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Santos Filho et al

Automatic detection of the wetland APA of Fazendinha (Brazil) and its surroundings with the use of the Water Plugin complement and SAR inputs of the P band

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A B S T R A C T

The Environmental Protection Area (APA) of the Fazendinha district, located within the urban perimeter, in the South Zone of the city of Macapá, has a legal area of approximately 140 hectares. It is composed of a floodplain forest of rich biodiversity, where human occupation is also increasingly present, either by the riverside residents who live in it or by the growing population of its surroundings, which has been increasingly present by the real estate exploitation of the last years. In this area of socio-environmental confrontation, authors have pointed out that there is a humid area beyond the limits established by the APA's creation decree. With the use of the Water Plugin extension and its statistical models implemented in it, it was possible to delimit the humid area that covers not only the APA, but its surroundings, covering a total area of about 240 hectares. In addition, it was possible to identify a flood risk area in the Fazendinha district that is being gradually and systematically occupied by its residents, in addition to the paving of urban roads that follow this occupation.

Keywords: APA, wetland, limits, Digital Terrain Model, cartographic base.

Detecção automática da área úmida APA de Fazendinha (Macapá – Amapá) e seu entorno com o uso do complemento *Water Plugin* e insumos SAR da banda P

R E S U M O

A Área de Proteção Ambiental (APA) do distrito de Fazendinha localizada dentro do perímetro urbano, na Zona Sul da cidade de Macapá, possui uma área legal cerca de 140 hectares. Ela é composta por uma floresta de várzea de rica biodiversidade, onde também a ocupação humana está cada vez mais presente, sejam pelos moradores ribeirinhos que nela vivem ou pela crescente população de entorno, que se tem mostrado cada vez mais constante pela exploração imobiliária dos últimos anos. Nesta área de confronto socioambiental, autores têm apontado que existe uma zona úmida além dos limites estabelecidos pelo decreto de criação da APA. Com o uso da extensão *Water Plugin* e seus modelos estatísticos nele implementado foi possível a delimitação da área úmida que compreende não somente a APA, mas o seu entorno, abrangendo uma superfície total cerca de 240 hectares. Além disso, foi possível identificar uma área de risco de inundação no distrito de fazendinha que está sendo ocupada de maneira gradual e sistematicamente por seus moradores, além da pavimentação de vias urbanas que segue esta ocupação.

Palavras-Chaves: APA, área úmida, limites, Modelo Digital de Terreno, base cartográfica.

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1. Introduction

The first Conservation Unit in Amapá is the Macapá Forest Park, created in 1974. After this period, it was named REBIO (Biological Reserve in Portuguese abbreviation) da Fazendinha in 1984, and currently, through decree no. 0873/2004, the Fazendinha Environmental Protection Area (APA - Portuguese abbreviation). This decree intends to reconcile the permanence of the local population with environmental protection through the rational use of its natural resources (UCB, 2020). This area of urban environmental conflict shows the nuances between man and nature, where the gradual growth of the residents, who live between bridges built for their locomotion within this APA, contrasts with the enormous trees of the dense floodplain-wetlands forest.

The Wetlands are the ecosystems most affected and threatened of destruction by man. The Ramsar international convention, held in February 1971, sought an intergovernmental treaty to protect aquatic habitats essential for the conservation of migratory birds. After the Ramsar international convention, it increased its concern with Wetlands to promote their conservation and sustainable use (MMA, 2020). In 1993, Brazil signed the RAMSAR Convention. However, Decree No. 1905 of May 16, 1996, was only enacted, which presupposes a national policy for the intelligent management and protection of wetlands and their biodiversity.

The Technical Note 001-2019 ADIN-CGUC-CGTIA/SEMA-AP is another relevant factor related to this wetland. The Technical Note shows the limits of the conservation units in the municipalities of Amapá. The execution of the official composition of the note data is regarding the RADAM project (Radar in the Amazon), which provides a drawing at a scale of 1:1 000 000, no longer meeting the current needs due to the low-resolution information for mapping in urban municipal areas (UCB, 2020).

However, a large amount of spatial data at the scale of 1:25 000, produced and made available by the project, Digital and Continuous Cartographic Base of Amapá, and high-resolution images obtained by aerial flights. The data come from an airborne Synthetic Aperture Radar (SAR) sensor system and radar signal interaction in the X and P band. This spectral range (P band) allows information to be obtained directly from the ground, making it especially useful in places with noise such as clouds or even dense vegetation cover. Furthermore, according to Prandel (2019), the interferometry techniques from the Digital Terrain Model P band can generate products with the region of wetlands.

The Qgis is a powerful GIS (Geographic Information System) developed by the international scientific community of free access - General Public License (GNU) for spatial processing data. Gary Sherman started it in 2002, and then this project was developed with the Open Souce Geospatial Foundation (OSGeo) in 2007(Menke et al., 2016). This tool allows the creation of add-ons in its programming through the aggregation of extensions called plugins. In all, for this tool, there are more than 1000 stable plugins built with various purposes serving the significant areas of geospatial knowledge.

This work aims to delimitate the Wetland Area of the Fazendinha APA and its surroundings using the automatic methods developed in the experimental Water Plugin extension.

2. Material and Methods

2.1 Delimitation of the study area

The location of Fazendinha APA is between the left side of the Salvador Diniz highway and near to Paxicu and Igarapé da Fortaleza rivers. The coordinates of wetland understudy is: parallels 0º 2' 30.00" and 0º 3' 26.25", south latitude, and meridians 51º 8' 26.25" and 51º 6' 33.75", west longitude.

