
0,40		
0,30	belts of trees	
0,20	trees and shrubs	2
0,10	farm with closed vegetation	
0,05	farm with open vegetation	
0,03	farm with few trees / buildings	1
0,02	areas of airports with buildings and trees	
0,01	areas of airport runways	
0,008	meadow	
0,005	plowed soil	
0,001	Snow	
0,0003	Sand	
0,0002		
0,0001	water (lakes, rivers, oceans)	0

Source: Caldas (2010)

Table 4 - Fuzzy variable based on roughness degrees

Class roughness	fuzzy variable
3	mf3AltaCidadeFlorestaSuburbios
2	mf2MediaAreaComArvoresArbustos
1	mf1MediaPastoAeroportosFazenda
0	mf0BaixaAreiaNeveAgua

Source: authors, (2015)

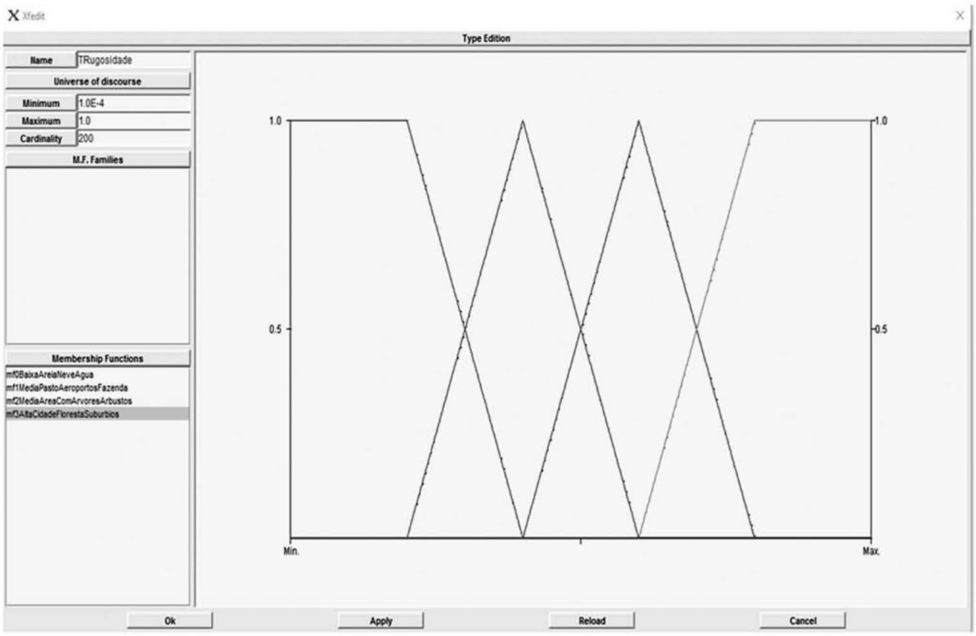

Figure 5 - membership function for type TRugosidade in XFUZZY

Source: authors, (2015)

The orography is one of the most important elements in the characterization of the atmospheric flow, according to Caldas (2010). For this *TOrografia* type was created consisting of

- mf0TerrenoPlano
- mf1ElevacoesDecliveSuave
- mf2TerrenoMontanhoso

Also were created the types:

1. *TProximidadeConstrucoes*: (proximity to buildings)
- mf0Distantes
- mf1Proximas
- mf2MuitoProximas

2. *TAlturaConstrucoes:* (height of buildings)
- mf0Baixa
- mf1Media
- mf2Altas

3. *TAlturaLocalInstalacao* : (instalation height)
- mf0Baixa

- mf1Media
- mf2Alta

4. *TAdequabilidade:* (suitability)
- mf0Baixa
- mf1Media
- mf2Alta

According to Shaw (2007), systems that use symbolic language end up requiring high computational demand, which does not occur with systems using fuzzy, as demonstrated by inference variables created. Thereby the computational analysis process becomes faster and simplified, the author talks about the nature which is indifferent to efforts to seek mathematically model their processes within which there is a certain difficulty in this, as in the case of a human operator this process becomes more streamlined. Fuzzy logic tends to behave as deductive reasoning through semantic examples that may present conclusions based on already known information, the example is the use of fuzzy controllers that can be independent and perform complex tasks without the intervention of external operators. Fuzzy logic allows data collection experts thus enabling the creation of an intelligent system to support decision based on characteristics of human intelligence.

A total of 86 inference rules were created for system tests, figure 6 demonstrates the creation of the rule bases that contain the expressions of the logical relations between the linguistic variables of the system. The XFL3 language can describe very complex relations between the variables by combining basic propositions (which compares the value of a variable with a linguistic label) via connectives and linguistic hedges (VELO et al., 2003), the Xfuzzy 3.0 provides the user a tool for software synthesis that represents the system as Java class (VELO et al., 2003) as shown in the Figure 7.

> The window for editing rule bases on xfedit presents three formats for the rule definition: matrix form, table form and free form. The matrix form constricts the rule base to two inputs and one output, and shows the rules in a compact form as a matrix. Each matrix element represents a rule like «if a is A & b is B then c is C». The table form is valid for any number of inputs and outputs, and each element of the table represents a rule like «if x0 is X0 & x1 is X1 & ... & xn is XN then z is Z». Finally, the free form allows exploiting the whole power of XFL3 to define complex relations like «if x0 is greater than X0 or not x3 is strongly equal to X3 then z is Z»" (VELO et al., 2003).

t		Rug		Orog		ProximConstr
f0...	&	Rug == mf0BaixaAreiaNeveAgua	&	Orog == mf0TerrenoPlano	&	ProximConstr == m...
f0...	&	Rug == mf1MediaPastoAeroportosFaz...	&	Orog == mf0TerrenoPlano	&	ProximConstr == m...
f0...	&	Rug == mf2MediaAreaComArvoresArb...	&	Orog == mf0TerrenoPlano	&	ProximConstr == m...
f0...	&	Rug == mf3AltaCidadeFlorestaSuburbios	&	Orog == mf0TerrenoPlano	&	ProximConstr == m...
f0...	&	Rug == mf3AltaCidadeFlorestaSuburbios	&	Orog == mf0TerrenoPlano	&	ProximConstr == m...
f0...	&	Rug == mf0BaixaAreiaNeveAgua	&	Orog == mf1ElevacoesDecliveSuave	&	ProximConstr == m...
f0...	&	Rug == mf0BaixaAreiaNeveAgua	&	Orog == mf2TerrenoMontanhoso	&	ProximConstr == m...
f0...	&	Rug == mf0BaixaAreiaNeveAgua	&	Orog == mf0TerrenoPlano	&	ProximConstr == m...
f0...	&	Rug == mf0BaixaAreiaNeveAgua	&	Orog == mf2TerrenoMontanhoso	&	ProximConstr == m...
f0...	&	Rug == mf0BaixaAreiaNeveAgua	&	Orog == mf0TerrenoPlano	&	ProximConstr == m...
f0...	&	Rug == mf0BaixaAreiaNeveAgua	&	Orog == mf0TerrenoPlano	&	ProximConstr == m...
f0...	&	Rug == mf0BaixaAreiaNeveAgua	&	Orog == mf0TerrenoPlano	&	ProximConstr == m...
f0...	&	Rug == mf0BaixaAreiaNeveAgua	&	Orog == mf0TerrenoPlano	&	ProximConstr == m...
f0...	&	Rug == mf0BaixaAreiaNeveAgua	&	Orog == mf0TerrenoPlano	&	ProximConstr == m...
f1...	&	Rug == mf0BaixaAreiaNeveAgua	&	Orog == mf0TerrenoPlano	&	ProximConstr == m...
f1...	&	Rug == mf1MediaPastoAeroportosFaz...	&	Orog == mf0TerrenoPlano	&	ProximConstr == m...

Figure 6 - Fuzzy Inference Rules created from XFUZZY with the window for editing rule bases on xfedit

Source: authors, (2015)

```java
public class SistemaAdequabilidadeEolica implements FuzzyInferenceEngine {

 //+++++++++++++++++++++++++++++++++++++++++++++++++++++//
 //  Rulebase RL_RegraAdequabilidade  //
 //+++++++++++++++++++++++++++++++++++++++++++++++++++++//

 private MembershipFunction[] RL_RegraAdequabilidade
 (MembershipFunction VelocVent, MembershipFunction Rug, MembershipFunction Orog,
 MembershipFunction ProximConstr, MembershipFunction AltConstr, MembershipFunction AltLocInstal) {
  double _input[] = new double[6];
  int _i_Adequabilidade=0;
  double _rl;
  _rl =
  _op.and(_op.and(_op.and(_op.and(_op.and(_t_VelocVent.mf0Calmo.isEqual(VelocVent),
  _t_Rug.mf0BaixaAreiaNeveAgua.isEqual(Rug)),_t_Orog.mf0TerrenoPlano.isEqual(Orog)),
  _t_ProximConstr.mf0Distantes.isEqual(ProximConstr)),
  _t_AltConstr.mf0Baixa.isEqual(AltConstr)),
  _t_AltLocInstal.mf0Baixa.isEqual(AltLocInstal));
  Adequabilidade.set(_i_Adequabilidade,_rl, _t_Adequabilidade.mf1NivelMedio);
  _i_Adequabilidade++;
  _rl =
  _op.and(_op.and(_op.and(_op.and(_op.and(_t_VelocVent.mf0Calmo.isEqual(VelocVent),
  _t_Rug.mf1MediaPastoAeroportosFazenda.isEqual(Rug)),
  _t_Orog.mf0TerrenoPlano.isEqual(Orog)),
  _t_ProximConstr.mf0Distantes.isEqual(ProximConstr)),
  _t_AltConstr.mf0Baixa.isEqual(AltConstr)),
```

Figure 7 - part of the Java code created from XFUZZY from rule base graphical design above using xfj module
Source: authors (2015)

2.3 Set of fuzzy logic tools

This study used a free access code tool GNU XFUZZY XML-based (MORENO VELO et al., 2012). This is JAVA programming language based tool. This kind of software allows integration with other systems, which can be useful in designing a decision support system that is available to all, as well as Juzzy is also a free also available (WAGNER et al., 2014).

