The Effect of Extreme Hydro-Meteorological Events on Labor Market Outcomes: Evidence from the Colombian Caribbean

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Abstract

How do urban households adapt to climate change in developing countries where perfect insurance is absent and communal insurance is lacking given the collective exposure to the same shock?

I match individual labor market information from adults and children from a sample of 800 thousand individuals during the period of 2001-2010 with NASA's daily rainfall data at the municipal level during the same period. This data is rich in both temporal and spatial dimension, allowing for fine-grained analysis of how extreme precipitation events impacted individuals' labor supply decisions and income in urban populations in the developing world. This project focuses its attention on labor supply in the developing world – the primary source of household income throughout the world. Also, household allocation of adult and child labor in response to precipitation represents an avenue for exploring potential adaptations that may minimize or worsen the welfare effects from climate change. My econometric results indicate that the welfare impacts of extreme weather are statistically significant, economically meaningful and heterogeneous across genders and members of the family. Firstly, the probability of unemployment due to living in a municipality that experienced at least one flood increases by 6.2 percentage points net of observable determinants of productivity and outside options, as well as for municipality, month and year fixed effects. This effect is twice as large for women (7 pp) than for men (4 pp). The marginal effect of one additional extreme hydro-climatic event on labor supply and labor income is negative in the short term, and the effect of a negative hydro-climatic event is larger for labor income than hours worked. This has an important implication for welfare: to smooth income, individuals need to work more hours at a lower rate after extreme weather. Hours worked and labor income fully recover after 13 months of one extreme rainfall event. Families cope with tighter labor markets and falling labor incomes using a set of alternatives. First, adult individuals try to smooth shocks by becoming "forced entrepreneurs", but men are more successful than women at finding income through this source: self-employment rises 7 percentage points for men and 2 percentage points for adult women. Finally, minors aged 12-17 enter the labor force. My statistical analysis shows that children's labor force participation jumps 1.4 percentage points for boys and 4.7 percentage points for girls in response to floods.

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1. Introduction

Individuals try to protect themselves from the costly effects of random extreme events described by a probability distribution that we call climate. The adaptation measures that individuals undertake can be *ex-ante* actions (such as investing in defensive measures) or *ex-post* changes in behavior, conditional on available information and technology. This study explores a fundamental and related question: to what extent is labor supply a consumption smoothing mechanism in response to extreme weather events?

This study is at the intersection of different strands of the literature. On the one hand, this project contributes to the new so called "Climate-Economy Literature" (Dell, Jones and Olken, 2013). The Climate-Economy Literature in this area has focused on estimations of labor supply outcomes responses to weather fluctuations in developed countries. Graff Zivin and Neidell (forthcoming) show using a panel of US daily temperature and individual data from the 2003-06 National Time Use Surveys that weather fluctuations lead to substantial changes in labor supply. They find a moderate aggregate response of time allocated to labor during hot temperatures, but when examining exposure to climatic elements by different industries they conclude that at daily maximum temperatures over 85 degrees F, workers in industries with high exposure to climate reduce daily time allocated to labor by as much as one hour.

Connolly (2008) measures the extent to which US workers respond to daily fluctuations in weather by substituting future leisure with present leisure. Her study shows that rainfall decreases enjoyment of leisure and therefore increasing hours at work and an increase in wages. In Conolly's study, men work 30 minutes more and have an average of 25 minutes less of leisure during a daily rain. There are heterogeneous regional effects, with men in drier regions working more than men in less dry regions. Conolly also concludes that precipitation, unlike snow, and temperature has an unambiguous effect on the labor/leisure decision.

This study adds up to the literature that controls for space and time-fixed effects (e.g. Auffhammer, Ramanathan and Vincent 2006; Deschenes and Greenstone 2007; Schelnker and Roberts 2009). This approach overcomes one important limitation of the initial cross-sectional approach to estimate response functions of economic variables due to climate and climate change: that there may be unobservable variables that vary across the municipalities, which are likely correlated with the climate/weather variables (e.g Kelly, Kolstad and Mitchell 2005; Mendelsohn, Nordhaus and Shaw 1994).

In this study, fixed-effects estimators rely on variation across time (2001-2010) within Caribbean municipalities in Colombia as the source of identifying variation rather than variation across these municipalities. This means that the underlying identification relates time series deviations from the municipality-specific mean in the climate indicators to deviations in the outcome variable of interest (Auffhammer, Hsiang, Schlenker and Sobel, 2013).

This project also contributes to the literature on the effects of shocks on income and labor market outcomes in the developing world. Shocks have proven to be detrimental to the lives of the poor (Rosenzweig and Wolpin 1993; Dreze 1995; Jacoby and Skoufias 1997; Jensen 2000; Jayachandran, 2006). Besides, shocks affect differentially poorer than richer households. Shocks may even worsen inequality through its effect on the labor market. For example, Jayachandran (2006) found that for the Indian case, productivity shocks cause larger changes in the wage when workers are poorer, less able to migrate, and more credit-constrained because of such workers' inelastic labor supply. This equilibrium wage effect hurts workers. In contrast, it acts as insurance for landowners. Most of these studies, however, rely on rural samples and are context dependent with some studies pointing to non-negative effects of floods in wages (Kaur, 2014) and other studies finding negative effects.

The Colombian Caribbean is a good context for studying the labor market effects of extreme rainfall. The annual average of natural disasters in Colombia reaches 600 events, greater than the combined number of shocks of these nature in Peru, Mexico and Argentina. The Caribbean region of Colombia is large and diverse: more than 10 million people live in this region that includes 8 Departamentos (equivalent to States), including indigenous groups. However, since the Colombian Caribbean has experienced more extreme weather events than its neighbors, individuals may have learned to adapt over time, which suggests that ther marginal cost of new events is lower in the Colombian Caribbean than in its Andean neighbors (Hsiang and Narita, 2012).

On the other hand, impacts of climate change by 2050 will include flooding in the Caribbean coasts, increases in the vulnerabilities of non-technically developed smallholders (Ramirez-Villegas, 2012) and changes in the variability and thus availability of water resources.

Finally, with more than half of the working adult population employed in the informal sector and therefore uninsured, a large proportion of the economically active population is increasingly vulnerable to the rising damages of extreme rainfall and climate change.