2.2 Data Acquisition

The study uses the Department of Environment - SEMA/AP data from the Digital and Continuous Cartographic Base of Amapá. Besides the obtained Digital Terrain Model, a high resolution (20 cm) color composite ortho-image was used, produced from the town's headquarters to use as "ground truth." The technical specifications of the study are UTM projection system / Zone 22, SIRGAS 2000, in TIF format, size 2.5m x 2.5m, scale 1:25 000. The reference of vertical datum is into Imbituba - Santa Catarina.

Developing the technical information, the Geographic Service Directorate (DSG) of the army, inform about its altimetric precision in open spaces, concerning the Cartographic Accuracy Standard (PEC - Portuguese abbreviation) former class A for scale 1:25 000 with a standard deviation of 3.33 m. In areas of dense vegetation, it admits to the old PEC class C for the scale 1: 25 000, with a standard deviation of 4.56 m. Its PEC is Class A for planimetric accuracy for a value less than or equal to 7.5 m.

2.3 Data Processing

The automatic delimitation of the wetland of the Fazendinha APA utilizes an extension for Qgis version 2.18.28 called "Water Plugin." This plugin following models for automatic wetland extraction was applied: Sturges' model (Sturges, 1926) defined by (Equation 1):

$$k = 1 + \log_2 n \qquad (1)$$

Where k is its number of classes and n is the number of samples.

Scott's function given by the formula (Equation 2):

$$k = 3.49\sigma n^{-1/3} \qquad (2)$$

Where σ is the standard deviation of the sample in the study.

Freedman y Diaconis's (Hyndman, 1995) formula given by (Equation 3):

$$k = 2(IQ)n^{-1/3} \qquad (3)$$

Where IQ is interquartile of the sample.

The Square Root as shown in Equation 4 (Cakmak & Cuhadaroglu, 2018):

$$k = \sqrt{n} \qquad (4)$$

and its variation: square root of 2N (Equation 5):

$$k = \sqrt{2n} \qquad (5)$$

The "Potency" model employed by Gonzalez and Woods (2003) in the quotation process (Equation 6):

$$n = 2^k \qquad (6)$$

The model composed as the Fifth Root of N to the third Potency formulated as shown in Equation 7:

$$k = \sqrt[5]{n^3} \qquad (7)$$

In addition, this plugin uses the Digital Terrain Model (MDT Portuguese abbreviation/DTM) as input.

Utilizes in the study the Digital Terrain Model from an airborne SAR sensor in the P-band spectrum because the P spectrum can pass through the canopy and returns information directly from the ground due to its wavelength (72 cm).

The algorithm's operation has input the Digital Terrain Model accompanied by its global or local perspective. If the perspective is global, then the whole image is used. Then the desired model is applied through its choice, which performs the classification showing the wetland area after activation. If the option is local, establish the size of the window for processing. The steps are an (i) division of image and apply the chosen model, (ii) classification of the image, and (iii) join (mosaic) of the image to show the wetland area (Dos Santos Filho, Cornero & Pereira, 2021).

2.4 Evaluation of results

Among the main instruments adopted to perform the validation, reliability, and objectivity of the mapping are the statistical comparison of the data through its interquartile, standard deviation, analysis of variance (ANOVA), Tukey's test, the overall accuracy, and the Kappa index (Moreira, 2011).

3. Results

The results present an image chart with the polygons at their edge boundaries for each model delimiting the Wetland Area of the APA and its surroundings (Figure 1).

Figure 1- Overlapping automatic detection models.