3 Case Study

In order to test the proposed procedure, studies have been developed in the central eastern part of the state of Rio de Janeiro, Brazil. It was made a field investigation by consulting the wind atlas of the State of Rio de Janeiro (RIO DE JANEIRO, 2014); gathering anemometer data collection to characterize the chosen micro region (Figure 8) wind regime; and eventually site visit in 3 different points which have different nearby urban characteristics, but that are also close enough in order to proof urban environment interference concerning surrounding constructions, height of buildings, terrain and local roughness. This was done by measurement using a simple handheld anemometer, thus demonstrating how the new approach can simplify the process of investigation of the wind potential of a region with the use of a portable device, site observation and using the developed system that assumes the characterization of uncertainties by fuzzy. variables.

The study was done with five measurements on July 13th, 2015, a day with few clouds and big gusts of winds. A portable anemometer with coupled and adapted tripod to not interfere with the measurements was used, being placed at a low height of approximately 1.10 m. The chose points are described as follows:

- Point 1 is approximately 50 m from the automatic weather station on the beach with no buildings around with low topography and low roughness of the terrain with good incidence of winds;
- Point 2 is 80 m from the automatic weather station and in urban areas with buildings around with a rise of 4m in relation to sea level;
- Point 3 is approximately 300 m from the automatic weather station at the foot of a hill and with plenty of buildings around, beyond the asphalt.

Figure 8 - Angels Beach Arraial do Cabo - RJ measurement location
Source: Google Earth, (2015)

Figure 9 - Point 1
Source: authors, (2015)

Figure 10 - Point 2
Source: authors, (2015)

Figure 11 - Point 3
Source: authors, (2015)

4 Results

To process the collected data it was used a fuzzy system created in XFUZZY in the Verification-Monitorization module (reference). The system design is shown in Figure 12, and results from a suitability inference test is presented in Figure 13. Gathered and fuzzyfied data from points 1, 2 and 3 are also displayed from Table 5 to 10.

> Xfuzzy 3.0 contains two tools for describing fuzzy systems: xfedit and xfpkg. The first one is dedicated to the logical definition of the system, that is, the definition of its linguistic variables and the logical relations between them. Although this description can be done by editing a file with a ".xfl" extension, the tool xfedit offers a graphical interface which avoids the need for a deep knowledge of the XFL3 language. The user defines the hierarchy of the system at the main window of xfedit. (VELO et al., 2003).

The logic of the relationship between different types of variables created to fuzzy inference system proposed for measuring the wind profiling efficiency in urban areas can be seen in Figure 12.

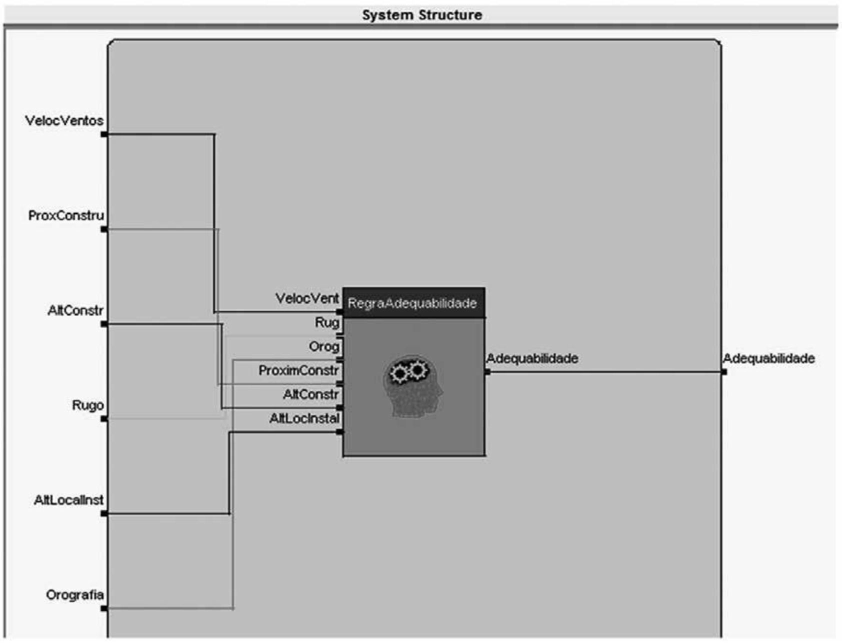

Figure 12 - Logical relationship between different types of variables fo wind profiling efficiency
Source: authors, (2015)

> The objective of the verification stage is to study the behavior of the system under development, detecting probable deviations on the expected behavior and identifying the source of these deviations. Xfuzzy 3.0 contains four verification tools for these purposes: xf2dplot, xf3dplot, xfmt, and xfsim. (VELO et al., 2003).

Even as quotes Velo (2003) the tool xfmt allows monitoring the system at all the hierarchical levels, showing the activation degree of every linguistic label and logical rule, as well as the value of the different inner variables, for some determined input values. The figure 13 shows the main window of xfmt that corresponds to the top level of the system hierarchy.

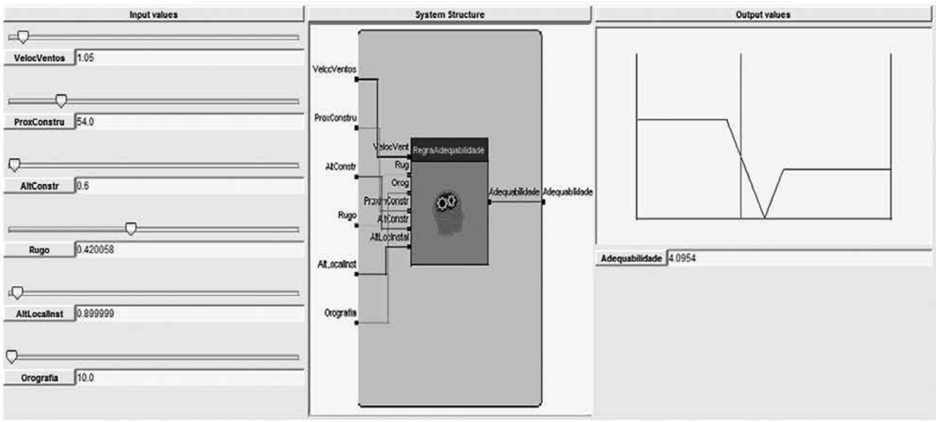

Figure 13 - Verification stage using xfmt tools from XFUZZY
Source: authors, (2015)

Recorded measurements for the selected points follows:

- Point 1:

Table 5 - Record of measured data in the site

Date	Time	Wind speed m/s	Temperature º C
11/07/2015	11h:45min	5.3	25
11/07/2015	12h:45min	5.5	25
11/07/2015	14h:00min	4.5	24
11/07/2015	15h:00min	2.8	28
11/07/2015	16h:00min	2.0	25

Source: authors, 2015

Table 6 - Profile section 1

Roughness	sand - 0,003	mf1
Average winds speed	4.02 m/s – Weak breeze 3	mf3
High buildings	low	mf0
Buildings proximity	distant	mf0
Orography	0m	mf0
Local height installation	Low 1.10m	mf0
Weather station distance	50m	
Suitability (using fuzzy)	mean	

Source: authors, 2015

- Point 2:

Table 7 - Record of measured data in the site

Date	Time	Wind speed m/s	Temperature º C
07/11/2015	11h:50min	2.2	28
07/11/2015	12h:50min	2.3	28
07/11/2015	14h:10min	2.1	28
07/11/2015	15h:10min	2.1	28
07/11/2015	16h:10min	2.0	25.9

Source: authors, 2015

Table 8 - Profile section 2

Roughness	City - 1	mf3
Average winds speed	2.14 m/s – weak breeze 2	mf2
High buildings	means	mf1
Buildings proximity	near	mf1
Orography	4m	mf1
Local height installation	Low 1.10m	mf0
Weather station distance	80m	
Suitability (using fuzzy)	High	

Source: authors, 2015

- Point 3:

Table 9 - Record of measured data in the site

Date	Time	Wind speed m/s	Temperature º C
07/11/2015	12h:00min	1.3	28.1
07/11/2015	13h:00min	2.3	28
07/11/2015	14h:20min	1.2	29
07/11/2015	15h:20min	0.9	27
07/11/2015	16h:20min	1.0	24

Source: authors, 2015

Table 10 - Profile section 3

Roughness	City - 1	mf3
Average winds speed	1.34 m/s – breeze 1	mf1
High buildings	means	mf1
Buildings proximity	Very close	mf3
Orography	6m	mf2
Local height installation	low 1.10m	mf0
Weather station distance	300m	
Suitability (using fuzzy)	low	

Source: Authors, 2015

5 Conclusion

Preliminary tests suggest the feasibility of the proposed method. Further testing is required for the verification of the method according to proposed rules of inference. This is also necessary for the calibration and set up of new inference rules. An initial observation of the urban environment, at a windy location may suggest a suitable site for installation of small wind towers. Notwithstanding, the measurements taken at the place showed that some parameters must be considered as terrain and nearby buildings. This demonstrates that the method is appropriate. In the case study that happened in point 3 installation, which is placed at the foot of a hill with lots of buildings around, it pointed out that it would not be a good place to install wind towers on top of houses.

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ARTIGO CIENTÍFICO 2

Study of Variation of Winds Behavior on Micro Urban Environment with use of Fuzzy Logic for Wind Power Generation: Case Study in the Cities of Arraial do Cabo and São Pedro da Aldeia, State of Rio de Janeiro, Brazil

Roberto Rosenhaim, Marcos Antonio Cruz Moreira, Robson da Cunha, Gerson Gomes Cunha

***Abstract*—** This work provides details on the wind speed behavior within cities of Arraial do Cabo and São Pedro da Aldeia located in the Lakes Region of the State of Rio de Janeiro, Brazil, to assist in decision making for wind energy microgeneratios installation of vertical axis in the urban environment. This region is the one that has one of the best potential for wind power generation in the state. In interurban layer, wind conditions are very complex and depend on physical geography, size and orientation of buildings and constructions around, population density and land use. In the same context, the fundamental surface parameter that governs the production of flow turbulence in urban canyons is the surface roughness. Such factors can influence the potential for power generation from the wind within cities. Moreover, the use of wind on a small scale is not fully utilized due to complexity of wind flow measurement inside cities. It is difficult accurately predict this type of resource. This study demonstrates how fuzzy logic can facilitate the assessment of the complexity of the wind potential inside cities. It presents a decision support tool and its ability to deal with inaccurate information using linguistic variables created by the heuristic method. It relies on already published studies about the variables that most influence the wind speed in the urban environment. These variables were turned into verbal expressions that used in computer system, which facilitated the establishment of rules for fuzzy inference and integration with an application for smartphones used in the research. In the first part of the study are described challenges of the sustainable development, followed by incentive policies to the use of renewable energy in Brazil. The next chapter follows the study area characteristics and the concepts of fuzzy logic. Data were collected in field experiment using qualitative and quantitative methods for assessment. As a result, is presented a map of the various points within the cities studied with its wind viability evaluated by a system of decision support using the method multivariate classification based on fuzzy logic.