This project focuses its attention on labor supply in the developing world – the primary source of household income throughout the world. Household allocation of adult labor in response to precipitation represents an avenue for exploring potential adaptations that may minimize or worsen the welfare effects from climate change. Finally, commercially mechanisms such as insurance can play a role in providing protection against losses due to climate change (National Climate Assessment Report, 2014; Shiller, 2014). The first necessary step for insurance to be commercially available and protect workers against extreme weather events is to quantify damages in different places and different groups of the population. In the remain sections of the paper, I describe rainfall patterns in the Caribbean, present the key variables used to measure rainfall shocks, introduce the empirical strategy, describe the data, the results of the econometric estimations and finally, conclude.

2. Institutional context

2.1 Background on floods in the Colombian Caribbean in 2001-2010

Rainfall exhibits a uni-modal annual cycle (May– October) at the northern Caribbean coast of Colombia. The El Niño/Southern Oscillation (ENSO) is the main forcing mechanism of inter-annual climate variability from hours to seasons to decades. In general, the warm phase of ENSO (El Niño) begins during the boreal spring, exhibiting a strong phase locking with the annual cycle, and encompassing two calendar years characterized by increasing sea surface temperature anomalies during the boreal spring and fall of the onset year, peaking in winter of the following year.

Anomalies then decline in spring and summer of the ensuing year (Alvarez, Poveda and Rueda, 2011). Originating in the tropical Pacific, ENSO influences virtually the entire tropics by radiating waves through the atmosphere, linking climates around the globe through so-called teleconnections. (Ropelewski, C. F. & Halpert, M. S., 1987 and Chiang, J. C. H. & Sobel, A. H., 2002). ENSO oscillates between its two extremes: El Niño (warm event) and La Niña (cold event).This study focuses on the cold phase of ENSO (La Niña events). In the Caribbean region of Colombia, La Niña increases the amounts of precipitation (IDEAM, 2010).

Generally, during a period of La Niña, the sea surface temperature across the equatorial Eastern Central Pacific Ocean will be lower than normal, reaching its peak at the end of the calendar year and tends to dissipate during the mid-year of the following year. In a typical Niña year in the Colombian Caribbean, rainfall starts increasing mid-year progressing to strong precipitation, river flooding and increases in the likelihood of hurricanes in the Atlantic Ocean (IDEAM, 2010).

During the period of study (2001-2010), the strongest Niña event occurred in 2010. In fact, it was the strongest Niña event since 1949 in Colombia (IDEAM, 2010). The States of La Guajira, Magdalena, Cesar, Sucre, Atlántico and Bolívar experienced rainfall greater than 70% of its monthly mean (IDEAM, 2010). Consistent with the high levels of precipitation of 2010, the Colombian government reported several river flooding in the Caribbean, as well as sudden and large increases in river volume (IDEAM, 2010). In Cartagena, the capital of the State of Bolivar, newspapers reported in November of 2010 shocking pictures of a completely flooded city, yielding millionaire material loses. Among the most affected, there were 700 families lost their dwellings after 12 hours of very strong rainfall in the city (El Espectador, November 3, 2010).

2.2 Labor Market in the Colombian Caribbean

The economically active population in the labor market in the Colombian Caribbean is largely made up of self-employed adults (DANE, 2012).

60% of working adults are self-employed, and some segments of the urban poor are mostly self-employed.

In qualitative studies working adults report relying heavily on weather, and in particular, on rainfall patterns to be able to generate labor income. For example, setting up small shops and operating them in the streets, information transportation (moto-taxismo), fruit and other food sales in the beach or in other public spaces depend on rainfall. Individuals report also that produce get spoiled due to excess rainfall and that this hampers their ability to generate income (UTB, 2012).

3. Conceptual Framework

In absence of insurance, and with all households in one market, individuals "self-insure". This means that instead of redistributing rainfall shock across states, individuals redistribute across time. The consequence of this time redistribution of rainfall shocks is that whereas in the presence of perfect insurance, marginal utility of consumption would be constant, individuals smooth consumption.

In the first case, marginal consumption equals:

$$U'(C_t) = \lambda = U'(C_{t+\tau})[(1 + \delta)/(1 + \mathrm{r})]^t$$

Instead, smoothing implies:

$$U'(C_t) = [(1 + r)/(1 + \delta)]^t E_t[U'(C_{t+\tau})]$$

Labor supply has the following features that make it a good consumption smoothing mechanism: 1) Labor supply can be partitioned into small pieces: small changes in marginal utility are possible, 2) The covariate between marginal utility and wages could be positive for certain occupations: when the rainfall shock hits and consumption decreases (and therefore marginal utility increases), some types of wages could increase, for example, construction workers. Finally, the depreciation of human capital is low.

4. Measurement of key variables

The main outcome variables of this study are two: 1) labor income and 2) labor supply.

4.1 Outcome variables

Labor income

The measure of labor income in this research is the logarithm of the real wage per hour. To obtain this variable, I took the self-reported weekly nominal labor earnings from DANE's Great Integrated Household Survey in pesos, deflated all the series to constant Colombian pesos, and divided by weekly hours worked. Finally, I calculated the log of the real wage per hour. Those who reported being unemployed were assigned a zero log wage per hour.

Labor supply

The measure of labor supply in this research is logarithm of the number of hours worked last week, as reported by each surveyed adult in the sample. As in the case with wages, the distribution of hours worked is highly skewed and truncated at zero, so the benefits of using the logarithm apply here as well. Those who reported being unemployed were assigned a zero hours worked, and zero log of worked hours.

4.2 Extreme rainfall shocks

This study relies on a flood indicator called "Days of heavy precipitation". It was calculated by counting the number of days in the municipality that witness rainfall larger than 10 mm per month (Aguilar et al, 2005).

4.3 Sample

The sample of adults in this research consists on individuals who were surveyed by DANE and reported being either employed, self-employed or unemployed and who are older than 18 years old. The sample of minors are individuals aged between 12 and 18 years old.

4.5 Empirical strategy

This research tests the hypothesis that individuals react to weather anomalies by changing their individual labor decisions in order to smooth consumption, in absence of unemployment insurance and the communal nature of the shock, which prevents communal insurance.

I estimate the log-linear model with Ordinary Least Squares in the model

$$\textbf{(1)}\ Log(Y_{ijt}) = \delta_j + v_t + X_{ijt}'\beta + E_{jt}'\alpha + \varepsilon_{ijt}$$

where i indexes individuals, j indexes municipalities, t indexes survey year. In Equation 1, Y_{ijt} represents both labor supply outcomes including hours worked and labor income. X_{ijt} is a vector of observed measures of productivity and outside options. These measures include gender, educational attainment, age, age squared, married status and urban/rural location.

v_t are year fixed effects and δ_j are municipality fixed effects. The Vector E includes the number of hydro-climatic events happening from January to December of last year (shock month), measured by the “days of heavy precipitation” indicator.