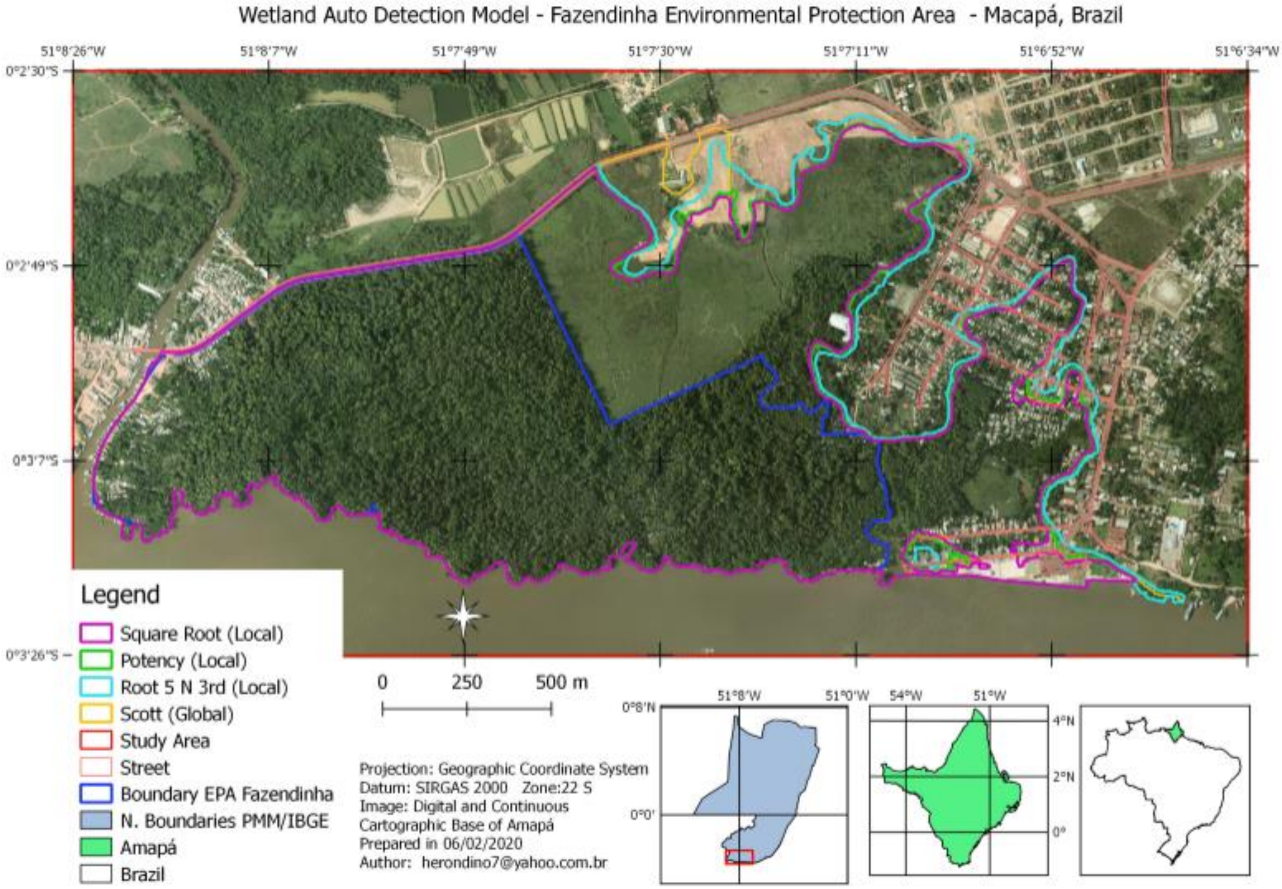
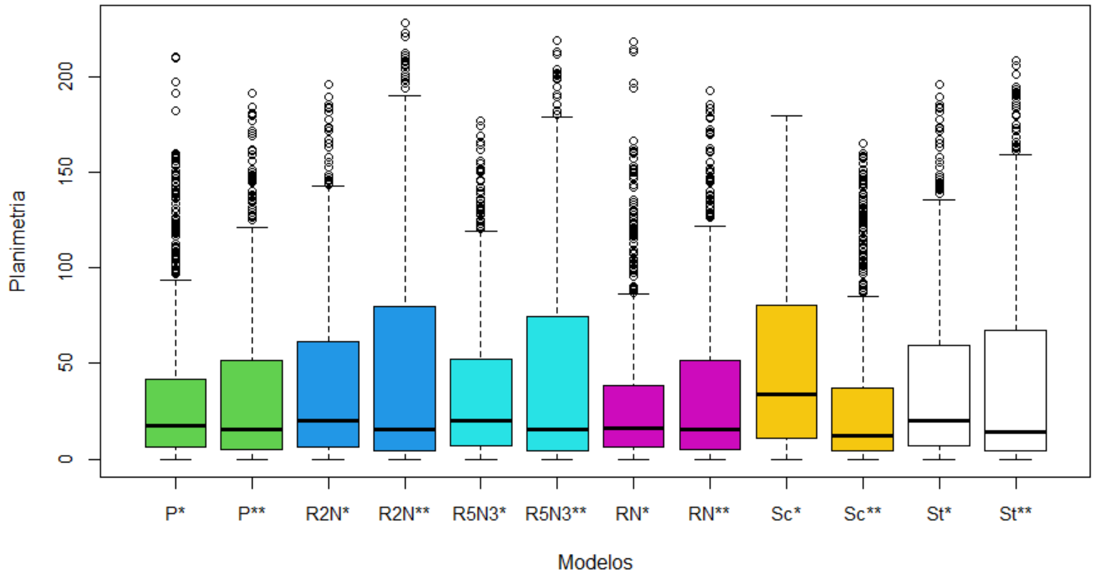


Figure 1 shows the boundary of the Fazendinha APA. Moreover, according to Santos Filho (2011) and Santos (2016), its wetland area indicated in the models is beyond the APA limits (in the northeast to the southeast direction of the study area). Analyze the generated models from their planimetric and altimetric perspectives.

3.1 Planimetric Perspective

The study utilizes a distance between the points (periphery of the polygons) the Santos (2016) mold references. From the values of the distances, creates a boxplot group of each model for its analysis. In it, the local Potency (P*), local Square Root of N (RN*), and global Scott (Sc**) models appear to be closest. Next, we have apparent proximity between the global Potency (P**), local Root 5 of N to the 3rd Potency (R5N3*), and global Square Root (RN**) models. The local 2N square root (R2N*), local Scott (Sc*), and local Sturges (St*) models have approximations (Figure 2).

Figure 2– Comparison of the distance between models by reference taken (Santos, 2016)



The models that showed more excellent symmetry were the local Potency (P*) and local Root of N (RN*), and global Scott (Sc**). The boxplot shows an asymmetric trend to the left (bottom) because the boundary to the south and clockwise west is defined by the Amazon River and igarapé da Fortaleza, having a minimum standard value in all groups 0.03 cm (Table 1). Furthermore, the minor interquartile differences and deviations found were in the following models: Square root of N (RN*), Scott (Sc**), Potency (P*), and the fifth root of N to the third Potency (R5N3*). Four models as being of the most significant relevance in this analysis.

The maximum values of the planimetric comparison with Santos (2016) reached a maximum distance between 165 and 219 meters approximate from the generated models. These and other statistical parameters are shown in Table 1, ordered by variance.

Table 1 – Statistical parameters of the models

Perspective: *Local and** Global.