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***Keywords*—** Behavior of winds, wind power, fuzzy logic, sustainable development.

I. Introduction

THE COP - Conference of the Parties to the United Nations Framework Convention on Climate Change, at its twenty-first edition (21th), played an important role in all countries to encourage the use of renewable energy sources by declining use of fossil fuels in order to meet the reduction targets of the global temperature to 1.5 ° C as stated in the agreement cop21 signed on April 22 of 2016**.**

Renewable energy sources can reduce the dependence of society on fossil fuels, which in turn would also reduce the emission of greenhouse gases on the environment [1].

Economic development is vital for the poorest countries, but the way forward may not be the same adopted by industrialized countries. There is a major challenge for emerging powers like China, India and Brazil, to maintain its economic growth by eliminating the use of fossil fuels, which worked in the past, but there is now need to establish a new green growth model based on the use clean energy, keeping the progress of these nations [2].

Another important point to be taken into account concerns reduction of carbon dioxide emission levels in the atmosphere in industrialized countries. It is also necessary to note that the economic and population growth of the last decades have been marked by differences. Although Northern Hemisphere countries have only one-fifth of the world population, they hold four-fifths of the world's income and consume 70% of energy, 75% metals and 85% of global wood production.

According to [2], some factors contributing to the increased use of renewable energy sources are:

1. The energy crisis due to the reduction of world oil reserves;

2. Environmental impacts caused by the use of polluting energy sources; and
3. Potential shortage of natural resources and increasing demand for energy supply

TABLE I
DOMESTIC SUPPLY OF ELECTRICITY

Specification	GWh		Structure (%)	
	2014	2015	2014	2015
Hydro	373.439	359.743	59,8	58,4
Sugarcane bagasse	32.303	34.163	5,2	5,5
Wind	12.210	21.626	2	3,5
Solar	16	59	0,003	0,01
Other renewable	13.879	14.864	2,2	2,4
Oil	31.668	25.662	5,1	4,2
Natural gas	81.075	79.490	13	12,9
Charcoal	18.385	19.096	2,9	3,1
Nuclear	15.378	14.734	2,5	2,4
Other nonrenewable	12.125	12.049	1,9	2
Import	33.775	34.422	5,4	5,6
Total	624.254	615.908	100	100
Renewable	465.623	464.877	74,6	75,5

According to the Energy Research Company (EPE) - the Ministry of Mines and Energy of Brazil - demographic, macroeconomic and sectoral assumptions, as well as those relating to energy efficiency and self-production, play a fundamental role in determining the dynamics of consumption electricity, with direct implications on the behavior of various market indicators. In the residential sector, the number of connections to the grid depends on demographic variables such as population, number of households and the number of inhabitants per household; the average consumption per consumer is related with income, with GDP and GDP per capita. These same variables are also important in explaining other consuming sectors, such as commercial grade (trade and services) and other consumption categories. Demand for Brazilian electricity is expected to grow at an average rate in residences like could be seen in the fig 1 [3], and the production of other renewable fonts of energy must grow up to like can be seen on table 1 [3].

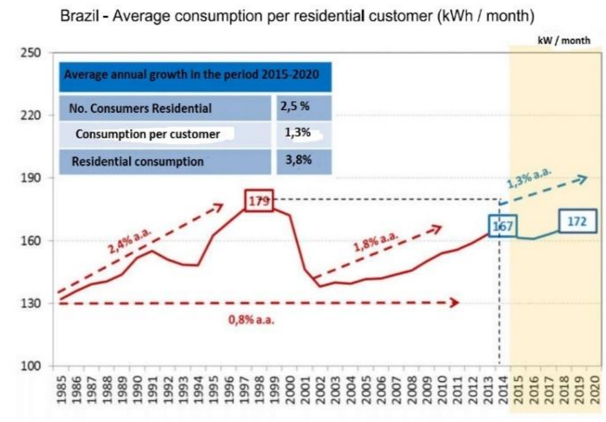


Fig. 1 Projection of electricity demand [3]

Brazil has an important role in the process of international climate agreement signed on April 20, 2016. For its continental size, its population, but mainly by the resources it has and that may replace the use of fossil fuels within relatively short time period. The country is able to use different sources of energy: wind, solar, bioenergy among others in a diverse array that does not make it dependent on a single resource as currently occurs on fossil fuels and the dependence on energy obtained from hydroelectric

In 2015 the amount of wind participant in the Brazilian energy matrix energy was only 3.5%, according to fig 2.

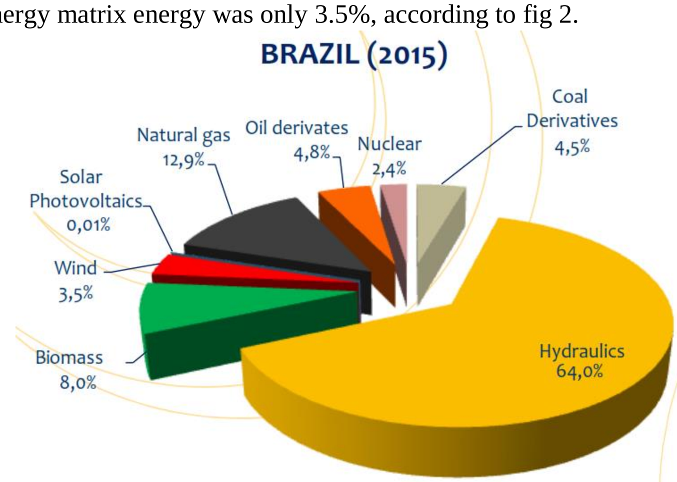


Fig. 2 Brazilian Energy Matrix [3]

As the fig 3, is remarkable the increase in wind power generation has been driven by political incentives as the Proinfa program of the Brazilian government.

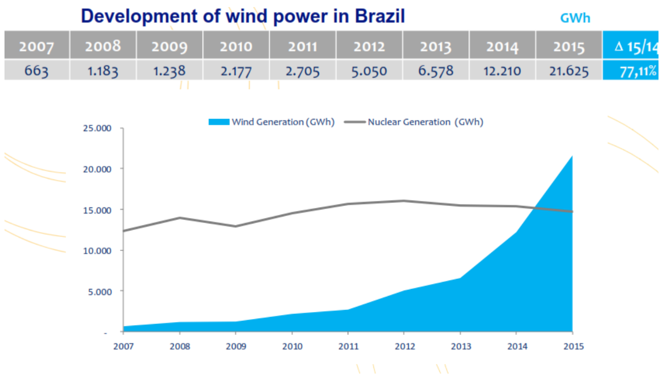


Fig. 3 Development of wind power in Brazil

The wind in inner cities suffer various influences of other variables which could affect the correct diagnosis of their actual efficiency in certain regions due to internal features found in urban micro environment also can be found according [4]:

1. The wind direction is highly variable in time and space, according to the geographical situation of the site, the surface roughness, relief, vegetation and the time of year ; and
2. Knowledge of the prevailing wind direction and average speeds that occur in a site provides important information for positioning windbreaks, guidelines on building stables, distribution of different crops in the field and especially in the positioning and sizing of the towers to the use of this natural energy source.

II. BRAZILIAN POLITICAL INCENTIVE

According to the Brazilian Association of Wind Energy, the first wind turbine to go into commercial operation in South America was the Fernando de Noronha Archipelago (Pernambuco state) in 1992, with little advanced due to the high cost and lack of incentive policies.

Economic development demand the use of more energy, as well as the increase in population and improvement of social conditions of the people and government incentives tend to encourage the use of clean sources [5].

In 2001 the Brazilian government created the PROELICA - Emergency Program for Wind Energy amid energy crisis which was replaced in 2005 by the Incentive Program for Alternative Sources of Electric Energy (Proinfa).

Another important program created by the Brazilian government is ProGD (Distributed Generation Development Program for Energy 15.12.2015), which encourages the generation of energy by consumers themselves based on renewable sources to broaden and deepen the stimulus actions the generation of energy by the consumers themselves, based on renewable energy sources.

According to ProGD some goals are noteworthy: achieve 23% share of renewable energy (in addition to hydropower) in electricity supply, participation of 28% to 33% by 2030 from renewable sources in the energy matrix, reduce emissions greenhouse gases compared to 2005 levels, by 37% by 2025 and by 43% by 2030. As can be seen in the graph of the fig. 4 [3], taken from Wind Energy Association Brazilian, a significant increase with respect to capacity and government incentives.

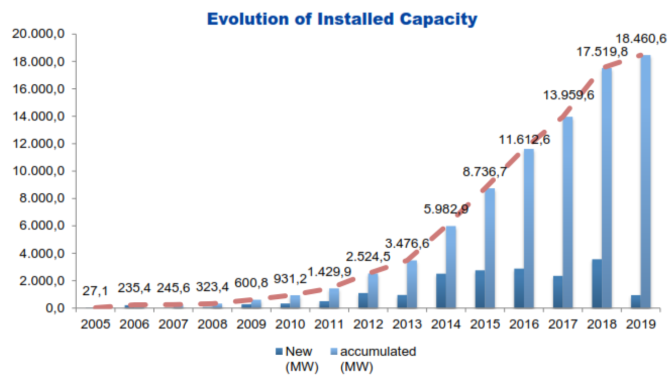


Fig. 4 Evolution of Installed Capacity

III. CHARACTERISTICS OF THE STUDIED REGION

The cities of Arraial do Cabo and São Pedro da Aldeia belong to micro-region of Lagos, usually known as Lake Region of Rio de Janeiro State. They also belong to the middle geographic region of coastal lowland. This region stands out a special microclimate province, due to the lower rainfall, high evapotranspiration, low cloudiness and wind regime, being dominated by dry vegetation [7].