This methodology will compare outcomes in the municipality j when a weather anomaly has occurred with outcomes in the same municipality in absence of the event. Since weather anomalies, as studied in this research, vary plausibly over time as random draws from the distribution in a given spatial area (i.e. “weather” draws from the “climate” distribution), this weather-shock approach has strong identification properties (Dell, Jones and Olken, 2013). Standard errors are clustered at the municipal level to allow for correlation across individuals within a municipality and within the same municipality over time.

According to the conceptual framework outlined below, I test that $\alpha \neq 0$ in Equation 1.

6 Data

6.1 Data sources

I match individual labor market outcomes collected by the Departamento Administrativo Nacional de Estadistica (DANE) during the rounds of 2001-2010 with NASA’s rainfall data at the municipal level during the same period.

Labor outcomes

DANE collects individual information on its “Great Integrated Household Survey”. The great integrated household survey is a survey that gathers information about the employment conditions of persons (whether they work, what they work in, how much they earn, if they have social security for health care, or if they are looking for a job), as well as about the general characteristics of the population, such as gender, age, marital status, and educational level, sources of income and expenses (what they buy, how often they buy, and where they buy). The GEIH provides information at the national, urban-rural, regional, and departmental levels, as well as for each one of the department capitals. Currently, the survey specializes in the measurement of the labor market structure and household incomes; it has an annual total sample of approximately 240,000 households, which makes it the largest survey in coverage in the country. This data is rich in both temporal and spatial dimension, allowing for fine-grained analysis of how the extreme precipitation event associated with La Niña that occurred in 2010 impacted individuals' labor decisions across different municipalities through the year (IDEAM, 2010).

The particular questions that I employ in the context of this study are the following: Employment status: employed, self-employed, unemployed; Labor income last week; Hours worked last week; Demographic characteristics: gender, age, marital status, and educational attainment.

Rainfall

This project uses NASA's TRMM Multi-satellite Precipitation Analysis (TMPA), which is available at 0.25 degree resolution (Huffman et al 2007). The work is being carried out as part of the Tropical Rainfall Measuring Mission, an international project of NASA and JAXA designed to provide improved estimates of precipitation in the Tropics, where the bulk of the Earth's rainfall occurs. The main advantages of this dataset include that it is routinely produced, publicly available, fine-scale in space and time, quasi-global and near-real-time produced.

6.2 Summary Statistics

Table 1 provide summary statistics for the key variables used in this paper. The average worker in the Colombian Caribbean generates income in the order of 2 dollars per hour (the mean of the log wage is 6.646). The average hours per week is 47.84 for those who work positive hours and are older than 18. Workers in this region have 9 years of education on average, and are 37 years old. Finally, 60% of the sample reports being married. There are, on average, 3 days of heavy rains in the Caribbean municipalities per month.

Figure 1 presents the average number of Hydro-Climatological Events by month, measured by the "Number of Heavy Rains" Indicator. Columns in orange represent the wet season of the Colombian Caribbean while the blue columns represent the dry season. Map 1 presents the distribution of floods measured by days of heavy rainfall for each municipality of the Caribbean region of Colombia during the period 2001-2010. In the figure, constant categories were used to graph the number of rainfall shocks per year, to facilitate the interpretation of both between and within-municipality variation across time. Darker colors indicate higher frequency of events.

Table 1: Summary Statistics

Variable	Mean	Standard deviation	N
Days of heavy rains (rainfall >10 mm)	3.175	3.127	998,926
Labor Market Outcomes			
Hours (Log) [3]	3.322	1.3016	745,408
Real income per hour (Log) [3]	6.646	2.734	666,784
Unemployed[3]	0.121	0.327	745,474
Self-Employed[3]	0.580	0.493	644,886
Worker in between 12-18 years old[4]	0.0264	0.1605	662,630
Child in labor force (working or looking for job) [5]	0.095	0.2933	211,625
Controls			
Years of educational attainment	8.9853	4.610	744,186
Age	37.602	12.8623	745,473
Married	0.60119	0.4896	745,473
Male	.5946	.49095	745,473

Notes:

1. Includes States (Departamentos) in the Caribbean region: Atlantico, Bolivar, Magdalena, Cordoba, La Guajira, Cesar and Sucre.
2. Days of heavy rains is defined as the annual count of days per municipality when rainfall exceeded 10 mm.
3. Sample includes wage employed, self-employed, workers who work for free and unemployed who are older than 18 years old.
4. Sample includes all workers (wage employed, self-employed and workers who work for free) who are between 12 and 18 years old.
5. Sample includes all surveyed minors (between 12-18) irrespective of employment status, plus minors who are looking for jobs.

*** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.

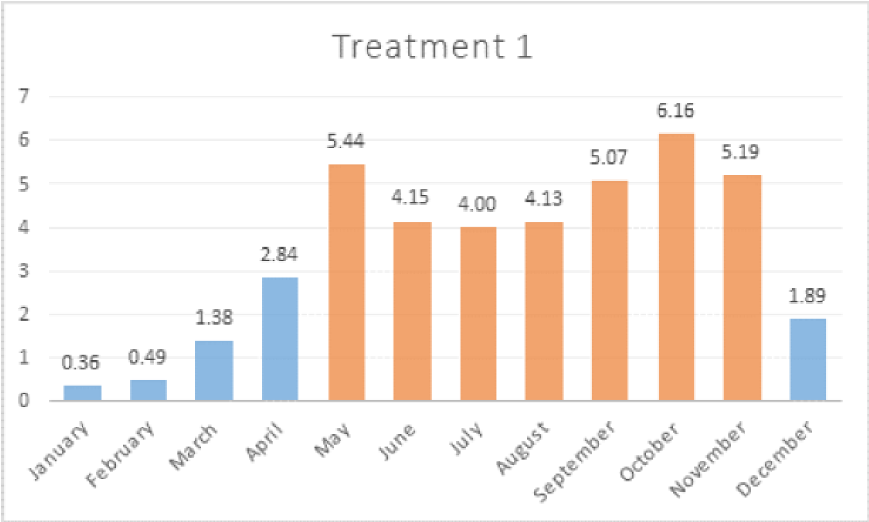
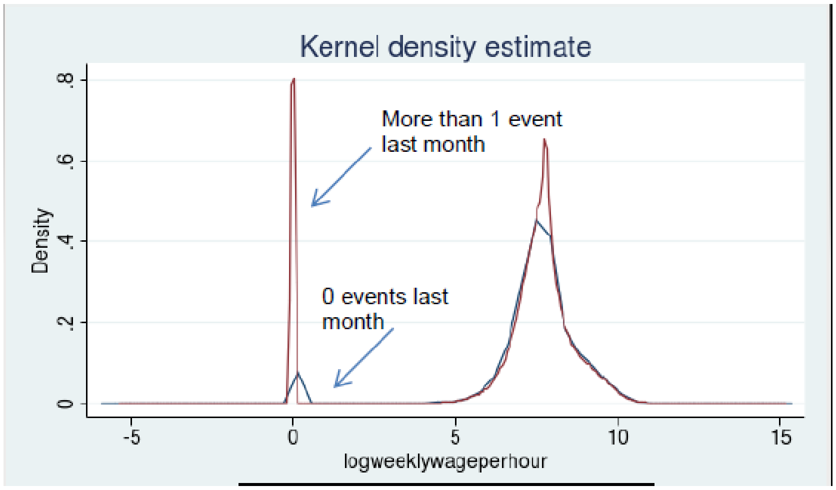