Models	Min	1º Q	Med	Me	3º Q	Max	Interq	Std Des
Sc**	0.03	4.57	12.59	28.9	37.30	165.02	32.73	37.48
R5N3*	0.03	6.90	20.04	34.8	52.33	176.87	45.42	38.09
RN*	0.03	6.60	16.26	31.0	38.54	217.94	31.94	38.47
P*	0.03	6.24	17.50	32.7	41.98	210.30	35.74	39.67
RN**	0.03	4.93	15.30	33.1	51.75	192.89	46.86	40.16
P**	0.03	4.94	15.58	33.3	51.78	191.15	46.84	40.25
St*	0.03	6.80	19.99	37.3	59.41	195.72	52.61	41.28
Sc*	0.03	10.85	33.61	47.3	80.21	179.31	69.35	42.57
R2N*	0.03	6.65	20.33	38.4	61.31	195.72	54.66	42.66
St**	0.03	4.73	14.33	39.2	67.05	208.54	62.32	47.23
R5N3**	0.03	4.61	15.58	42.8	74.44	219.12	69.83	50.86
R2N**	0.03	4.70	15.75	45.5	79.91	227.96	75.21	54.27

Utilizes the ANOVA analysis to verify the estimate of which models would be closest around the mean (to rule out the null hypothesis). The results were a minimal probability, i.e., <2e-16, that all models were estimated equal (Table 2).

Table 2 – Analysis of variance (ANOVA) planimetric between the models

ANOVA	df	Sum Sq	MeanSq	F Value	P(>F)
Models	11	300944	27359	14.76	<2e-16
Residuals	9720	18018923	1854		

Applies the Tukey test between the models to find the closest ones, as shown in Table 3. It presents the most relevant values with a 95% confidence interval.

Table 3 – Tukey's Comparative Test between the models at 95% confidence level

Models	diff	lwr	upr	p adj
P**-P*	0.6432882	-6.34587600	7.6324525	1.0000000
R5N3*-P*	2.1140272	-4.87513708	9.1031914	0.9979500
RN*-P*	-1.7334057	-8.72256992	5.2557586	0.9996803
RN**-P*	0.4104087	-6.57875552	7.3995730	1.0000000
Sc**-P*	-3.7746713	-10.76383556	3.2144929	0.8368384
St*-P*	4.5724155	-2.41674874	11.5615797	0.5947873
R5N3*-P*	1.4707389	-5.51842533	8.4599032	0.9999366
RN*-P**	-2.3766939	-9.36585816	4.6124703	0.9942502
RN**-P**	-0.2328795	-7.22204376	6.7562847	1.0000000
Sc**-P**	-4.4179596	-11.40712380	2.5712047	0.6471145
St*-P**	3.9291273	-3.06003699	10.9182915	0.7972000
R5N3*-R2N*	-3.6357926	-10.62495684	3.3533717	0.8684741
R5N3**-R2N*	4.3472351	-2.64192915	11.3363993	0.6705625
St*-R2N*	-1.1774043	-8.16656850	5.8117600	0.9999934
St**-R2N*	0.7682291	-6.22093518	7.7573933	0.9999999
R5N3**-R2N**	-2.6588713	-9.64803553	4.3302930	0.9854214
Sc*-R2N**	1.8158921	-5.17327214	8.8050563	0.9995008
RN*-R5N3**	-3.8474328	-10.83659708	3.1417314	0.8187280
RN**-R5N3*	-1.7036184	-8.69278268	5.2855458	0.9997297
St*-R5N3*	2.4583883	-4.53077591	9.4475526	0.9923412
St**-R5N3*	4.4040217	-2.58514259	11.3931859	0.6517668
Sc*-R5N3**	4.4747634	-2.51440086	11.4639276	0.6280178
St**-R5N3**	-3.5790060	-10.56817028	3.4101582	0.8802668
RN**-RN*	2.1438144	-4.84534984	9.1329786	0.9976745
Sc**-RN*	-2.0412656	-9.03042988	4.9478986	0.9985094
Sc**-RN**	-4.1850800	-11.17424429	2.8040842	0.7224832
St*-RN**	4.1620068	-2.82715747	11.1511710	0.7296183
St**-St*	1.9456333	-5.04353093	8.9347976	0.9990433

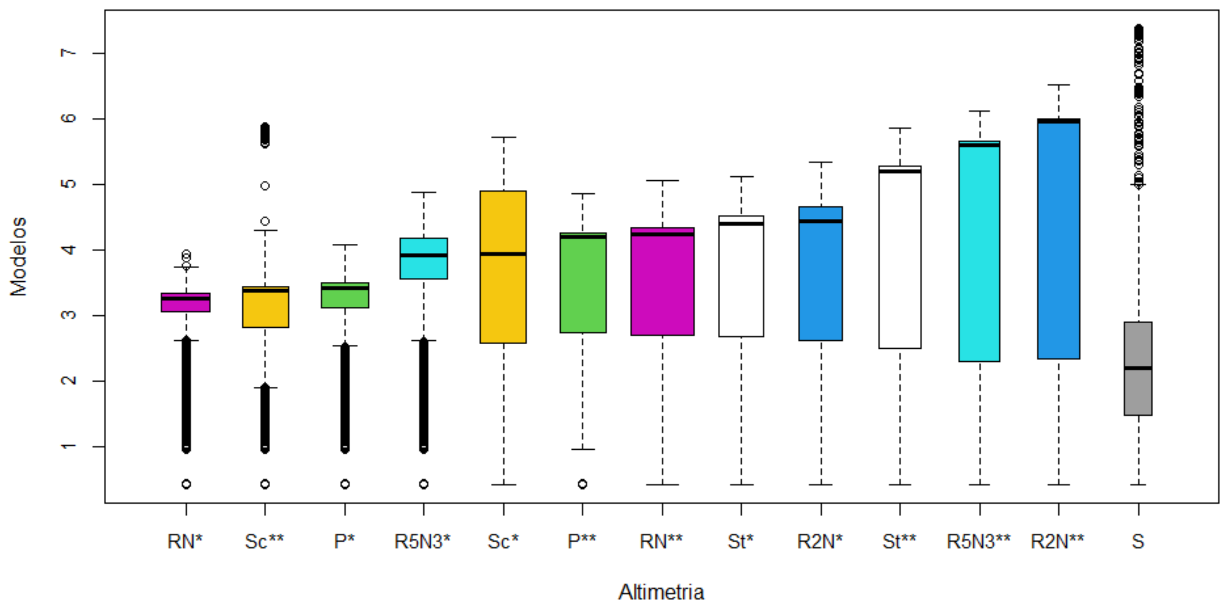
The Local Potency model (P*) showed equal estimates with the models Global Potency (P**), Root 5 of N at the 3rd local Potency (R5N3*), Local Square Root (RN*), Global Square Root (RN**) at values of 100%, 99.79%, 99.96%, and 100%, respectively (Table 3).