São Pedro da Aldeia is located at latitude 22º50'21" south and longitude 42º06'10" west with a population estimated at 93,659 inhabitants according to Brazilian Institute of Geography and Statistics in 2013; and are delimited to an area of 358.66 km^2.

Arraial do Cabo is located at latitude 22 ° 57'57 " South and longitude 42 ° 01'40" West with a population of approximately 28,866 inhabitants according to Brazilian Institute of Geography and Statistics in 2014.

The presence of a large bay, influenced the behavior of the local thermal circulation as a boundary condition in the surface boundary layer [6].

According whit [7], the region of Cabo Frio, near Arraial do Cabo and São Pedro da Aldeia, suffers various influences on the variation of the wind regime of coastal breezes from both the ocean as the Araruama Lagoon.

Weather features near the southeast coast of Rio de Janeiro show large high pressure scale system, called anticyclone Subtropical South Atlantic Maritime (asthma) which controls the atmospheric circulation in Cabo Frio. It generates sector Northeast winds, and it alternates with polar anticyclonic systems related to cold fronts passing the coast of Rio de Janeiro, reversing seasonally the wind to southwest, south and southeast. The result is a predominance of atmospheric circulation of East-Northeast during the summer and fall and

Southwest West during the winter and spring how could be seen in the fig. 5.

Fig. 5 Dominant synoptic mechanisms in the Brazilian North Fluminense and Lakes Regions wind regime [8]

According to the Wind Atlas of the State of Rio de Janeiro [8], from the past are the famous windmills of Cabo Frio salt and São Pedro da Aldeia, which demonstrate the great wind potential in the region and which allowed the generation of profit these small urban centers.

As Fig. 6 from the Wind Atlas of Rio de Janeiro [8], one can see places with potential for installing wind farms of tens to hundreds of Megawatss scattered among existing landforms. Areas with low cost of interconnection to the electrical system, such as São Pedro da Aldeia (82 GWh) and Arraial do Cabo (44 GWh), two cities target of this study, where the annual average wind speeds reach close to 7.0 m / s (50 m high).

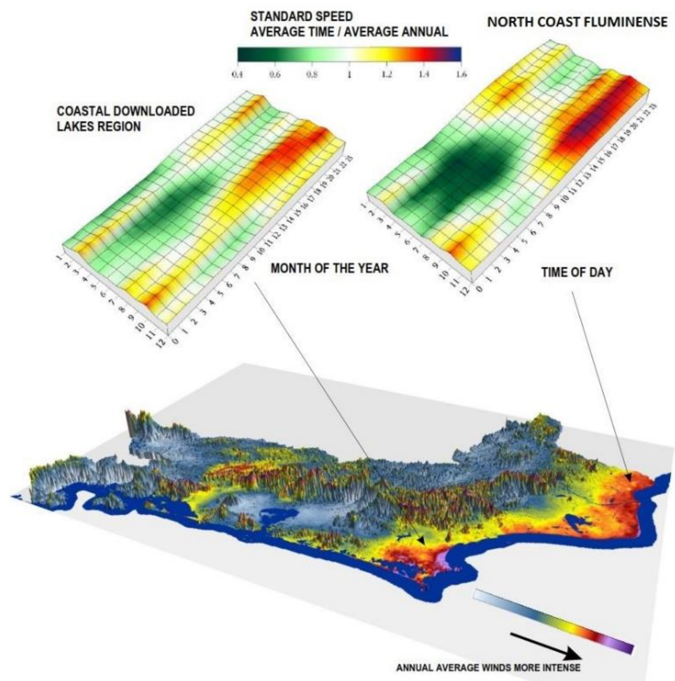


Fig. 6 Intensity distribution of winds and seasonal diurnal regimes on the state of Rio de Janeiro [8]

IV. FUZZY LOGIC

Fuzzy logic includes inaccurate aspects of logical reasoning used by humans, and has as a special feature that innovative representation of the handling of inaccurate information, separately in the theory of probability [9]. It provides a method to translate verbal expressions, vague, imprecise and qualitative common in human communication in numerical values.

With this approach, it becomes possible to transfer the human experience for computers, with an immense practical value, including formulation of decision-making strategies.

Fuzzy logic allows you to capture information already perceptible by human beings, behaving as such.

The mathematical approach many difficulties powder to work with uncertainty parameters, and changes due to environmental variations [10], this problem is found when the need for measurement of wind speeds within the urban environment into account. Its constant variability due to several variables such as soil type, buildings around among others make difficult this kind of evaluation.

Instead of using real numbers, the inputs and outputs can be described as "fuzyy values" [9]:

IF <variable> = HIGH THEN <output> BIG

Where HIGH and BIG are defined by membership functions describing the inaccuracy of such input and output values

Such expressions can be built using the heuristic method which consists in carrying out a task according to previous experiences

It notes that the fuzzy control strategies are born of experiments experience rather than mathematical models.

While the inference based on the *modus ponens* inference rule in classical [11] artificial intelligence systems is based only on symbolic processing, fuzzy inference (approximate reasoning) is based both on symbolic processing as in the processing of meaning.

A. Fuzzy Inference Rules

This study used a free access code tool GNU XFUZZY XML-based [11]. That is JAVA programming language based tool. This software allows integration with other systems.

To design the system was necessary to build sets of variables as recent research [12].

Based on Beaufort scale [13] – shown in Table II – was created fuzzy variable TVelocidadeVentos (wind speed), shown in Table III.

TABLE II
BEAUFORT SCALE

Degree	Type	m/s	Ground effect
0	calm	<0,3	Smoke rises vertically
1	breeze	0,3 a 1,5	Smoke indicates wind direction
2	light breeze	1,6 a 3,3	The leaves move; mills start working
3	light breeze	3,4 a 5,4	Leaves flutter-and unfurl flags in the wind
4	moderate breeze	5,5 a 7,9	Dust and small raised roles; move the tree branches
5	strong breeze	8 a 10,7	Movement of large branches and small trees
6	fresh wind	10,8 a 13,8	Moving large trees; difficulty walking against the wind

TABLE III
FUZZY TYPE TVELOCIDADEVENTOS

Degree	Type	m/s	*Fuzzy variable*
0	calm	< 0,3	mf0Calmo
1	breeze	0,3 a 1,5	mf1Aragem
2	light breeze	1,6 a 3,3	mf2BrisaLeve
3	light breeze	3,4 a 5,4	mf3BrisaFraca
4	moderate breeze	5,5 a 7,9	mf4BrisaModerada
5	strong breeze	8 a 10,7	mf5BrisaForte
6	fresh wind	10,8 a 13,8	mf6VentoFresco

Roughness table that clusters terrain features in roughness classes Table IV [14], the variable Roughness Land as TRugosidade was estabilished, as presented in following Table V.

TABLE IV
ROUGHNESS

z0	Terrain features	Class roughness
1,00	City	
0,80	Forest	
0,50	outskirts	3
0,40		
0,30	belts of trees	
0,20	trees and shrubs	
0,10	farm with closed vegetation	2
0,05	farm with open vegetation	
0,03	farm with few trees / buildings	
0,02	areas of airports with buildings and trees	
0,01	areas of airport runways	1
0,008	meadow	
0,005	plowed soil	
0,001	snow	
0,0003	sand	
0,0002		
0,0001	water (lakes, rivers, oceans)	0

TABLE V
FUZZY TYPE TROUGHNESS

Class roughness	fuzzy variable
3	mf3AltaCidadeFlorestaSuburbios
2	mf2MediaAreaComArvoresArbustos
1	mf1MediaPastoAeroportosFazenda
0	mf0BaixaAreiaNeveAgua

Also were created the variables:

1. TProximidadeConstrucoes: (proximity of buildings)

- mf0Distantes
- mf1Proximas
- mf2MuitoProximas

2. TAlturaConstrucoes: (height of buildings)

- mf0Baixa
- mf1Media
- mf2Altas

3. TAlturaLocalInstalacao : (instalation height)

- mf0Baixa
- mf1Media
- mf2Alta

4. TAdequabilidade: (suitability)

- mf0Baixa
- mf1Media
- mf2Alta

Systems that use symbolic language end up needing high computational demand, which does not occur with systems using fuzzy, as demonstrated by inference variables created. Thereby the computational analysis process becomes faster and simplified, this is indifferent to efforts to seek mathematically model their processes within which there is a certain difficulty in this, as in the case of a human operator this process becomes more streamlined. Fuzzy logic tends to behave as deductive reasoning through semantic examples that may present conclusions based on already known information. Fuzzy logic allows data collection experts thus enabling the creation of an intelligent system to support decision based on characteristics of human intelligence.

V.METHODOLOGY

The methodology relies on a simpler and faster gathering of wind regime corresponding to data acquired from an anemometer inside urban area. At a second step, the anemometer installation site, which is also a candidate location for turbine placement, is described through fuzzy sets that express the location adequacy. Finally rules relating macro and local wind distribution along with location adequacy are established for fuzzy inference purpose and processed by fuzzy inference toolkits

To analyze the data were observed several points with different characteristics based on the types of variables created using XFUZZY such variables were inserted in the smartphone database, being used SQLITE, and data entry was through an application developed for this purpose.

The application was developed using the Android Studio tool in JAVA programming language.

Android has integration with SQLITE [15], a lightweight and powerful database, the database was created directly within the source code itself.

The variables mapped using XFUZZY[16] tool and subsequently exported to Java code which facilitated the integration between the Graphical user interface and the generated code.

The application developed consists of a map which uses the Google Maps Android API v2 [15], the application basically consists of a map in which a point is scored, that point just click the marker that the user is directed to a screen with questions about the profile found in the current environment. That is, the use of linguistic variables created from the heuristic method and subsequently calibrated, after answering the questionnaire the user returns to the current map view and can check which the suitability regarding the regime winds that place based on 87 inference rules created from XFUZZY figures demonstrate the use of the application:

Altogether were mapped 86 points, 40 in the city of Arraial do Cabo and 46 in the city of San Pedro village. In addition to mapping were harvested the speed of the wind through the automatic weather station in the city of Arraial do Cabo latitude -22.975468º and longitude -42.021450º, altitude 3 m, in the microenvironment and the average speed measured in this device was compared with the speeds at every point.

