Analysis of the malaria profiles in high-risk incidence municipalities in the Brazilian Amazon using Principal Component Analysis in the period 2011-2013 and 2017-2019

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Malaria in Brazil

- Between the period 2011 to 2019, Brazil went from 310,450 positive cases of malaria registered per year to 184,869, a reduction of approximately 60%.
- The Legal Amazon (LA) is an endemic malaria region and *Plasmodium Vivax* cases corresponded to 84% of total cases
- In 2019, 6.2% of municipalities had high transmission and included 62.8% of the total cases
- As countries accelerate towards malaria elimination, reduction in malaria transmission is highly variable leading to significant heterogeneity in residual transmission across their territories.
- Annual Parasite Incidence (API) that show us the average of positive cases by thousands of inhabitants in each municipalities in the period.

Risk of Malaria in Legal Amazon

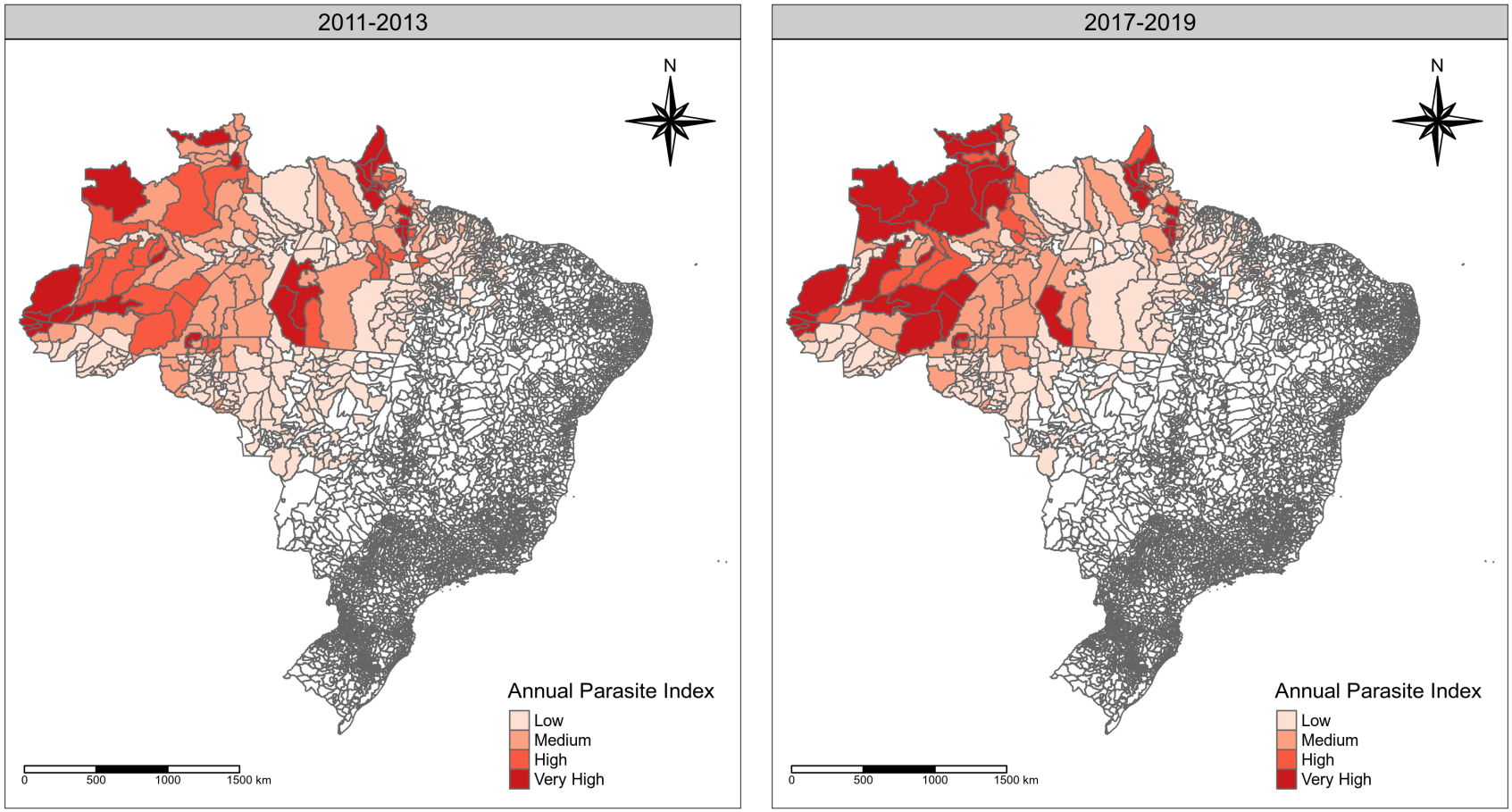

Figure 1: Risk of malaria transmission in Brazil

Source: SIVEP Malaria, 2011-2013; 2017-2019.

