DOCUMENT DE TRAVAIL DT/2022-07

Rainy days and learning outcomes: Evidence from Sub-Saharan Africa

Yasmine BEKKOUCHE

Kenneth HOUNGBEDJI

Oswald KOUSSIHOUEDE

UMR LEDa
Place du Maréchal de Lattre de Tassigny 75775 • Paris •Tél. (33) 01 44 05 45 42 • Fax (33) 01 44 05 45 45
DIAL • 4, rue d'Enghien • 75010 Paris • Tél. (33) 01 53 24 14 50 • Fax (33) 01 53 24 14 51
E-mail : dial@dial.prd.fr • Site : dial.ird.fr

RAINY DAYS AND LEARNING OUTCOMES: EVIDENCE FROM SUB-SAHARAN AFRICA*

YASMINE BEKKOUCHE⋆, KENNETH HOUNGBEDJI†‡ and OSWALD KOUSSIHOUEDE§

⋆Université Libre de Bruxelles; †Institut de Recherche pour le Développement;
‡LEDa-DIAL (IRD, CNRS, Université Paris-Dauphine, Université PSL);
§UNESCO International Institute for Educational Planning

This version: November 2022

Abstract: We combined information on daily rainfall at school locations and standardized test scores to study how learning outcomes at primary schools are affected by precipitation during school days in Sub-Saharan Africa. Our results suggest that student test scores are lower in schools that are exposed to more rainy days during the academic year. Students in locations that had more rainy school days are also more likely to experience grade repetition. We tested the mechanisms through which rainfall affects learning outcomes in our study area and found that teachers are more likely to be absent in locations with more rainy school days. We discuss the implications of these results and draw attention to policy options to mitigate learning loss during rainy school days.

Keywords: Education, Children, Climate

JEL Classification: I21, Q54

---

* The authors gratefully acknowledge the PASEC for access to unique data on academic performances at primary schools across Sub-Saharan Africa, Moussa Hamani Ounteni and Alexis Le Nestour for assistance in recovering data and information on past surveys carried out at the PASEC, TAHMO for access to data from their weather stations, Open Street Map-Benin, as well as Saliou Abdou and Parfait Menou for excellent assistance and fieldwork when mapping primary schools in Benin. Funding from the French National Institute for Sustainable Development, the UKRI GCRF Accelerating Achievement for Africa's Adolescents Hub and the J-PAL's Post-Primary Education (PPE) Initiative is gratefully acknowledged. The study benefited from excellent research assistance by Edouard Pignede and Claire Kremer, scoping work on education in Benin undertaken by Kamon Yebie, as well as comments and insights from Luc Behaghel, Isabelle Chort, Denis Cogneau, Isabel Günther, Karen Macours, Karine Marazyan, Paul Glewwe and seminar participants at the CSAE, DIAL, the ICDE conference in Clermont-Ferrand, the PEGNET Conference in Cotonou and the IIEP-AFD research seminars. All usual disclaimers apply, particularly that the views expressed in this paper do not represent the views of IIEP-UNESCO. Any remaining errors or omissions are ours.

1 Introduction

About 59 million primary-aged children were not in school for the academic year ending in 2018. Worldwide, this number has stagnated since 2007, and its level is worrisome in Sub-Saharan Africa where six out of ten primary-aged children are not in school (see UNESCO, 2019). Moreover, learning outcomes in the region are estimated to be among the lowest in the world (see Angrist et al., 2021). If low-level learning outcomes reduce incentives for schooling, efforts to improve school learning outcomes in Sub-Saharan Africa may prove effective at encouraging enrollment and attendance.

To contribute to the identification of public policy options that encourage demand for education in Sub-Saharan Africa, this paper studies the limits that climatic conditions can place on instruction time and learning outcomes. Throughout the region, academic calendars seldom vary across countries despite large variation in climatic conditions from one country to another. Likewise, within each country, most schools are usually subject to the same calendar regardless of the climatic differences between school locations. In that context, we argue that the number of school days provided by each school in an academic year may vary depending on rainfall at the local level during those days, which can have deleterious effects on learning.

Rainfall during school days may affect learning outcomes through two mechanisms which are of interest to this study. First, rainfalls induce flooding and hinder presence at school. Students attending schools in localities that experience more rainy days during the academic year may therefore receive less instruction time than their peers in localities with less rainfall. Second, raindrops may disturb classroom acoustics and more generally create conditions that are less than ideal for the learning experience. However, this can be mitigated by implementing measures either to maintain school attendance for students and teachers or to compensate for learning time lost during rainy days. The net effect of rainfall activities on learning outcomes is thus theoretically ambiguous and warrants an empirical investigation to identify areas in which additional measures may be useful.