The smartphone application development and used for this research can be seem in the pictures above:

Fig. 7 Markers in São Pedro da Aldeia, Rio de Janeiro state, Brazil

Fig. 8 Markers in Arraial do Cabo , state of Rio de Janeiro, Brazil

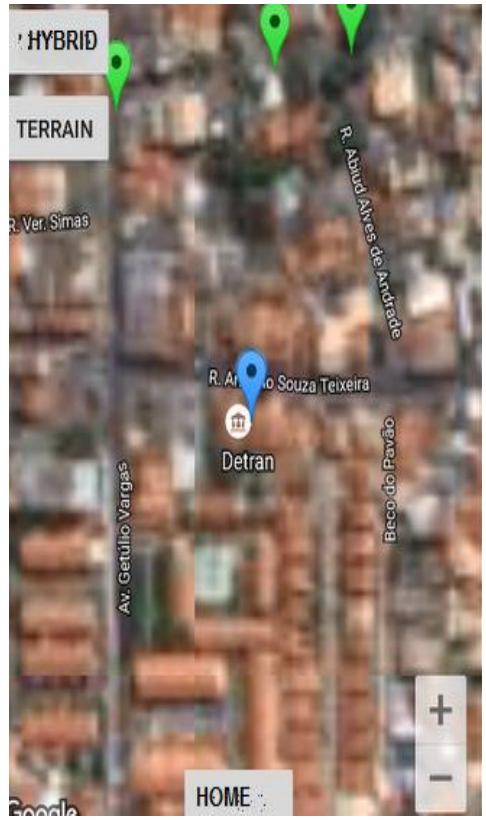


Fig. 10 New marker example

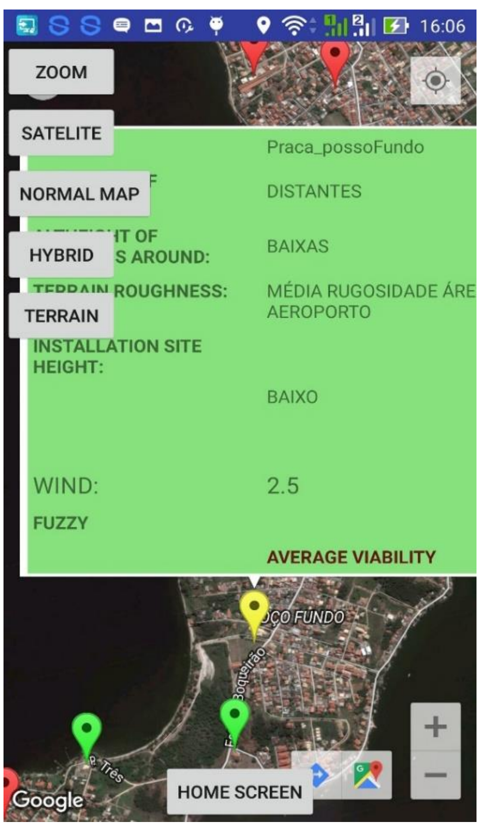


Fig. 9 Window marker fuzzy variables evaluation

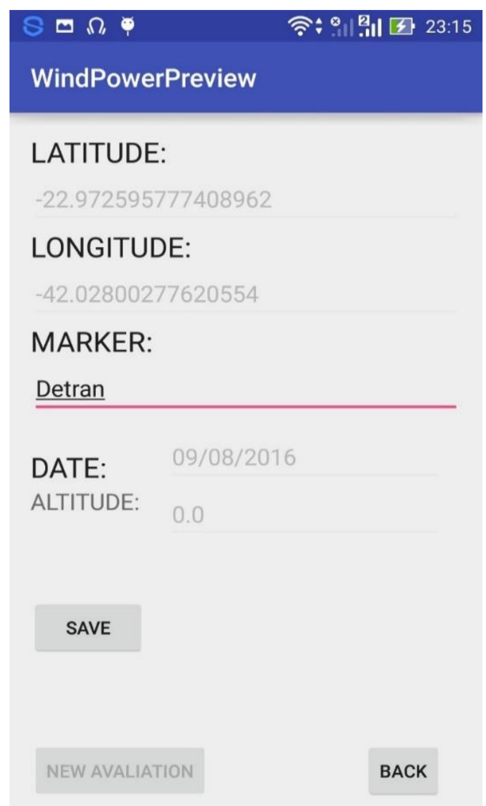


Fig. 11 Marker details

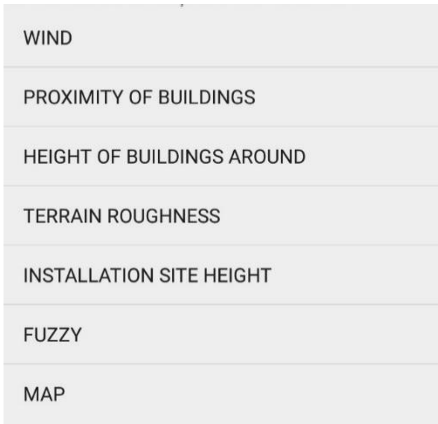


Fig. 12 List with fuzzy linguistic variables

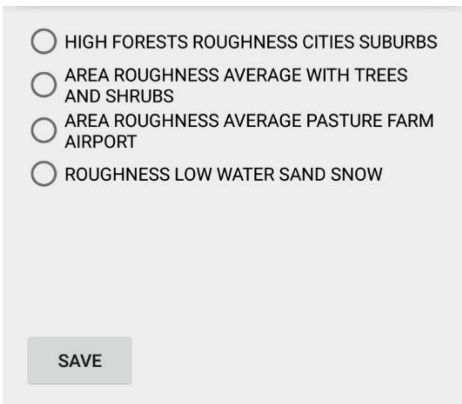


Fig. 13 Marker roughness evaluation

The application is responsible for taking the latitude and longitude, and write the data in different tables, it allows integration with other software such as online use on websites beyond the export of the latitude and longitude data to software as QGIS to elaborate more maps complex.

The following data were collected from points:

TABLE VI
ARRAIAL DO CABO MARKERS

id	nomemarcador	Latitude	longitude
2	Constru_frente_IEAPM	-22.97654999	-42.02220585
3	Pousada Santo Anjo	-22.97753991	-42.02254146
4	Esquina_IEAPM	-22.97823751	-42.02260382
5	Esquina_Ieapm2	-22.97760874	-42.02249553
6	Ponto_Frente_entrada_ieapm	-22.97775073	-42.02315368
7	Predio_frente_entrada_ieapm	-22.97743866	-42.02324957
8	Construcao_predio	-22.97681174	-42.02342995
9	Barzinho_esquina_castelo_branco	-22.97714913	-42.02483844
10	Hotel_ressurgencia	-22.97472199	-42.0214089
11	Posto_salvavidas_frente_ressurgencia	-22.97460932	-42.0211494
12	Residencial_Vila_ElisabetaI	-22.97390769	-42.02149775
13	Porto_forno	-22.9702303	-42.01752238
14	Praia_anjos_proximo_porto	-22.97031704	-42.01946966
15	Igreja_nossa_senhora_remedios	-22.96931595	-42.01965641
16	Mirante_pontal_atalaia	-22.98124457	-42.02899721
17	Recanto_arcanjo_Miguel	-22.97371167	-42.03118019
18	Praia_grande_proximo_guarda	-22.97368327	-42.0315557
19	Praia_grande_associacao_pescadores	-22.9730977	-42.03142561
20	Praia_grande_restaurante_deck_praia	-22.97331193	-42.03167103
21	Praia_grande_quiosque_do_max	-22.97267789	-42.03150876
22	Praia_grande_restaurante_por_do_sol	-22.97253219	-42.03115102
23	Hotel_varandas_ao_mar	-22.9719	-42.03088649
24	Praia_grande-condominio_lado_varandas	-22.97137739	-42.03100517
25	Cobdoninio_praia_grande	-22.97086805	-42.03041073
26	Padaria_delicias_praia_grande	-22.97291002	-42.02962685
27	Pousada_genesis	-22.97250965	-42.02683736
28	Pousada_Pavanelli	-22.97404011	-42.02636529
29	Pracinha_frente_loja_pintando	-22.97467569	-42.02883594
30	TEAR_pilates	-22.97190988	-42.02788308
31	Esquina_abuid_alves_com_machado_assis	-22.97185832	-42.02758066
32	Bar_amarelinho	-22.97202162	-42.02851105
33	Brinquedo_festa	-22.97080261	-42.02785123
34	Instituto_agape	-22.96846951	-42.02466242
35	Camara_municipal	-22.96938417	-42.02588886
36	Primeira_Igreja_batista	-22.96752089	-42.0267988
37	Praca_castelo_branco	-22.9675357	-42.02344302
38	Edificio_prainha	-22.96087724	-42.02497859
40	Quisoque_prainha_vasco	-22.96105012	-42.02283282
41	Pousada_thetis	-22.95949173	-42.02556565
42	Entrada_condominio_vilage_pontal	-22.95482356	-42.03178369

TABLE VII
ARRAIAL DO CABO WIND

_id	speed	markerid	date
1	2.0	2	02/07/2016
2	1.2	3	02/07/2016
3	2.5	5	02/07/2016
4	2.7	6	02/07/2016
5	3.8	7	02/07/2016
6	2.6	8	02/07/2016
7	1.8	9	02/07/2016
8	3.1	10	02/07/2016
9	4.4	11	02/07/2016
10	3.6	12	02/07/2016

11	1.9	13	02/07/2016
12	2.5	14	02/07/2016
13	1.4	15	02/07/2016
14	2.3	16	02/07/2016
15	4.8	17	04/07/2016
16	1.2	18	04/07/2016
17	1.9	19	04/07/2016
18	2.6	21	04/07/2016
19	0.7	22	04/07/2016
20	2.3	24	04/07/2016
21	2.6	25	04/07/2016
22	2.3	26	04/07/2016
23	2.4	27	04/07/2016
24	2.1	28	04/07/2016
25	1.0	29	04/07/2016
26	1.3	30	04/07/2016
27	0.1	31	04/07/2016
28	1.3	32	04/07/2016
29	1.3	33	04/07/2016
30	0.8	34	04/07/2016
31	2.2	35	04/07/2016
32	2.3	36	04/07/2016
33	1.6	37	04/07/2016
34	2.0	38	04/07/2016
35	3.0	40	04/07/2016
36	1.8	41	04/07/2016
37	1.9	42	04/07/2016