The global Potency (P**) model estimates equality with the local Potency (P*), and showed equality with the models, Root 5 of N to the 3rd local Potency (R5N3*), local Square Root (RN*), and global Square Root (RN**) in the values of 99.99%; 99.42% and 100% respectively.

3.2 Altimetric Perspective

Utilizes the DTM for the altimetric parameters to compare the elevations through models from points on edge. Through the boxplot, we observed the behavior of each model in its altitudes (Figure 3).

Figure 3 – Altimetric comparison between the models



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The models with the most excellent apparent symmetry, except for their outlier and median, are the RN*, Sc**, P*, and R5N3* models. Moreover, it observes the boxplot increasing, starting from its median, and the first three models with awfully close median and variability values. The six subsequent models starting from R5N3* to R2N* indicate proximity in their median. Finally, observes in their deviation and interquartile that the three best results are the model's RN*, P*, and R5N3* (Table 4).

Table 4 – Altimetric values of the models

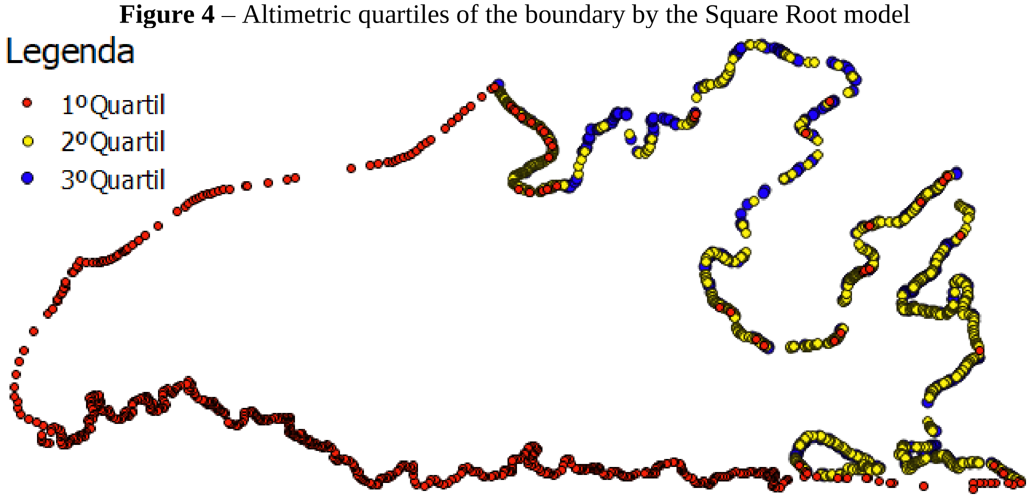
Models	Min	1º Q	Med	Me	3º Q	Max	Interq	StdDes
RN*	0.42	3.05	3.25	2.89	3.33	3.93	0.28	0.82
P*	0.42	3.11	3.41	2.99	3.50	4.07	0.39	0.89
R5N3*	0.42	3.55	3.92	3.44	4.18	4.87	0.63	1.14
P**	0.42	2.73	4.20	3.53	4.25	4.86	1.52	1.24

RN**	0.42	2.69	4.25	3.59	4.33	5.06	1.65	1.31
St*	0.42	2.67	4.41	3.66	4.51	5.12	1.84	1.35
R2N*	0.42	2.62	4.43	3.70	4.66	5.34	2.05	1.41
Sc*	0.42	2.58	3.94	3.53	4.89	5.73	2.32	1.41
S	0.42	1.48	2.19	2.44	2.89	7.38	1.41	1.72
Sc**	0.42	2.82	3.38	3.06	3.44	5.88	2.78	1.74
St**	0.42	2.49	5.20	4.16	5.27	5.87	2.78	1.74
R5N3**	0.42	2.29	5.59	4.30	5.66	6.13	3.36	1.96
R2N**	0.42	2.34	5.96	4.58	6.01	6.52	3.66	2.09

Verifying in Table 4, the minimum values in each model are 0.42 meters. However, the first quartile of each model varies. The lowest median found is for the RN* model (3.25 m) and the highest for R2N** (5.96 m), except for the S reference (2.19 m). The third quartile ranged from 3.33 m (RN*) to 6.01 m (R2N**).

Selecting the local N square root points in their quartiles and performing their mapping as shown in Figure 4, the first quartile values surround the entire perimeter of the polygon (red color).