Objective

To analyze the high incidence risk profiles in the municipalities in the period 2011-2013 and 2017-2019

Features

- Data were obtained from the Malaria Epidemiological Surveillance System (SIVEPMalaria) for the 2011 to 2019 period, National Institute for Space Resarch's (PRODES), 2010 Demographic Census and Registry of Health Establishments (CNES)
- Only positive cases were used, and grouped by the municipality of infection and year of registration, counting the number of occurrences of each variable used in each category.
- The results were divided between the periods 2011-2013 and 2017-2019, by high-risk municipality through the API, by species of *Plasmodium (P. vivax and P. falciparum), and by a group of Environmental and Health Variables; and group of Demographic and Socioeconomic Variables.*

Features

Variables	Description	Unit
MUN_INFE	Infection municipality code	-
IPA_total_class	Malaria incidence rate by classified by low, medium and high risk	categories
Demographic and Socioeconomic Variables		
Illiterate Sch5to8grade_Incomplete CollegeComplete	Education level	%
Pregnant	1st, 2nd, 3rd trimester pregnant women and ignored gestational age	%
Non_Pregnant	Non-pregnant	%
Livestock	Main activity performed by the patient in the last 15 days	%
Agriculture		
Tourism		
Domestic		
GoldPanning		
Brown	Patient skin color	%
Indian		
Black		
White		
Male	Patient sex	%
Age_Under5	Age of patient in years, by group	%
Age_15to49		
Environmental and Health Variables		
less_than_half_crosses	Less than half cross: number of crosses detected in the blood test	%
WithSymptoms	Has symptoms related to malaria	%
Hydrography	Area of rivers and lakes in the municipality	Km²
Increment	Deforested Increment	-
crudemigrate_2010	Taxa de migração bruta daquele municipio em 2010	rate
propActiveDetection	Proportion of cases notified by active detection	%
Cloud	Quantity of clouds - proxy for rainfall in the municipality	absolute
esLevGeneralCare	number of health facilities by level of general care	absolute
Negative	Negative for other hemoparasites	%
Deforested	Deforested area in the period	Km²

Figure 2: Variables used in the models

Principal Component Analysis Algorithm

- Principal Component Analysis (PCA) algorithm is a method used to assist in understanding the most significant relationships between variables, making it possible to analyze how each chosen variable is associated with each component to identify these relationships and used as an exploratory tool