Figure 1: Average Number of Heavy Rain Days By Month

7. Results

7.1 Monthly results on labor supply and income

Figure 2 presents the log real wage per hour by hydro-climatological events. When I split the sample between those economically active adults who were hit by at least one rainfall shock last month and those who did not, there is a striking difference in the (log) wage distribution of these two samples. In particular, there is a lot of mass around zero wages for the sample of adults hit by at least an extreme rainfall event (measured here by days of heavy rainfall) compared to the sample of economically active adults who were not.



Note: Sample includes adults (older than 18), who are employed, unemployed or self-employed. Unemployed are assigned zero wages and hours worked. Events measured by rainfall > 10 mm/day

Figure 2: Log real wage per hour by hydro-climatological events

I then first estimate by how much the probability of unemployment increased due to at least one rainfall shock, for individual i located in municipality j surveyed at time t:

$$\textbf{(2)}\ Y_{ijt} = \delta_j + \nu_t + X_{ijt}'\beta + \alpha F_{jt} + \varepsilon_{ijt}$$

Where Y_{ijt} stands for the probability of unemployment, X_{ijt} is a vector of observed measures of productivity and outside options and α measures the causal effect of experiencing at least one flood during the previous month.

I first estimate the effect that at least one day of floods has on the probability of unemployment using the adult individual labor market survey. I present the results in Table 2, where I add controls additively. My preferred specification in table 2 shows that the probability of unemployment due to living in a municipality that experienced at least one flood increases by 6.2 percentage points. This estimate is statistically significant at the 1% level (Column 3) and its magnitude is important as the mean of unemployment is 0.12. This estimate is robust to controlling for observable determinants of productivity and outside options, as well as for municipality, month and year fixed effects.

Table 2: Short Term Labor Market Effects of at Least One Negative Shock Last Month: Unemployment

VARIABLES	(1)	(2)	(3)
Flood	0.0491*	0.0475***	0.0624***
	(0.0230)	(0.0125)	(0.0152)
Male			-0.0413***
			(0.00448)
Educational attainment			0.00687***
			(0.000442)
Age			0.000279
			(0.000432)
Age squared			-3.81e-05***
			(7.63e-06)
Married			-0.0758***
			(0.00562)
Municipality fixed effects	X	X	X
Year fixed effects	X	X	X
Month fixed effects		X	X
Observations	745,474	745,474	744,186
R-squared	0.120	0.123	0.172

Notes:
Flood is a binary variable that takes on a value of 1 if the number of days with heavy rain (>10 mm/day) is positive, and 0 otherwise, measured the month previous to the survey month.
Clustered standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Not all individuals in the labor market who report positive wages are employees, but also self-employed. It is important to understand the extent to which adult individuals try to smooth shocks by becoming “forced entrepreneurs”. I therefore estimate by how much self-employment increases in response to floods measured as before, and estimate Equation 2 again. The probability of self-employment also increases by 4.5 percentage points on average, controlling for observed predictors of productivity and outside options, municipality indicators, month and year fixed effects. This coefficient is also significant at all statistical levels (Table 3, column 3).

Table 3: Short Term Labor Market Effects of at Least One Negative Shock Last Month: Self-Employment

VARIABLES	(1)	(2)	(3)
Flood	0.184*	0.156***	0.0455***
	(0.0753)	(0.0406)	(0.00902)
Male			0.153***
			(0.0126)
Educational attainment			-0.0267***
			(0.00172)
Age			0.0215***
			(0.000470)
Age squared			-0.000183***
			(8.60e-06)
Married			0.00320
			(0.00882)
Municipality fixed effects	X	X	X
Year fixed effects	X	X	X
Month fixed effects		X	X
Observations	644,886	644,886	643,654
R-squared	0.574	0.580	0.643

Notes:
Flood is a binary variable that takes on a value of 1 if the number of days with heavy rain (>10 mm/day) is positive, and 0 otherwise, measured the month previous to the survey month.
Clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Figure 2 presents suggestive evidence that average wages largely decrease as a consequence of extreme rainfall. I then estimate econometrically what the magnitude of this loss is per shock month on next year's labor outcomes. With this goal in mind, I estimate Equation (3) for each survey month (eg, January through December):

$$\textbf{(3)}\ Log(Y_{ijt}) = \delta_j + v_t + X_{ijt}'\beta + \sum_{m=1}^{12} E_{m,t-1}'\Delta + \varepsilon_{ijt}$$

In Equation (3), the main interest resides in the estimation of Δ. Δ is the vector of coefficients of lagged extreme rainfall shocks, by month of occurring during t-1, where t is the survey year. Therefore, Equation (3) estimates the labor outcomes effects surveyed for individual i who lives in municipality j, surveyed in month m of year y, as a function of characteristics that affect his or her labor supply and earnings, as well as a set of lagged shocks. Equation (2) also includes municipality fixed effects and year effects.

Estimated coefficients measure by how much one additional extreme event during each month last year change log wages and log hours in the survey month, holding constant additional covariates. However, the main interest resides in measuring by how much events happening in each month of last year (eg Dec t-1) affect labor outcomes the following year. For example, by how much December events affect labor outcomes in January, in February,…. December. I therefore transposed the results matrix.