TABLE VIII
ARRAIAL DO CABO BUILDING PROXIMITY AND HEIGHT OF BUILDINGS AROUND

_id	markerid	Proximity	height
1	2	NEAR	MODERATE
2	3	FAR	LOW
3	4	VERY CLOSE	LOW
4	5	VERY CLOSE	LOW
5	6	FAR	LOW
6	7	FAR	LOW
7	8	NEAR	LOW
8	9	NEAR	HIGH
9	10	FAR	MODERATE
10	11	FAR	LOW
11	12	FAR	LOW
12	13	FAR	LOW
13	14	FAR	LOW
14	15	FAR	LOW
15	16	FAR	LOW
16	17	VERY CLOSE	LOW
17	18	FAR	MODERATE
18	19	FAR	LOW
19	20	FAR	HIGH
20	21	FAR	LOW
21	22	VERY CLOSE	HIGH
22	23	VERY CLOSE	HIGH
23	24	NEAR	HIGH
24	25	NEAR	MODERATE
25	26	VERY CLOSE	MODERATE
26	27	FAR	MODERATE
27	28	NEAR	LOW
28	29	NEAR	LOW
29	30	NEAR	LOW
30	31	NEAR	MODERATE
31	32	VERY CLOSE	LOW
32	33	NEAR	MODERATE
33	34	FAR	LOW
34	35	FAR	LOW
35	36	NEAR	LOW
36	37	FAR	MODERATE
37	38	VERY CLOSE	LOW
38	40	VERY CLOSE	MODERATE
39	41	FAR	HIGH
40	42	FAR	LOW
			LOW

TABLE IX
ARRAIAL DO CABO HEIGHT OF TERRAIN ROUGHNESS

_id	markerid	roughness
1	2	HIGH FORESTS ROUGHNESS CITIES SUBURBS
2	3	HIGH FORESTS ROUGHNESS CITIES SUBURBS
3	4	HIGH FORESTS ROUGHNESS CITIES SUBURBS
4	5	HIGH FORESTS ROUGHNESS CITIES SUBURBS
5	6	HIGH FORESTS ROUGHNESS CITIES SUBURBS
6	7	HIGH FORESTS ROUGHNESS CITIES SUBURBS
7	8	HIGH FORESTS ROUGHNESS CITIES SUBURBS
8	9	HIGH FORESTS ROUGHNESS CITIES SUBURBS
9	10	HIGH FORESTS ROUGHNESS CITIES SUBURBS
10	11	ROUGHNESS LOW WATER SAND SNOW
11	12	HIGH FORESTS ROUGHNESS CITIES SUBURBS

12	13	ROUGHNESS LOW WATER SAND SNOW
13	14	ROUGHNESS LOW WATER SAND SNOW
14	15	HIGH FORESTS ROUGHNESS CITIES SUBURBS
15	16	AREA ROUGHNESS AVERAGE WITH TREES AND SHRUBS
16	17	HIGH FORESTS ROUGHNESS CITIES SUBURBS
17	18	AREA ROUGHNESS AVERAGE PASTURE FARM AIRPORT
18	19	HIGH FORESTS ROUGHNESS CITIES SUBURBS
19	20	ROUGHNESS LOW WATER SAND SNOW
20	21	HIGH FORESTS ROUGHNESS CITIES SUBURBS
21	22	HIGH FORESTS ROUGHNESS CITIES SUBURBS
22	23	HIGH FORESTS ROUGHNESS CITIES SUBURBS
23	24	HIGH FORESTS ROUGHNESS CITIES SUBURBS
24	25	HIGH FORESTS ROUGHNESS CITIES SUBURBS
25	26	HIGH FORESTS ROUGHNESS CITIES SUBURBS
26	27	HIGH FORESTS ROUGHNESS CITIES SUBURBS
27	28	HIGH FORESTS ROUGHNESS CITIES SUBURBS
28	29	AREA ROUGHNESS AVERAGE WITH TREES AND SHRUBS
29	30	AREA ROUGHNESS AVERAGE WITH TREES AND SHRUBS
30	31	AREA ROUGHNESS AVERAGE WITH TREES AND SHRUBS
31	32	HIGH FORESTS ROUGHNESS CITIES SUBURBS
32	33	HIGH FORESTS ROUGHNESS CITIES SUBURBS
33	34	HIGH FORESTS ROUGHNESS CITIES SUBURBS
34	35	HIGH FORESTS ROUGHNESS CITIES SUBURBS
35	36	HIGH FORESTS ROUGHNESS CITIES SUBURBS
36	37	HIGH FORESTS ROUGHNESS CITIES SUBURBS
37	38	HIGH FORESTS ROUGHNESS CITIES SUBURBS
38	40	ROUGHNESS LOW WATER SAND SNOW
39	41	AREA ROUGHNESS AVERAGE PASTURE FARM AIRPORT
40	42	AREA ROUGHNESS AVERAGE WITH TREES AND SHRUBS

TABLE X
ARRAIAL DO CABO INSTALLATION SITE HEIGHT

_id	Markerid	height
1	2	HIGH
2	3	HIGH
3	4	LOW
4	5	LOW
5	6	LOW
6	7	HIGH
7	8	HIGH
8	9	MODERATE
9	10	MODERATE
10	11	MODERATE
11	12	MODERATE
12	13	LOW
13	14	LOW
14	15	MODERATE
15	16	HIGH
16	17	MODERATE
17	18	MODERATE
18	19	MODERATE
19	20	LOW
20	21	MODERATE
21	22	HIGH
22	23	HIGH
23	24	MODERATE
24	25	MODERATE
25	26	HIGH
26	27	LOW
27	28	MODERATE
28	29	LOW
29	30	LOW
30	31	LOW
31	32	MODERATE
32	33	LOW
33	34	MODERATE
34	35	MODERATE
35	36	HIGH
36	37	LOW
37	38	HIGH
38	40	LOW
39	41	LOW
40	42	LOW

TABLE XI
ARRAIAL DO CABO FUZZY

_id	markerid	fuzzy_avaliation
2	2	LOW VIABILITY
3	3	LOW VIABILITY
4	4	NOT YET DONE
5	5	LOW VIABILITY
6	6	HIGH VIABILITY
7	7	LOW VIABILITY
8	8	LOW VIABILITY

9	9	LOW VIABILITY
10	10	LOW VIABILITY
11	11	AVERAGE VIABILITY
12	12	LOW VIABILITY
13	13	AVERAGE VIABILITY
14	14	AVERAGE VIABILITY
15	15	LOW VIABILITY
16	16	LOW VIABILITY
17	17	LOW VIABILITY
18	18	LOW VIABILITY
19	19	LOW VIABILITY
20	20	NOT YET DONE
21	21	LOW VIABILITY
22	22	LOW VIABILITY
23	23	NOT YET DONE
24	24	LOW VIABILITY
25	25	LOW VIABILITY
26	26	LOW VIABILITY
27	27	HIGH VIABILITY
28	28	LOW VIABILITY
29	29	LOW VIABILITY
30	30	LOW VIABILITY
31	31	LOW VIABILITY
32	32	LOW VIABILITY
33	33	LOW VIABILITY
34	34	LOW VIABILITY
35	35	LOW VIABILITY
36	36	LOW VIABILITY
37	37	HIGH VIABILITY
38	38	LOW VIABILITY
40	40	LOW VIABILITY
41	41	AVERAGE VIABILITY
42	42	HIGH VIABILITY

TABLE XII
SÃO PEDRO DA ALDEIA MARKERS

id	Nomemarcador	latitude	longitude
43	Garagem_ampla	-22.83152944	-42.09818244
44	Jardim_escola_coracao_sabido	-22.83129367	-42.09916178
45	Predio_esquina_vila_militar	-22.83070686	-42.10014246
46	Escola_estadual	-22.8300978	-42.09989201
47	Casa_421	-22.82810684	-42.09987257
48	Serralheria_caires	-22.82909475	-42.10130285
49	Praca_estacao	-22.83075692	-42.10226275
50	Segunda_igreja_batista	-22.82966735	-42.10443735
51	Silver_hawk_cross_fit	-22.83083387	-42.10707061
52	Escola_almirante_carneiro_ribeiro	-22.82778979	-42.11217385
53	Terreno_frente_posto	-22.82690384	-42.11408392
54	Fisio_trauma	-22.8316172	-42.10450742
55	Capoteiro_proximo_academia_artes_marciais	-22.83333249	-42.10163847
56	Travessazproximo_garagem_ampla	-22.83243298	-42.09860455
57	Posto_Puma	-22.83330375	-42.09858209
59	Mercado_peixe	-22.83426351	-42.10106112
60	Tere_frutas	-22.83530453	-42.10058469
61	Mercado_economico	-22.83522821	-42.1016378
62	Caixa_economica	-22.83567718	-42.10271806
63	Praca_centro	-22.83518464	-42.10438941
64	Rua_da_parra	-22.83699907	-42.10327193
65	Igreja_matriz	-22.83868895	-42.10285384
66	Beco_das_massas	-22.8397973	-42.10297253
67	Pastel	-22.84027345	-42.10294906
68	Hospital_missao	-22.84069058	-42.10359447
69	Pousada_vilaMares	-22.84481981	-42.10401189
70	Prefeitura	-22.84096341	-42.10109733
71	Forum	-22.84038221	-42.10081268
72	Sport_clube_SaoPedro	-22.84072209	-42.09929589
73	Academia_CTLA	-22.83922196	-42.10023098
74	Razao_contabilidade	-22.83847729	-42.10091226
75	Teatro_municipal	-22.8395294	-42.09754843
76	Bar_refugio	-22.84256766	-42.09716454
77	Espaco_atelie21	-22.84142905	-42.09428854
78	Capela_saoFranciscoAssis	-22.84838659	-42.09729396
79	Grupo_espiritaFranciscoAssis	-22.8483489	-42.10212462
80	Capela_SaoPedro	-22.84945253	-42.10352808
81	Super_epa	-22.85128469	-42.10304059
82	Praca_possoFundo	-22.86034718	-42.10805599
83	Creche_tiaMarcia	-22.86317304	-42.10938904
84	Restaurante_delicias_lagoa	-22.86263487	-42.11374428
85	Pousada	-22.8636006	-42.11650092
86	Proximo_pousada_xodo_praia	-22.87315653	-42.11537708
87	Pousada_xodo_praia	-22.87287944	-42.11614318
88	Esquina_robertoMarinho	-22.87639822	-42.1190621
89	Predio_construcao	-22.83539538	-42.09468585