Overview

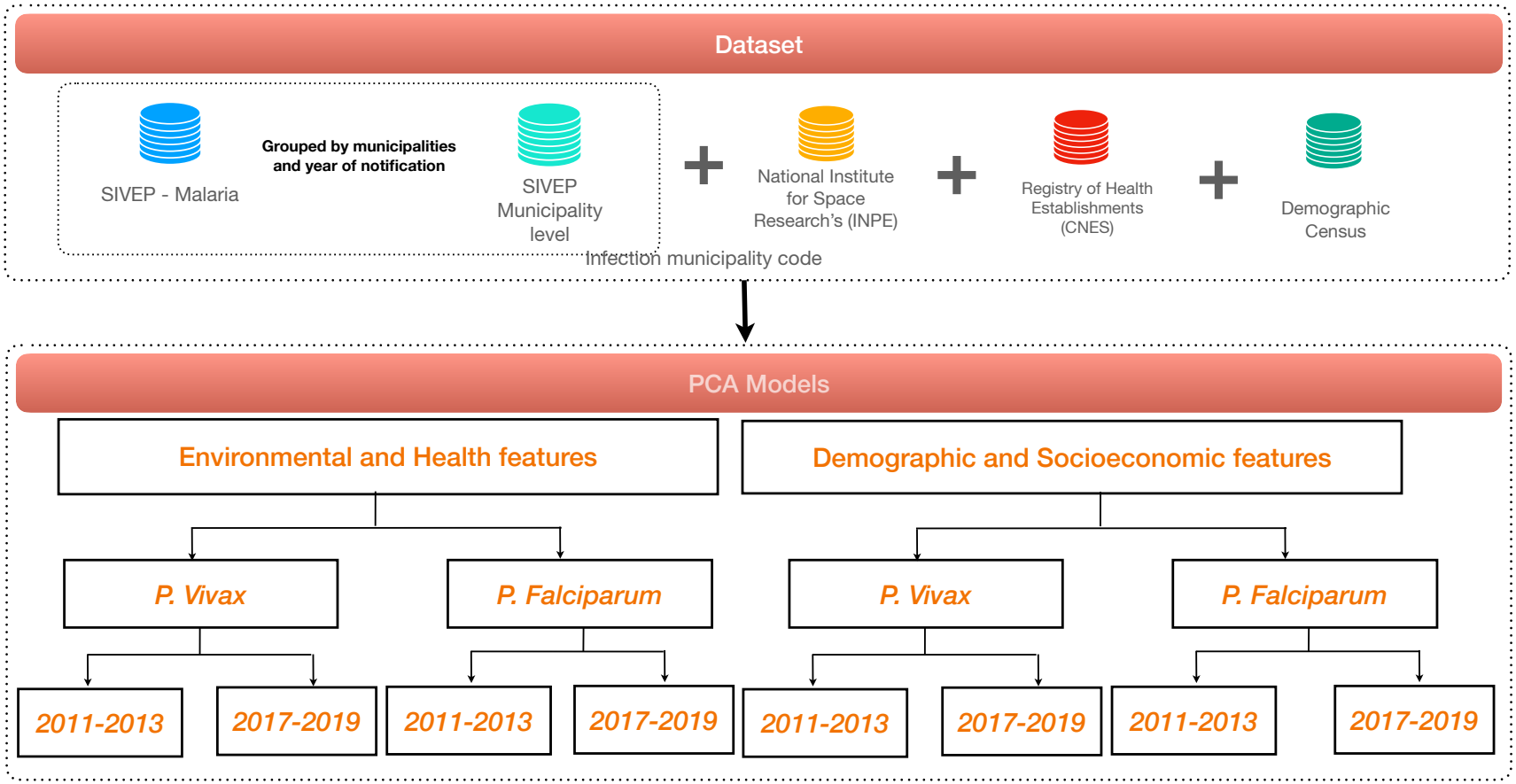

Figure 3: Overview of Material and Methods

Explained Variance

Period 2011 to 2013					
Principal Components	*P. vivax* (n=48)		Principal Components	*P. falciparum* (n=48)	
	Demographic and Socioeconomic (%)	Environmental and Health (%)		Demographic and Socioeconomic (%)	Environmental and Health (%)
PC1	30.79	31.81	PC1	30.52	31.13
PC2	12.92	15.14	PC2	13.97	15.86
PC3	11.34	15.02	PC3	10.14	13.58
PC4	10.12	10.82	PC4	8.81	10.66
Total Variance*	**65.17**	**72.79**	**Total Variance***	**63.44**	**71.23**
Period 2017 to 2019					
Principal Components	*P. vivax* (n = 48)		Principal Components	*P. falciparum* (n = 45)	
	Demographic and Socioeconomic (%)	Environmental and Health (%)		Demographic and Socioeconomic (%)	Environmental and Health (%)
PC1	36.04	27.08	PC1	24.2	26.91
PC2	14.29	18.25	PC2	17.42	17.61
PC3	10.51	15.88	PC3	10.79	15.27
PC4	9.26	10.36	PC4	7.72	10.73
Total Variance*	**70.1**	**71.57**	**Total Variance***	**60.13**	**70.52**