Figures 3 and 4 plots the transposed matrix coefficients, which can be then interpreted as by how much extreme events happening each month of last year affect the following year labor outcomes. Figure 3 plots the coefficients for log(hours) and Figure 4 for log(wages), respectively. Some patterns emerge from Figures 3 and 4. Focusing on the 2 months that are closest to each survey month (December and November), and are therefore more precisely estimated than coefficients from earlier months, it's possible to see that all coefficients lie under zero, meaning that one additional extreme hydroclimate event, measured by rainfall larger than 10 mm, decreases hours worked throughout the following year. December has the best precisely estimated coefficients because it's the closest lag to all months of next year.

(Log) Wages and (Log) Hours coefficients follow similar patterns as a result of extreme rainfall. That means that the graphs of both outcome variables together. However, the effect of negative hydro-climatic event is larger in magnitude for labor income than hours worked (more negative). The results from Figure 3 indicate that 1 additional extreme rainfall event in December of last year causes a decrease in 3% in hours worked in January of the following year. The effect is statistically significant at 10 percent level; however, the mean effect is larger, as the mean number of extreme rainfall events in December mean is 1.89. This effect is statistically significant at 10 percent level. Likewise, 1 additional extreme rainfall event in December of last year causes a decrease in 7% in real labor income in January of the following year. The effect is statistically significant at all statistical levels. The effects still persist in July (important vacation season), when effect is a decrease in 9%, and significant at 1% level.

Figures 5 and 6 show the smoothing patterns after a rainfall shock has occurred in December of last year. There is an upward response trend to the effect of extreme precipitation. After one year, effects are zero for hours worked and still small negative for wages.

I now turn to examine the effects of extreme rainfall during the rainy season. For this purpose I focus on the November results, which is the second closest month to all survey months. The effect of a marginal day with heavy rains is -2% in hours and -8% in wages, significant at 5% and 1% level respectively. Starting in February, an additional day of heavy rainfall happening in November has a lower effect on log hours than December. However, the mean effect of extreme rainfall shocks is five times larger than December, given that November is still part of the rainy season whereas December is not. Finally, it’s possible to see from Figures 3 and 4 that after 13 months of the extreme event, hours and wages have recovered their initial levels in real terms.

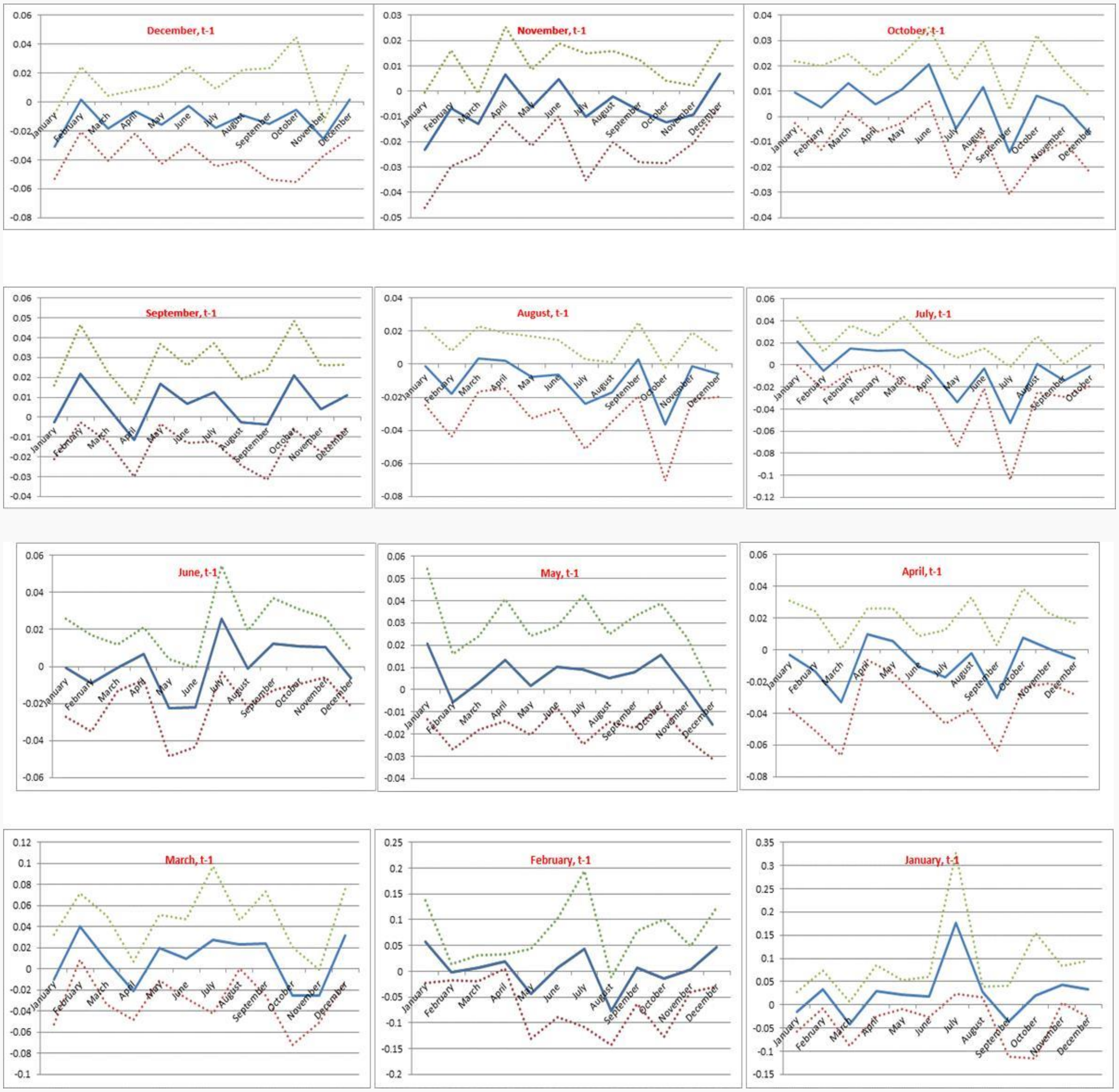


Figure 3: By How Much Extreme Events Happening Each Month of Last Year Affect This Year's Log (Hours Worked)