TABLE XIII
SÃO PEDRO DA ALDEIA WIND

_id	markerid	speed	date
38	43	2.0	07/07/2016
39	44	1.5	07/07/2016

40	45	2.3	07/07/2016
41	46	2.5	07/07/2016
42	47	2.0	07/07/2016
43	48	2.3	07/07/2016
44	49	2.0	07/07/2016
45	50	3.5	07/07/2016
46	51	3.5	07/07/2016
47	52	4.0	07/07/2016
48	53	4.5	07/07/2016
49	54	2.8	07/07/2016
50	55	2.3	07/07/2016
51	56	1.8	07/07/2016
52	57	2.0	07/07/2016
53	59	1.5	07/07/2016
54	60	1.5	07/07/2016
55	61	1.5	07/07/2016
56	62	1.0	07/07/2016
57	63	6.0	07/07/2016
58	64	0.8	07/07/2016
59	65	2.7	07/07/2016
60	66	1.7	07/07/2016
61	67	2.3	07/07/2016
62	68	2.3	07/07/2016
63	69	1.5	07/07/2016
64	70	2.3	07/07/2016
65	71	2.5	07/07/2016
66	72	2.5	07/07/2016
67	73	3.0	07/07/2016
68	74	1.3	07/07/2016
69	75	2.5	07/07/2016
70	76	2.4	07/07/2016
71	77	3.3	07/07/2016
72	78	3.0	07/07/2016
73	79	1.2	07/07/2016
74	80	2.3	07/07/2016
75	81	3.4	07/07/2016
76	82	2.5	07/07/2016
77	83	1.4	07/07/2016
78	84	2.8	07/07/2016
79	85	4.0	07/07/2016
80	86	1.3	07/07/2016
81	87	5.3	07/07/2016
82	88	1.9	07/07/2016
83	89	4.6	07/07/2016

TABLE XIV
SÃO PEDRO DA ALDEIA BUILDING PROXIMITY AND HEIGHT OF BUILDINGS AROUND

_id	markerid	proximity	height
41	43	FAR	LOW
42	44	NEAR	MODERATE
43	45	NEAR	LOW
44	46	FAR	LOW
45	47	NEAR	LOW
46	48	NEAR	LOW
47	49	FAR	LOW
48	50	FAR	LOW
49	51	NEAR	LOW
50	52	NEAR	LOW
51	53	FAR	LOW
52	54	NEAR	MODERATE
53	55	VERY CLOSE	MODERATE
54	56	NEAR	LOW
55	57	NEAR	MODERATE
56	59	NEAR	HIGH
57	60	FAR	LOW
58	61	NEAR	MODERATE
59	62	VERY CLOSE	HIGH
60	63	FAR	LOW
61	64	VERY CLOSE	MODERATE
62	65	NEAR	LOW
63	66	VERY CLOSE	LOW
64	67	NEAR	LOW
65	68	NEAR	LOW
66	69	VERY CLOSE	MODERATE
67	70	NEAR	LOW
68	71	FAR	LOW
69	72	FAR	LOW
70	73	NEAR	MODERATE
71	74	VERY CLOSE	LOW
72	75	FAR	LOW
73	76	FAR	MODERATE
74	77	FAR	LOW
75	78	FAR	LOW
76	79	VERY CLOSE	MODERATE
77	80	FAR	LOW
78	81	NEAR	HIGH
79	82	FAR	LOW
80	83	FAR	LOW
81	84	NEAR	LOW
82	85	FAR	LOW

83	86	NEAR	LOW
84	87	VERY CLOSE	LOW
85	88	FAR	LOW
86	89	VERY CLOSE	HIGH

TABLE XV
SÃO PEDRO DA ALDEIA HEIGHTS OF TERRAIN ROUGHNESS

_id	markerid	roughness
41	43	ROUGHNESS LOW WATER SAND SNOW
42	44	ROUGHNESS LOW WATER SAND SNOW
43	45	ROUGHNESS LOW WATER SAND SNOW
44	46	ROUGHNESS LOW WATER SAND SNOW
45	47	HIGH FORESTS ROUGHNESS CITIES SUBURBS
46	48	HIGH FORESTS ROUGHNESS CITIES SUBURBS
47	49	AREA ROUGHNESS AVERAGE PASTURE FARM AIRPORT
48	50	HIGH FORESTS ROUGHNESS CITIES SUBURBS
49	51	ROUGHNESS LOW WATER SAND SNOW
50	52	HIGH FORESTS ROUGHNESS CITIES SUBURBS
51	53	ROUGHNESS LOW WATER SAND SNOW
52	54	HIGH FORESTS ROUGHNESS CITIES SUBURBS
53	55	HIGH FORESTS ROUGHNESS CITIES SUBURBS
54	56	ROUGHNESS LOW WATER SAND SNOW
55	57	HIGH FORESTS ROUGHNESS CITIES SUBURBS
56	59	HIGH FORESTS ROUGHNESS CITIES SUBURBS
57	60	HIGH FORESTS ROUGHNESS CITIES SUBURBS
58	61	HIGH FORESTS ROUGHNESS CITIES SUBURBS
59	62	HIGH FORESTS ROUGHNESS CITIES SUBURBS
60	63	ROUGHNESS LOW WATER SAND SNOW
61	64	HIGH FORESTS ROUGHNESS CITIES SUBURBS
62	65	HIGH FORESTS ROUGHNESS CITIES SUBURBS
63	66	AREA ROUGHNESS AVERAGE WITH TREES AND SHRUBS
64	67	HIGH FORESTS ROUGHNESS CITIES SUBURBS
65	68	HIGH FORESTS ROUGHNESS CITIES SUBURBS
66	69	ROUGHNESS LOW WATER SAND SNOW
67	70	HIGH FORESTS ROUGHNESS CITIES SUBURBS
68	71	HIGH FORESTS ROUGHNESS CITIES SUBURBS
69	72	HIGH FORESTS ROUGHNESS CITIES SUBURBS
70	73	AREA ROUGHNESS AVERAGE WITH TREES AND SHRUBS
71	74	HIGH FORESTS ROUGHNESS CITIES SUBURBS
72	75	AREA ROUGHNESS AVERAGE PASTURE FARM AIRPORT
73	76	AREA ROUGHNESS AVERAGE PASTURE FARM AIRPORT
74	77	HIGH FORESTS ROUGHNESS CITIES SUBURBS
75	78	AREA ROUGHNESS AVERAGE PASTURE FARM AIRPORT
76	79	HIGH FORESTS ROUGHNESS CITIES SUBURBS
77	80	HIGH FORESTS ROUGHNESS CITIES SUBURBS
78	81	ROUGHNESS LOW WATER SAND SNOW
79	82	AREA ROUGHNESS AVERAGE PASTURE FARM AIRPORT
80	83	AREA ROUGHNESS AVERAGE PASTURE FARM AIRPORT
81	84	ROUGHNESS LOW WATER SAND SNOW
82	85	AREA ROUGHNESS AVERAGE PASTURE FARM AIRPORT
83	86	ROUGHNESS LOW WATER SAND SNOW
84	87	HIGH FORESTS ROUGHNESS CITIES SUBURBS
85	88	AREA ROUGHNESS AVERAGE WITH TREES AND SHRUBS
86	89	HIGH FORESTS ROUGHNESS CITIES SUBURBS

TABLE XVI
SÃO PEDRO DA ALDEIA INSTALLATION SITE HEIGHTS

_id	markerid	height
41	43	LOW
42	44	MODERATE
43	45	HIGH
44	46	LOW
45	47	LOW
46	48	LOW
47	49	LOW
48	50	HIGH
49	51	LOW
50	52	MODERATE
51	53	LOW
52	54	HIGH
53	55	MODERATE
54	56	LOW
55	57	LOW
56	59	LOW
57	61	MODERATE
58	62	HIGH
59	63	LOW
60	64	MODERATE
61	65	LOW
62	66	LOW

63	67	MODERATE
64	68	LOW
65	69	MODERATE
66	70	LOW
67	71	MODERATE
68	72	LOW
69	73	LOW
70	74	MODERATE
71	75	MODERATE
72	76	LOW
73	77	LOW
74	78	MODERATE
75	79	HIGH
76	80	LOW
77	81	HIGH
78	82	LOW
79	83	LOW
80	84	LOW
81	85	HIGH
82	86	LOW
83	87	MODERATE
84	88	LOW
85	89	HIGH

TABLE XVII
SÃO PEDRO DA ALDEIA FUZZY

_id	markerid	fuzzy_avaliation
43	43	AVERAGE VIABILITY
44	44	LOW VIABILITY
45	45	LOW VIABILITY
46	46	AVERAGE VIABILITY
47	47	LOW VIABILITY
48	48	LOW VIABILITY
49	49	AVERAGE VIABILITY
50	50	LOW VIABILITY
51	51	AVERAGE VIABILITY
52	52	LOW VIABILITY
53	53	AVERAGE VIABILITY
54	54	LOW VIABILITY
55	55	LOW VIABILITY
56	56	HIGH VIABILITY
57	57	LOW VIABILITY
59	59	LOW VIABILITY
61	61	LOW VIABILITY
62	62	LOW VIABILITY
63	63	LOW VIABILITY
64	64	LOW VIABILITY
65	65	LOW VIABILITY
66	66	LOW VIABILITY
67	67	LOW VIABILITY
68	68	LOW VIABILITY
69	69	LOW VIABILITY
70	70	LOW VIABILITY
71	71	LOW VIABILITY
72	72	HIGH VIABILITY
73	73	LOW VIABILITY
74	74	LOW VIABILITY
75	75	LOW VIABILITY
76	76	LOW VIABILITY
77	77	HIGH VIABILITY
78	78	LOW VIABILITY
79	79	LOW VIABILITY
80	80	HIGH VIABILITY
81	81	LOW VIABILITY
82	82	AVERAGE VIABILITY
83	83	HIGH VIABILITY
84	84	HIGH VIABILITY
85	85	LOW VIABILITY
86	86	HIGH VIABILITY
87	87	LOW VIABILITY
88	88	HIGH VIABILITY
89	89	LOW VIABILITY

VI. CONCLUSION

Mamdani [17] was the model of inferences used for measurement of points which best suited the processing power of the smartphone, and this model uses union and intersection operations between sets just as Zadeh.