Figure 4: Percentage of total variance explained for the four PC

Source: SIVEP Malaria, 2011-2013; 2017-2019

Loadings - *P.Vivax*

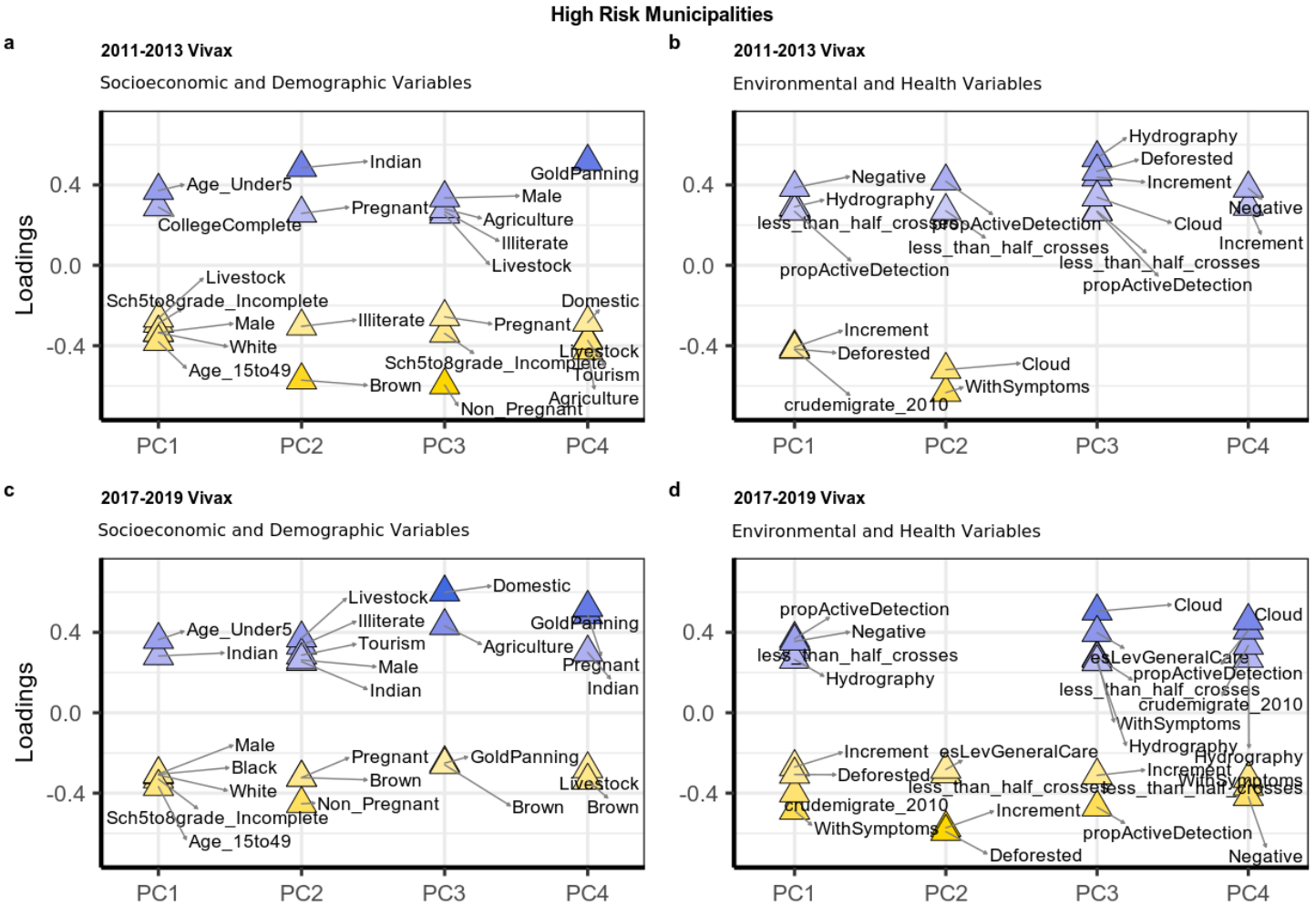

Figure 5: Loadings of PCA on *P.Vivax*

Source: SIVEP Malaria, 2011-2013; 2017-2019

Loadings - *P.Falciparum*

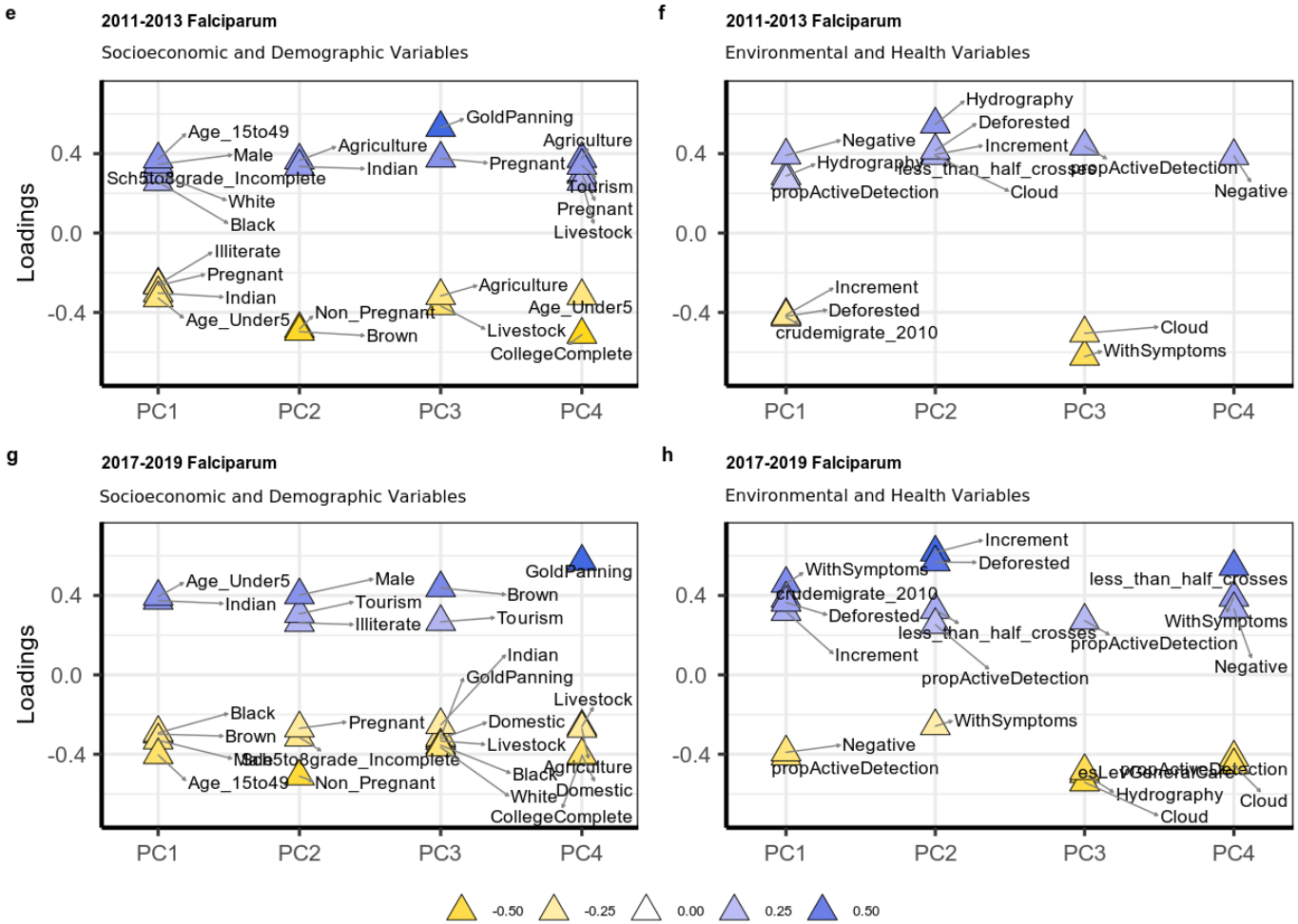

Figure 6: Loadings of PCA on *P.Falciparum*

Source: SIVEP Malaria, 2011-2013; 2017-2019

Scores

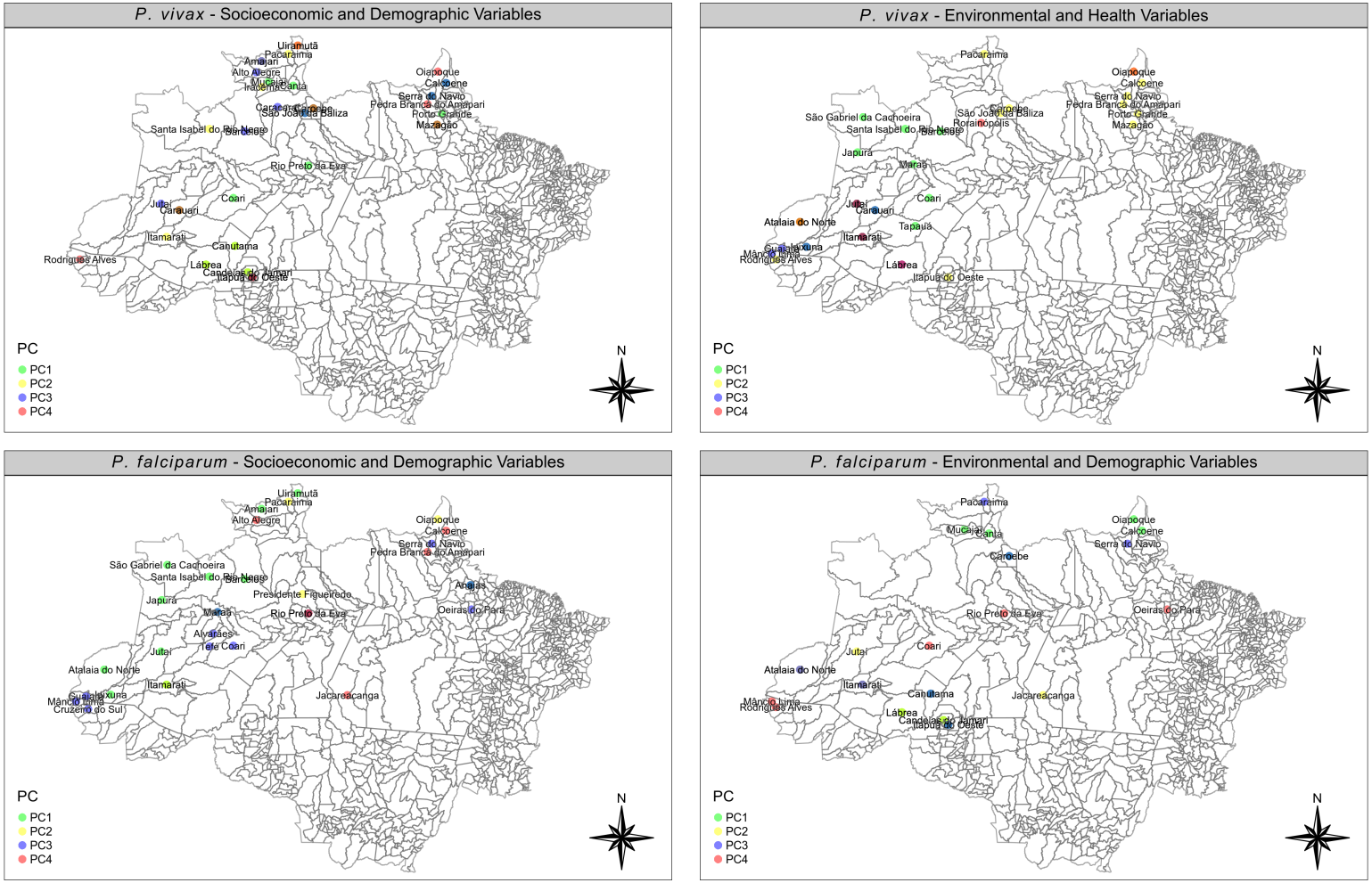

Figure 7: Scores of PCA - period of 2017 to 2019

Groups with same characteristics

- Combining the loadings with the characteristics and scores of municipalities we can draw the following profiles when we look at high-risk municipalities in the recent period (2017-2019).
- Group 1: vulnerability profile, that is, high-risk municipalities with cases more associated with socioeconomic and demographic variables with vulnerability characteristics, such as children and the indigenous population, high proportions of illiteracy, incomplete secondary schooling, and little or no association with environmental or health variables, to the extent that they're captured in our data