Figure 4 – Altimetric quartiles of the boundary by the Square Root model



Twenty-five percent of the second quartile (yellow color) is related to the boundary northeast to the southeast of part of the study area. The third quartile (blue color) on the northeast with a few points southeast of the area. The interquartile difference (Q3-Q1) of the Square Root model is 0.82 meters.

Observes the best results in the Square Root of N and Potency models (Local). In the sequence, the models' Sc**, R5N3*, the Global Scott, and Local R5N3 approximate variances and interquartile. Analyzing the variance (ANOVA) can rule out the null hypothesis that the models are equal (probability of equal is <2e-16) (Table 5).

Table 5 – Analysis of variance between the group models

ANoVA	df	Sum Sq	MeanSq	F Value	P(>F)
Models	12	2332	194.31	69.14	<2e-16

Residuals	10530	29592	2.81

The results of Tukey's test, the RN* and P* models have a 99.88% equality. About Santos' (2016) and the Potency (P*) models, this probability is 99.99%. The Sturges (St*) and Square Root of 2N(R2N*) models have a 99.99% equality estimate. The other models do not present a significant relationship (Table 6).

Table 6 – Tukey's Comparative Test between the models at 95% confidence level

Models	diff	lwr	upr	p adj
RN*-P*	-0.08253	-0.35838	0.19331	0.99887
S-P*	0.06364	-0.21220	0.33948	0.99992
R2N*-P**	0.16303	-0.11281	0.43888	0.76012
R5N3*-P**	-0.11020	-0.38604	0.16564	0.98391
RN**-P**	0.16674	-0.10909	0.44259	0.73117
Sc**-P**	-0.05637	-0.33222	0.21946	0.99997
St*-P**	0.11222	-0.16362	0.38807	0.98128
RN**-R2N*	0.00371	-0.27213	0.27956	1.00000
St*-R2N*	-0.05080	-0.32665	0.22503	0.99999
R5N3**-R2N**	-0.16891	-0.44476	0.10693	0.71370
Sc**-R5N3*	0.05382	-0.22202	0.32966	0.99998
St**-R5N3**	-0.14473	-0.42057	0.13111	0.87895
S-RN*	0.14617	-0.12966	0.42202	0.87119
St*-RN**	-0.05452	-0.33036	0.22132	0.99998
St*-Sc**	0.16860	-0.10724	0.44445	0.71622

Table 6 presents a significant estimate of equality around the mean at a confidence interval of 87% between the RN* model and the model of Santos (2016).

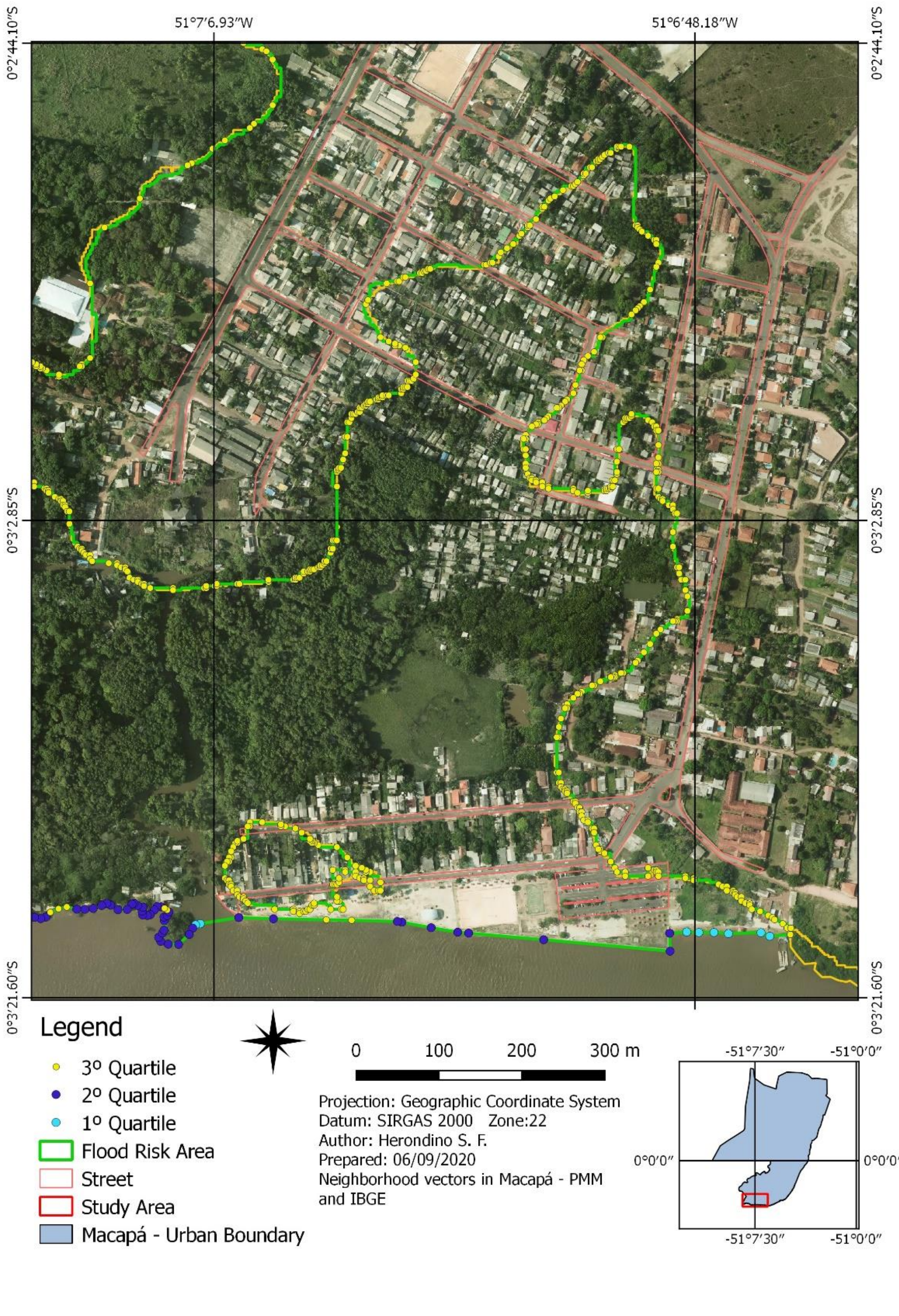
The analysis found the best result (Local Square Root) and executes the comparison to the other models and the reference through the overall accuracy and Kappa (Table 7).