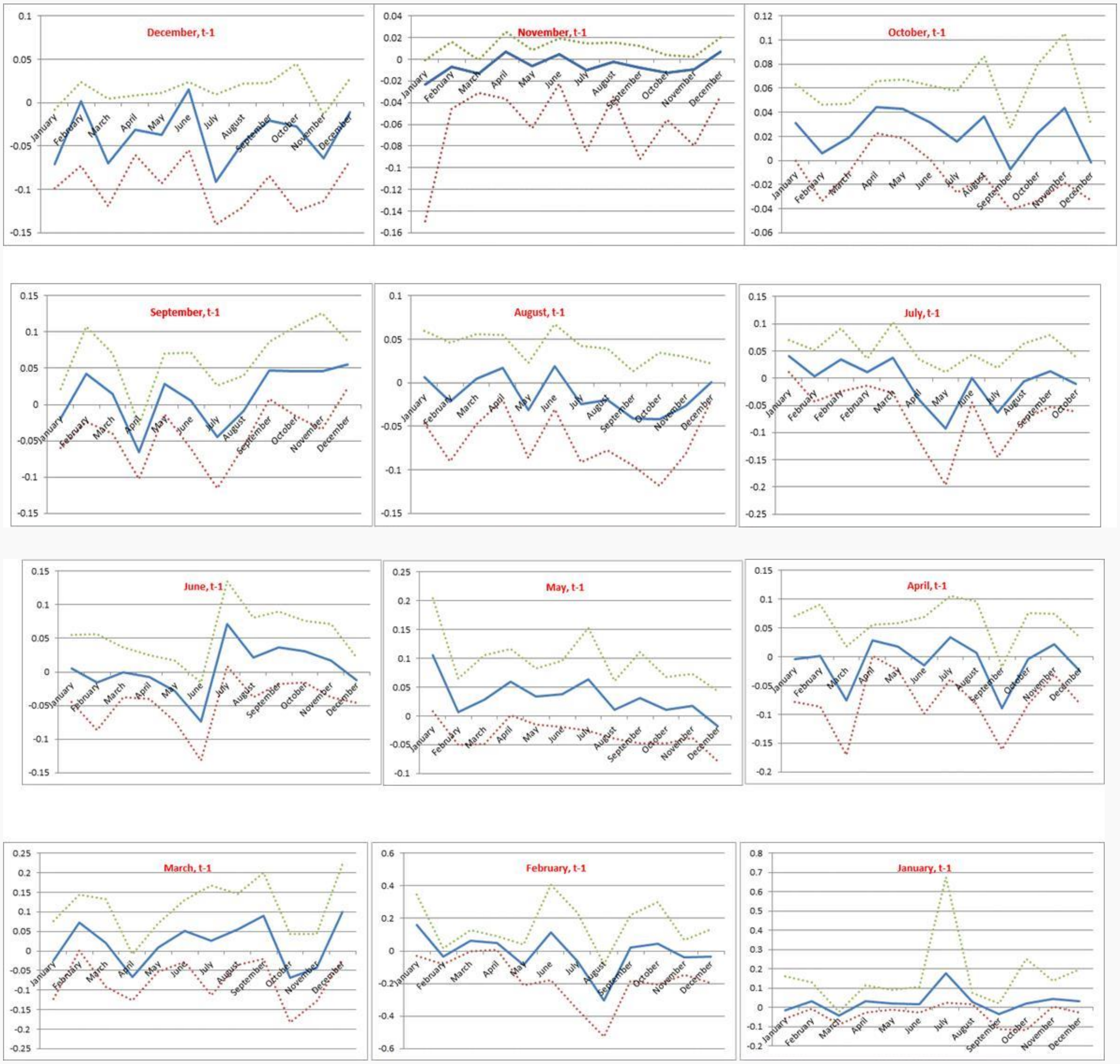


Figure 4: By How Much Extreme Events Happening Each Month of Last Year Affect This Year's Log (Wages)

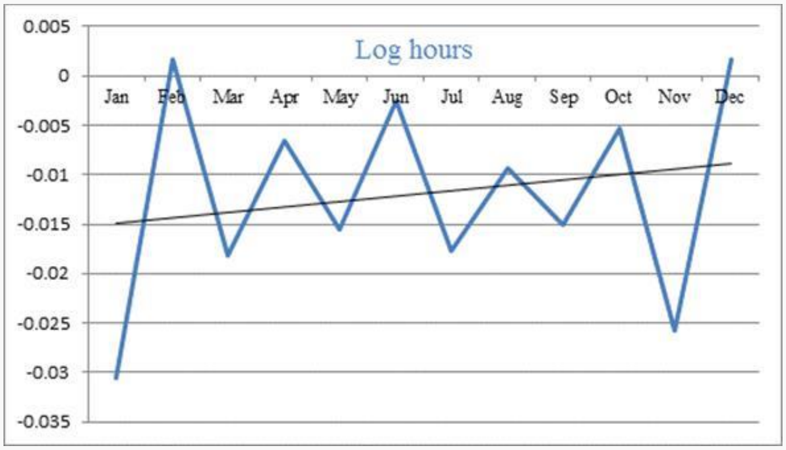


Figure 5: Smoothing Patterns (Log Hours) After a Rainfall Shock has Occurred in December of Last Year

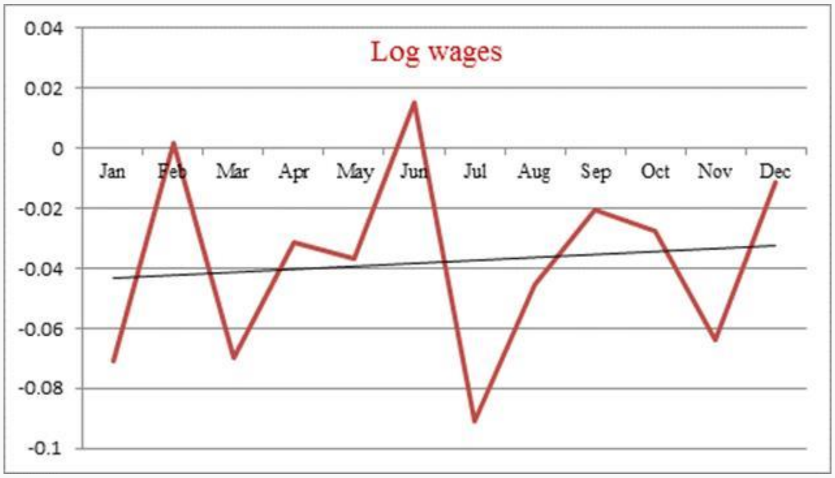


Figure 6: Smoothing Patterns (Log Wages) After a Rainfall Shock has Occurred in December of Last Year

7.2 Heterogeneous effects and Composition of the Labor Market

To measure the extent of heterogeneous effects in the impact of rainfall shocks on the labor markets and its composition, I estimate the linear model 4 for different sub-samples of the population, and particularly, for women and men separately.