Groups with same characteristics

- Group 2: profile of occupation and working age, of high-risk municipalities with cases more related to socioeconomic and demographic variables linked with specific occupations and a working-age population, such as men, people aged between 15 and 49 years old, with low education and in occupations such as agriculture, livestock and gold panning in addition to environmental characteristics related to deforestation and hydrography

Groups with same characteristics

- Group 3: profile associated with different characteristics of *P. falciparum* and *P. vivax*, such as the municipality of Rio Preto da Eva, which for the cases of *P. vivax*, may be more related to children under 5 years and differently, *P. falciparum* in this municipality could be more related to mining, deforestation and the presence of large bodies of water (high loading in PC4). A few other municipalities appear to follow the same differentiated profile between the two types of Plasmodium, such as Coari, Canutama, and São Gabriel da Cachoeira

Conclusion

- We found that municipalities with a high-risk transmission have heterogeneous profiles
- The results shows a predominance of high risk of Malaria by *P. Falciparum* in border regions and mining regions, although other highly vulnerable occupational groups, such as tourism and agriculture, are also observed.
- Few changes occurs in the infection profile between the two periods for these high-risk municipalities which is a concern because, unlike low-risk municipalities, they show no improvement trends, maintaining transmission or even increasing

Conclusion

- The objective of this work was to draw profiles associated with the risk of incidence in the municipalities by combining data from the malaria surveillance and control data with environmental and health data from the municipalities.
- Understand the socio-environmental determinants at the local level is essential for the success of malaria prevention and control strategies.