Table 7 – Overall Accuracy and Kappa index

Model	**Overall-Accuracy (%)**	**Kappa**
Potency*	99.022433	0.980203
Scott**	97.890527	0.957552
Root Fifth from N to Third *	96.420532	0.927123
Potency**	96.356286	0.926909
Square Root **	95.222430	0.904470
Sturges*	94.512793	0.887837
Scott*	94.528931	0.888280
Square Root of 2N*	94.141979	0.880165
Sturges**	93.032344	0.861176
Root Fifth from N to Third **	91.863290	0.838268
Square Root of 2N**	91.079652	0.822973
Santos 2016	38.900282	0.244143

It observes in the eastern and southeastern part of the study area a risk zone (subject to flooding), with housing and paved roads built. In this area, the result of the Local Potency (P*) presents (Figure 5).

Figure 5 – Map of the flood risk area - Fazendinha District (Macapá)

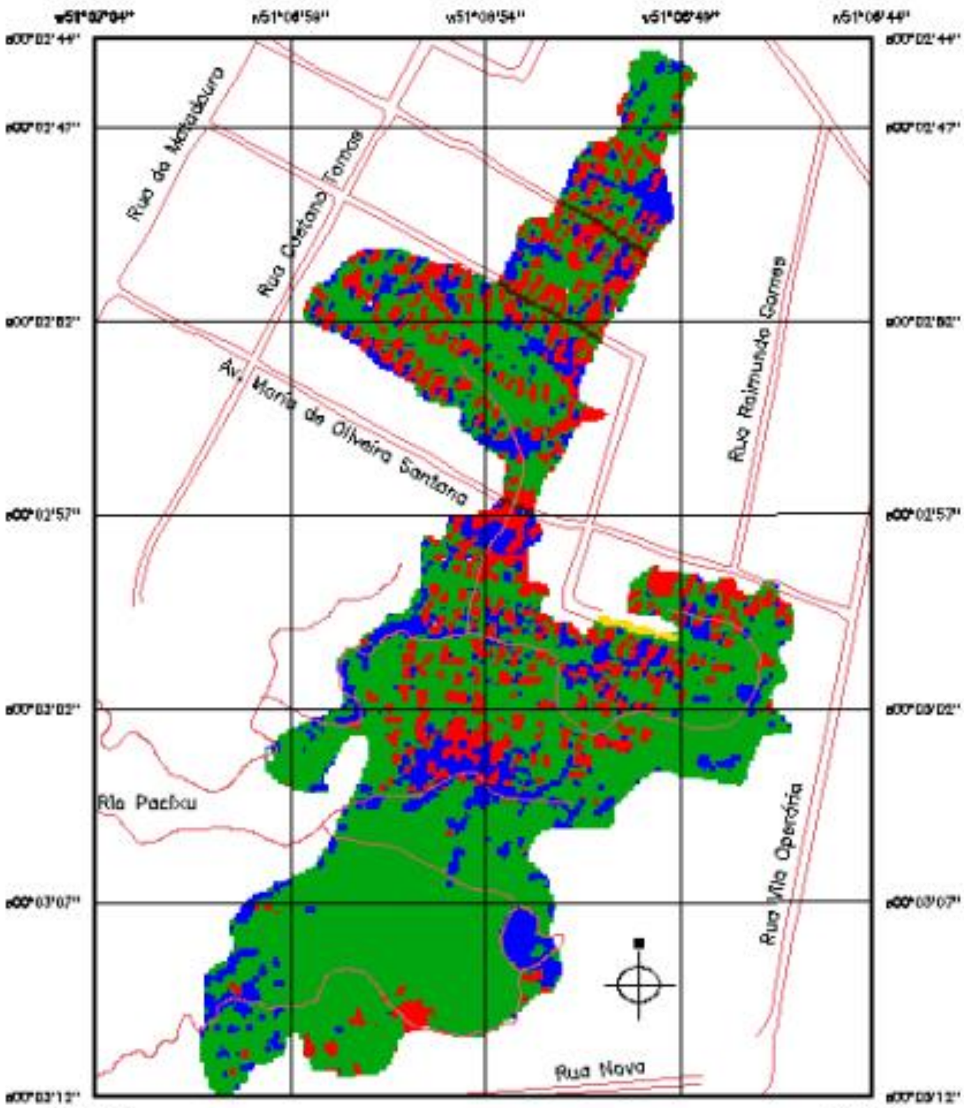


4. Discussion

4.1 Optical vs. radar sensor

Santos Filho (2011), through mapping using supervised classification through CBERS-2B/2008, calls the risk zone "Fazendinha Hangover" (Figure 5). However, in its southwestern area, due to the typical vegetation cover of floodplain forest not perceptible to optical sensors, this classification cannot be called a wetland (Figures 5 and 6).