In this section, Y_{ijt} stands for either the probability of unemployment, probability of self-employment, probability of being a minor (younger than 18) given that the person is on the labor force, or the probability of being in the labor force worker (in exchange for a salary or for free, or looking for employment) given that the surveyed person is a child. The Vector E includes measures the number of “days of heavy precipitation” during the survey month-year in municipality j.

α measures the causal effect of one additional extreme event during the survey year.

Tables 4-7 present the estimated regression coefficients of equation 3 for the different studied outcomes (Table 4: probability of unemployment, Table 5: probability of self-employment, Table 6: probability of being a minor -younger than 18- given that the person is on the labor force, Table 7: probability of being a worker -in exchange for a salary or for free- given that the surveyed person is a child).

All Tables present results for the men in column 1 and women in column 2.

Table 4: Adult Labor Market Outcomes: Unemployment Effects by Gender

VARIABLES	(1) Women	(2) Men
Flood	0.0746***	0.0449**
	(0.0161)	(0.0132)
Municipality fixed effects	X	X
Year fixed effects	X	X
Month fixed effects	X	X
Observations	331,606	412,580
R-squared	0.214	0.145

Notes:
Standard errors clustered in parentheses. Flood is a binary variable that takes on a value of 1 if the number of days with heavy rain (>10 mm/day) is positive, and 0 otherwise, measured the month previous to the survey month. Other explanatory variables included in the regression, but not shown, include educational attainment, married status, age and age squared. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.

Too much rainfall in a municipality compared to its usual seasonal rainfall raises unemployment for all population groups, and the average effects masks differences among genders (Table 4). Column 1 of Table 4 shows that, having socio-economic characteristics, municipality indicators and month and year effects fixed, experiencing at least one flood increases the probability of unemployment by 0.07 for women and by 0.044 for men. These results, that are net from the impact of other characteristics that impact labor market outcomes, suggest that women witness the largest increase in unemployment as a result of rainfall shocks. The coefficients are both statistically significant and economically meaningful.

Another important indicator of employment quality is self-employment. Qualitatively, the effect of floods on self-employment is very similar to that of unemployment, that is, floods increase self-employment differently for men and women. However, unlike unemployment, the magnitude of the effect is smaller for women than for men. The coefficient presented in column 1 of Table 5 indicate that too much rainfall measured by at least one additional day of heavy rain in the municipality during the previous month increases the probability of being self-employed by 0.02 for adult women living in urban areas, net of any impact of other characteristics that determine employment outcomes. Men seem better able to cope with floods by turning to self-employment than women. Column 2 shows that the probability that an urban adult man is self-employed as a result of experiencing at least one flood increases by 0.07, significant at the 1 percent level. These results are robust after controlling for invariable features of the municipalities where the surveyed individuals live or unrelated shocks that occurred during the studied years or seasonal economic activity.

Consistent with the worsening of labor market conditions, the probability that a worker is a minor is also larger in the months with very heavy rains (Table 6), and results are significant for both, women and men separately. The coefficient of floods in columns 1 and 2 of Table 6 is around 0.06, which suggests that having socio-economic characteristics, municipality indicators and month and year effects fixed, the presence of at least one day of heavy rainfall in the municipality increases the probability that a worker is a minor (between 12 and 18 years old) by 0.06. This effect is very large given that the mean probability that a worker is a minor is 0.03.

Table 5: Adult Labor Market Outcomes: Self-Employment Effects by Gender

VARIABLES	(1) Women	(2) Men
Flood	0.0207*	0.0762***
	(0.00888)	(0.0138)
Municipality fixed effects	X	X
Year fixed effects	X	X
Month fixed effects	X	X
Observations	272,437	371,217
R-squared	0.538	0.693

Notes:
Standard errors clustered in parentheses. Flood is a binary variable that takes on a value of 1 if the number of days with heavy rain (>10 mm/day) is positive, and 0 otherwise, measured the month previous to the survey month. Other explanatory variables included in the regression, but not shown, include educational attainment, married status, age and age squared. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.

Finally, urban households may resort to sending their children, defined by individuals between 12 and 17 years old, to work, after experiencing the negative effects on the adult labor market described below. I test this hypothesis by calculating by how much the probability that surveyed minors enter the labor force changes as a consequence of witnessing at least one flood in the municipality. I find, that in fact, this probability increases for both girls and boys, but the effect for boys is 4 times larger than for girls (Table 7). The estimated coefficient from equation

4 for boys is 0.04 and for girls 0.01, statistically significant at the 1 and 5 percent level, respectively.

Table 6: Probability that Worker is a Minor by Gender

VARIABLES	(1) Women	(1) Men
Flood	0.0580***	0.0661***
	(0.0126)	(0.0142)
Municipality fixed effects	X	X
Year fixed effects	X	X
Month fixed effects	X	X
Observations	279,072	382,319
R-squared	0.122	0.133

Notes:
Standard errors clustered in parentheses. Flood is a binary variable that takes on a value of 1 if the number of days with heavy rain (>10 mm/day) is positive, and 0 otherwise, measured the month previous to the survey month. Other explanatory variables included in the regression, but not shown, include educational attainment, married status, age and age squared. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.

Table 7: Probability that a Minor Works or is Looking for a Job by Gender

VARIABLES	(1) Girls	(2) Boys
Flood	0.0141** (0.00452)	0.0467*** (0.0125)
Municipality fixed effects	X	X
Year fixed effects	X	X
Month fixed effects	X	X
Observations	105,880	105,664
R-squared	0.125	0.156

Notes:

Standard errors clustered in parentheses. Flood is a binary variable that takes on a value of 1 if the number of days with heavy rain (>10 mm/day) is positive, and 0 otherwise, measured the month previous to the survey month. Other explanatory variables included in the regression, but not shown, include educational attainment. *** is significant at the 1% level, ** is significant at the 5% level, * is significant at the 10% level.