Dashboard with the results

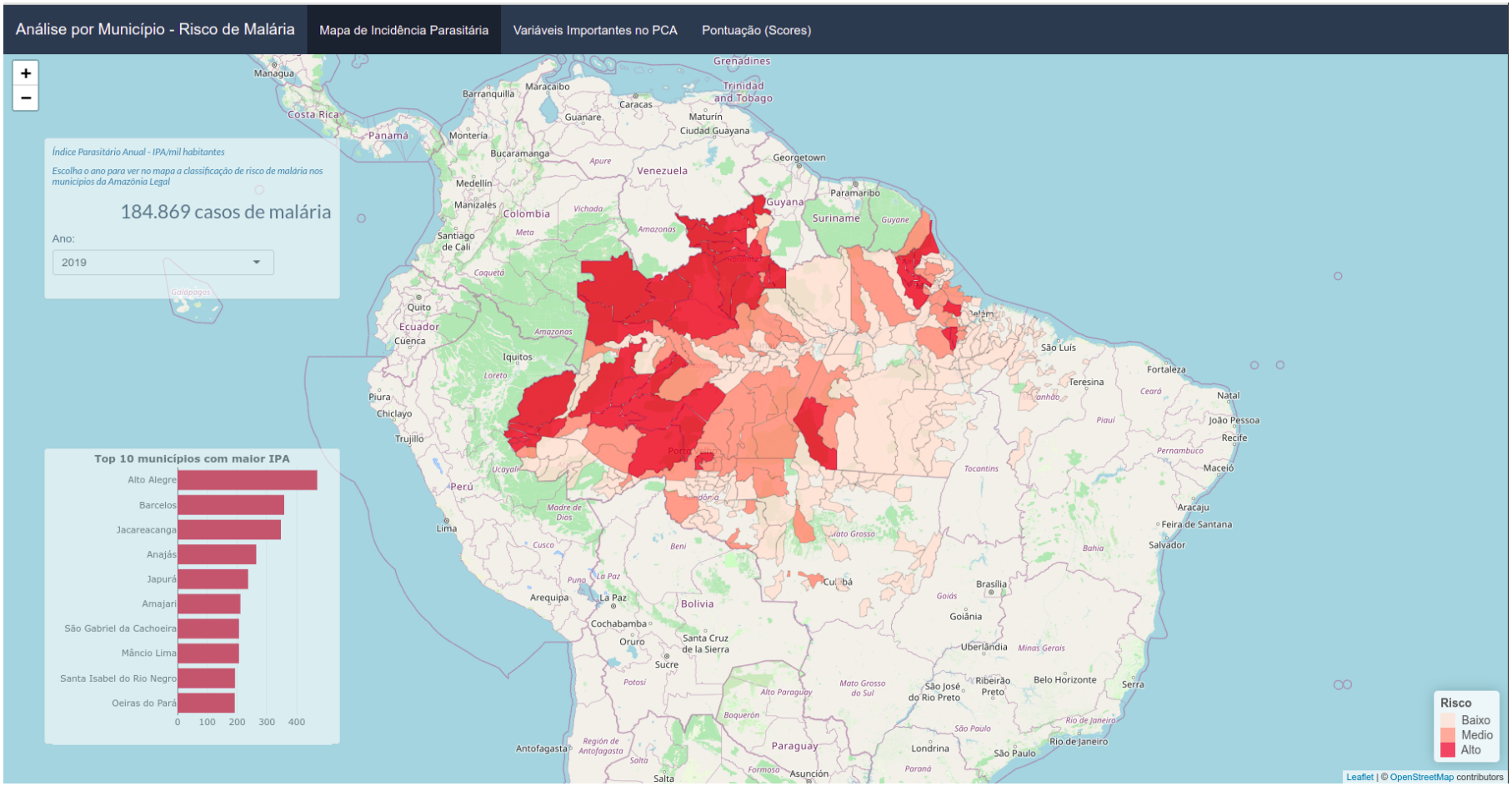

Figure 8: Interactive risk Map

Dashboard with the results

Figure 9: Interactive Loadings Results

Dashboard with the results