Figure 6 – "Fazendinha Hangover"



Fonte: Santos Filho (2011)

Using the radar inputs in the "P band," the mapping uses as preponderant the terrain information return, as in the local Potency (P*) model (Figure 5). In this sense, the Digital Terrain Model through SAR sensors presents a significant advantage over optical instruments subject to noise, such as clouds and treetops (Dos Santos Filho, Cornero & Pereira, 2021).

Classifying coastal Wetlands, Santos (2016) uses GeoEye and Quick Bird images from 2009 and SRTM (Shuttle Radar Topography Mission) data with PEC class "A" classification for mapping at planimetric in scale 1:10 000. The paper uses the SRTM to reference the planimetric comparison of the models applied in the Water Plugin. However, do not evaluate the SRTM data as Digital Surface Model (MSD) due to inherent errors for the scale of work (Santos, 2016).

Comparatively, the Digital Terrain Model employed for the generation of the models under study by the Water Plugin has a dimension of 2.5 m x 2.5 m and a PEC class A at a scale of 1: 10 000 for the altimetric representation of the contour lines (Santos Filho, Cornero & Pereira, 2021). In addition, it uses a high-resolution orthoimage (20 cm x 20 cm) for the "ground truth" verification instrument for data proofing.

4.2 Best Minimal Results

The best minimal results for the study are presents for the models "Square Root (RN*)" and "Potency (P*)" as shown in Fig. 2 and Fig. 3. In addition, it observes the minimum values in the "plan-altimetric" analysis for wetlands in interquartile, standard deviation (Table 1 and Table 4), and data variability. The analysis of variance (ANOVA) showed rejection of the null hypotheses (Table 2 and Table 5), indicating that the generated models do not simulate the exact representation of the wetland under study.

The equality estimates check (Tukey's test), the models, P* and RN*, showed the probability of 99.96% and 99.88% for the plan-altimetric perspectives, respectively. Thus, the result shows a high degree of confidence that the two models simulate the exact spatial representation. However, the models, P* and RN*, do not verify the equality estimate with other models (Altimetric analysis - Table 6).

The 3rd quartile values obtained in the models, Local Square Root (RN*), Local Potency (P*), and Global Scott (Sc**), measure 3.33 m, 3.50 m, and 3.44 m, respectively (Table 4). The local Square Root (RN*) and local Potency (P*) models have in their third quartile points that cover the entire perimeter of their polygons (Figures 4 and 5). In this sense, Silva, Freitas, and Dalazoana (2012) report that the maximum value of the monthly averages of sea level for the years 2008, 2009, and 2010, from the tide gauge of Santana/AP, were 3.568 m in April, 3.839 m in May and 3.605 m in April (respectively to the years). The average of the maximums of these three periods results in 3.67 m. Thus, the models' RN*, P*, and Sc** in their 75% of the edge points (3rd quartile), are below the average maximums of these three years, which shows excellent results for their representation.

4.3 Best Maximum Results

Three other models show promising results in their plan-altimetric maximum evaluation: the local Root Fifth of N to Third Potency(R5N3*), global Scott (Sc**), and global Potency (P**). Observes the model variability in the variances and interquartile in Tables 1 and 4. After the models, P* and RN*, the R5N3* model has the lowest altimetric deviation and interquartile (Figure 3).

From an altimetric perspective, the turkey's analysis observes a 99.99% of equality between Sc** - R5N3* (Table 6). Observes others model verifications, as the 99.99% probability of equality between Sc** and P** and 98.39% between R5N3* and P**. Tukey presents the equality estimate between Sc** and RN* models at 99.85% confidence around the mean (Planimetric perspective) (Tab. 3 and Tab. 1).

4.4 Comparison with the Best Results

In comparison, the RN* model with the local Potency (P*) and global Scott (Sc**) models generates 99.0% and 97.9% accuracy, respectively. Other models follow overall accuracies of 96.4% (local Root Fifth of N to Third (R5N3*) and global Potency (P**)) (Tab. 7).

Similarly, the Kappa index shows P*, Sc**, R5N3*, and P** the respective values: 0.98, 0.96, 0.93, and 0.93.

The overall accuracy and Kappa index ratify the analysis of items 4.2 and 4.3, presenting the best models for representing the wetland under study (models RN* and P*) and for the maximum values (R5N3*, Sc** and P**). The overall accuracy with Santos (2016) was 38.9%, with a Kappa index of 0.24. Its maximum distance from this model was 217.94 meters away (Tab. 1), justified by its low resolution of the MDS used (30 m) compared to 2.5 m from the MDT.

5. Conclusion

The delimited wetland area covers beyond the limits of the Fazendinha APA: to the north, northeast, and towards the southeast, reaching the beach of the Fazendinha district in the southern part. Observes the best results of the models implemented in the Water Plugin for the minimum representation values of the APA wetland area, the Square Root (RN*), and the Potency (P*), with an area of 236.16 and 240.36 hectares, respectively.

For the maximum values of the representation of the wetland, observe the local Root Fifth of N to Third Potency (R5N3*) and the Global Scott (Sc**) models, reaching areas of 252.16 and 247.26 hectares, respectively.

The accuracy found in the data used and the comparison performed with the reference utilizing the Kappa index, model RN* and P* have the best results for a minimum value of representation of the wetland area and models R5N3*, Sc** and P** for maximum values in an extrapolation of its representation. Thus, the Digital Terrain Model production from SAR sensors had a significant advantage over optical instruments.

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