All variables used in the fuzzy system, as well as its evaluation algorithm were based on studies of other authors as cited throughout the text. We came to the maps of fig. 7 and fig. 8 which show dots in different colors, as in the XVIII and XX tables can be seen that there are many variations with the points which would have better use of wind power as can be extracted in tables below.

Most points had in common distant buildings and low installation site with the exception of point with id 79 in São Pedro da Aldeia, but still it is difficult to know if the roughness or proximity of buildings among other variables have influenced really in deciding which places with better wind suitability. However it is observed that case be inserted more variables in the system, perhaps the result can be different variables such as temperature, dew point elevation.

The smartphone application is a tool that well measured facilitates the process of gauging friendly places wind energy production in order to use common linguistic variables the language of beings human as well as using the potential of new technologies found in smartphones today. This type of technology can contribute considerably with respect to the encouragement to use more and more renewable energy sources contributing to the reduction of carbon dioxide emissions into the atmosphere in order to enable countries in development continue to grow without harm to the environment.

The following points in the tables below are noteworthy because they have the best rates of suitability and feasibility wind because the terrain roughness characteristics combined with the height of the buildings around and the proximity of the buildings around, which, according to the algorithm execution, proved to be the variables that have the greatest influence on the system and definitely determined that these points would be the best for wind micro generators vertical shaft installation.

It is noteworthy that may be considered in future work other variables such as relative humidity, velocity measurements at different times, ambient temperature, seasonality of the region and even issues for better extraction of wind power according to the law of Betz.

TABLE XVIII
MARKERS WITH HIGH AVAILABILITY ARRAIAL DO CABO

idmarker	LAT	long	installation height	wind speed
6	-22,977751	-42,023154	LOW	2.7
27	-22,97251	-42,026837	LOW	2.4
37	-22,967536	-42,023443	LOW	1.6
42	-22,954824	-42,031784	LOW	1.9

TABLE XIX
MARKERS WITH HIGH AVAILABILITY ARRAIAL DO CABO

Idmarker	roughness	height of buildings around	buildings proximity
6	HIGH FORESTS ROUGHNESS CITIES SUBURBS	LOW	FAR
27	HIGH FORESTS ROUGHNESS CITIES SUBURBS	LOW	FAR
37	HIGH FORESTS ROUGHNESS CITIES SUBURBS	LOW	FAR
42	AREA ROUGHNESS AVERAGE WITH TREES AND SHRUBS	LOW	FAR

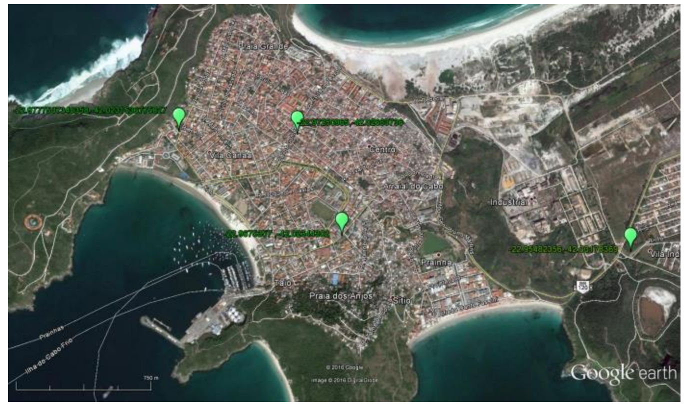


Fig. 14 Markers with high availability Arraial do Cabo

TABLE XX
MARKERS WITH HIGH AVAILABILITY SÃO PEDRO DA ALDEIA

idmarker	LAT	long	installation height	windspeed
56	-22,832433	-42,098605	LOW	1.8
72	-22,840722	-42,099296	LOW	2.5
77	-22,841429	-42,094289	LOW	3.3
79	-22,848349	-42,102125	HIGH	1.2
80	-22,849453	-42,103528	LOW	2.3
83	-22,863173	-42,109389	LOW	1.4
84	-22,862635	-42,113744	LOW	2.8
86	-22,873157	-42,115377	LOW	1.3
88	-22,876398	-42,119062	LOW	1.9

TABLE XXI
MARKERS WITH HIGH AVAILABILITY SÃO PEDRO DA ALDEIA

idmarker	roughness	height of buildings around	buildings proximity
56	ROUGHNESS LOW WATER SAND SNOW	LOW	NEAR
72	HIGH FORESTS ROUGHNESS CITIES SUBURBS	LOW	FAR
77	HIGH FORESTS ROUGHNESS CITIES SUBURBS	LOW	FAR
79	HIGH FORESTS ROUGHNESS CITIES SUBURBS	MODER ATE	VERY CLOSE
80	HIGH FORESTS ROUGHNESS CITIES SUBURBS	LOW	FAR
83	AREA ROUGHNESS AVERAGE PASTURE FARM AIRPORT	LOW	FAR
84	ROUGHNESS LOW WATER SAND SNOW	LOW	NEAR
86	ROUGHNESS LOW WATER SAND SNOW	LOW	NEAR
88	AREA ROUGHNESS AVERAGE WITH TREES AND SHRUBS	LOW	FAR

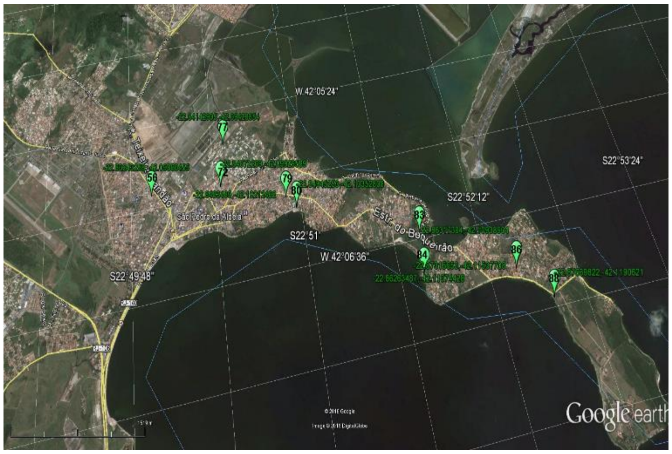
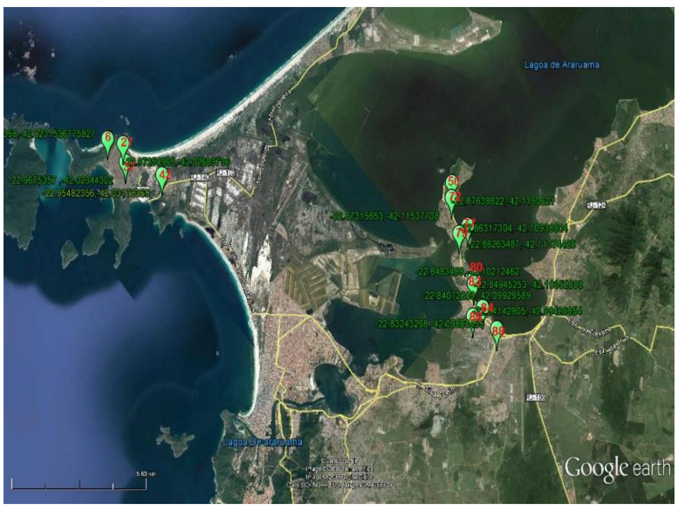


Fig. 15 Markers with high availability São Pedro da Aldeia

F



ig. 15 Markers with high availability

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APÊNDICE

APÊNDICE A – Fotos dos locais aferidos

Figura 1A – Marcador id 11 lat -22.974609320696 long -42.0211493968964

Fonte: o autor (2016)

Figura 2 A – Marcador id 17 lat -22.9737116724197 long -42.0311801880598

Fonte: o autor (2016)

Figura 3 A – Marcador id 19 lat -22.9730976997903 long -42.0314256101847

Fonte: o autor (2016)

Figura 4 A – Marcador id 28 lat -22.9740401111327 long -42.026365287602

Fonte: o autor (2016)

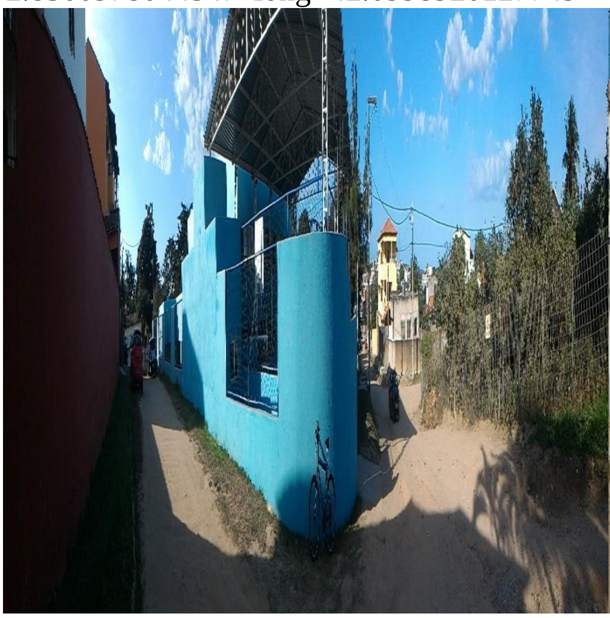
Figura 5 A – Marcador id 30 lat -22.9719098755442 long -42.0278830826283

Fonte: o autor (2016)

Figura 6 A – Marcador id 41 lat -22.9594917335204 long -42.0255656540394

Fonte: o autor (2016)

Figura 7 A – Marcador id 46 lat -2.8300978044547 long -42.0998920127749



Fonte: o autor (2016)

Figura 8 A – Marcador id 47 lat -22.8281068357946 long -42.0998725667596

Fonte: o autor (2016)

Figura 9 A – Marcador id 50 lat -22.8296673522671 long -42.1044373512268

Fonte: o autor (2016)

Figura 10 A – Marcador id 53 lat -22.8269038353393 long -42.1140839159489

Fonte: o autor (2016)

Figura 11 A - Marcador id 57 lat -22.8333037497398 long -42.0985820889473

Fonte: o autor (2016)

Figura 12 A - Marcador id 65 lat -22.838688949804 long -42.1028538420796

Fonte: o autor (2016)

Figura 13 A – Marcador id 68 lat -22.8406905781603 long -42.1035944670439

Fonte: o autor (2016)

Figura 14 A – Marcador id 78 lat -22.8483865926431 long -42.0972939580679

Fonte: o autor (2016)