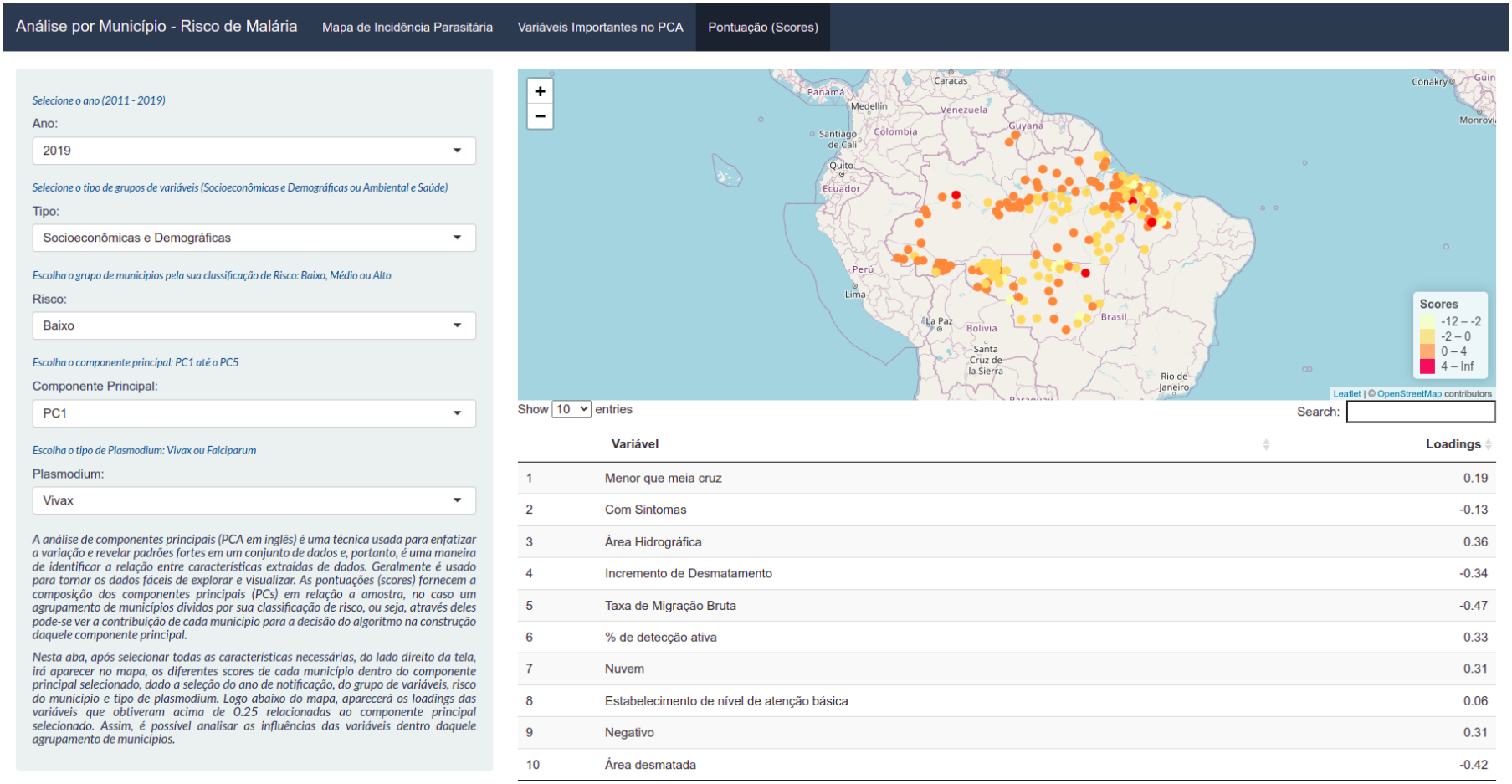

Figure 10: Interactive Map with score results

Acknowledgments

Execution

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Thank you

Figure 11: Mining in Yanomami Indigenous Land