8. Conclusions

This study used a large sample of workers from the period 2001-2010 and matched their labor market information as well as socioeconomic characteristics that explain these outcomes with daily rainfall information in the municipality where these workers live. The main objective of this research project was to calculate the effect of floods on labor market outcomes, as well as their heterogeneous effects on different sub-samples of the population. Econometric estimation of labor market equations was performed to study this question, controlling for municipality indicators that absorb time-invariant characteristics of the municipalities where workers live and time indicators that control for common shocks to all municipalities in the same time period.

I find evidence that urban labor market adjustments in response to negative shocks occur partly through increases in adult unemployment and “forced entrepreneurship”. This suggests that at least a fraction of the population is unable to rely on their labor supply to smooth extreme rainfall shocks.

The marginal effect of one additional extreme hydro-climatic event on hours worked and labor income is negative in the short term, and the largest estimated marginal effect on real wage is -8%. This estimate is most likely an under-estimation of the effect of floods on real wages per hour, as people adapt to extreme events (Hsiang et al, 2012) and surveyors collecting labor market data could not visit the most affected municipalities during the floods of 2010. This means that the true estimate of the effect of floods on unemployment and losses in labor income is larger. On the other hand, the mean effect of floods in the course of a year are larger, as there are more than 1 extreme rainfall events on average during the rainy season in the Caribbean, and these estimates are marginal effects. Another important conclusion of this study is that the effect of negative hydro-climatic events is larger for labor income than hours worked. This has an important implication for welfare: if people wanted to smooth income and obtain the same earnings they did before the extreme rainfall shock, they would have to work more hours at a lower rate. Finally, hours worked and labor income fully recover after 13 months of the extreme rainfall event.

My econometric results show that floods measured by extreme rainfall events compared to usual seasonal rainfall have important heterogeneous effects on the labor market of the Colombian Caribbean. Unemployment raises twice as much for adult women than for men (0.07 versus 0.02), and these effect are statistically significant and robust to common shocks to all municipalities, as well as seasonal economic activity and to invariant municipality characteristics that affect the labor markets. Men are better able to cope with extreme weather by resorting to self-employment than women, however. My evidence points to a larger probability of minor workers as a consequence of extreme rainfall shocks, and this is both a compositional effect (less adults working) and an absolute increase in child labor. That is, the proportion of children in the total pool of workers increases as less adults work as well as more children are likely to work or look for jobs as a consequence of living in a municipality that experienced at least one day with heavy rains the previous month.

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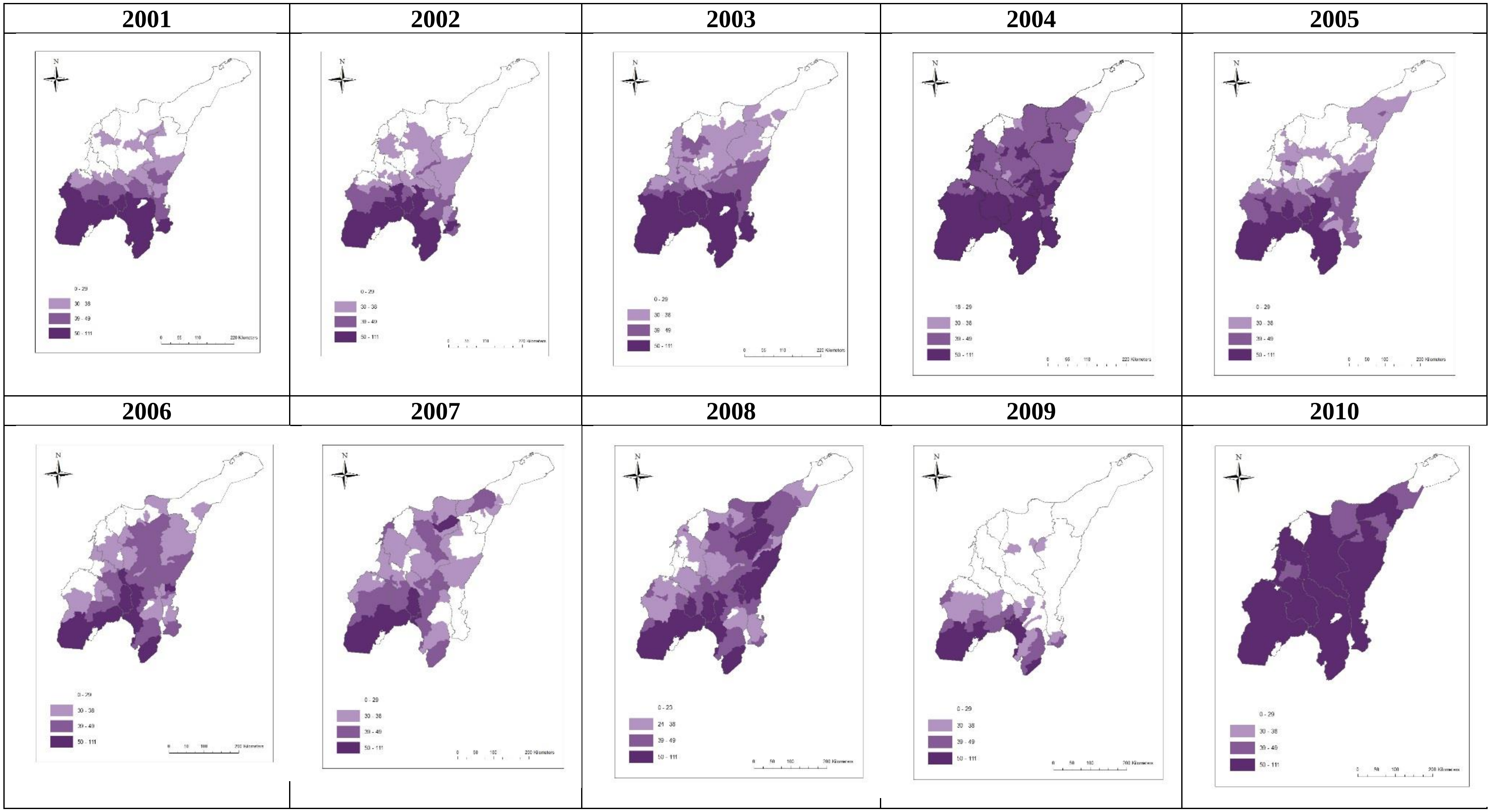
Map 1. Days of Heavy Rainfall, 2001-2010



Source: Own elaboration based on NASA TRMM rainfall data and municipal polygons by Agustin Codazzi Institute ;