Since rainfall can also affect learning through other mechanisms, measuring the net effect of learning time lost due to climatic conditions can be challenging. For instance, the variation of rainfall patterns during school days across localities is likely determined in part by the differences in atmospheric conditions. In that case, the net effect of rainfall patterns on learning outcomes during the academic year may be explained by residential sorting. Families who chose to live in localities with more rainy days have different characteristics that affect their children's learning outcomes. Likewise, when the academic and agricultural calendars overlap, some students may spend time helping with agricultural activities. In that case, we would expect the opportunity costs of children attending schools in localities with more rainfall to be higher and students' involvement at school to be lower (see Nordman et al., 2022, for a review of existing studies of this *income-effect* mechanism).

The remaining of the paper proceeds as follows: in Section 2 we will describe the research design and main data used to overcome the confounding mechanisms outlined above and explore the relationship between rainfall patterns during school days and student achievements. Section 3 presents the main results of the study and explores the channels underlying the link between rainfall and academic performance. Section 4 offers concluding observations.

2 Data and Methods

2.1 Data

We were able to leverage several rounds of surveys conducted with the Programme for the Analysis of Education Systems (PASEC) across Sub-Saharan Africa. Between 2003 and 2010, in a set number of countries, PASEC conducted a series of standardized tests in mathematics and reading one month after the beginning and one month before the end of the academic year on random samples of students in the second and fifth grades. Within each country, a sample of 140 to 180 schools was randomly selected from a sampling frame of active primary schools. Once a school was sampled, one class of second grade and one class of fifth grade were randomly selected, and up to 15 students were randomly drawn from each class to take the tests. Detailed questionnaires intended for the students who took part in the standardized tests, their teachers and the principals were also used to provide information on student characteristics along with their home and school environments. The resulting data set covered 1,643 schools, and we have identified and recovered the geographical extent of the 535 lowest administrative units for these schools. Class sizes varied from one school to another, and some schools may only have had one of the two grades. Hence, the number of second and fifth-grade classrooms was unbalanced, and we relied on information from 23,460 students in second grade from 1,579 classrooms and 22,312 students in fifth grade from 1,523 classrooms in Benin, Burkina Faso, Burundi, Cameroon, Chad, Congo, Gabon, Madagascar, Senegal and Togo (see Table A-1 and A-2 for details of the sample characteristics across the countries).

The academic calendars of the countries included in our study invariably start in October and end in June of the following calendar year. We used high-resolution map of daily rainfall produced by the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) to count the number of weekdays with a rainy event detected within the boundaries of each school's administrative unit between the months of October and June of the relevant academic year.[1] We observed that rainfall patterns during weekdays in the academic year varied from zero rainy days in parts of Senegal to 177 rainy days in the tropical rainforest of the Republic of Congo. We also observed a wide variation of rainfall patterns across administrative units within a single country. In Cameroon, the number of rainy days measured during the academic year 2004-05 varied from 21 in the department of *Logone-et-Chari* to 153 in the department of *Momo*. As rain clouds travel through space, the number of rainy days may be higher in larger administrative units. Rainfall patterns may therefore be overestimated for schools located in large administrative units. To mitigate this measurement error, our analyses explicitly consider the area of the administrative units. To provide alternative estimates of the main results of the paper, we collected detailed Global Positioning System (GPS) coordinates for the schools surveyed in Benin and Senegal and exploited the variation of rainfall patterns at the exact school locations.

2.2 Methods

We considered the following specification to estimate the impact of rainfall during weekdays in the academic year:

$$\mathbf{Y}^{e}_{il} = \beta_0 + \beta_r \mathbf{R}_l + \beta_a \mathbf{A}_l + \mu_c + \epsilon_{il} \tag{1}$$

The primary variable of interest is $\mathbf{Y}^{e}_{il}$, the normalized test score at the end of the academic year and the likelihood of grade repetition for student i attending school in the administrative unit (or locality) l. We sought to estimate the net effect of $\mathbf{R}_l$, the normalized number of school

---

[1] CHIRPS' datasets combine observations of cold cloud derived from satellites, rain gauge measurements from stations and models of rainfall to produce detailed maps of daily precipitation for pixels of approximately 5 km × 5 km since 1981 (see Funk et al., 2015, for more details). In Benin, we compared the estimate of daily rainfall produced by CHIRPS to the measures of daily rainfall reported by the meteorological stations at the locations of each station (see Supplementary Materials S1). Our results show that the variation of the number of rainy days across stations reported by CHIRPS is highly correlated with the variation measured using the measurements produced by the meteorological stations (see Figure A-4). However, the levels of rainfall reported by both methods are poorly correlated. Our analyses use the measurements reported by CHIRPS to detect rainy events and do not consider the variations in rainfall intensity.

days with rainfall during the academic year. Since $\mathbf{R}_l$ is measured throughout the locality l, students attending different schools in l share the same level of exposure to rainfall during the academic year. To attenuate the effects of the measurement errors related to using the number of rainy days across a locality to estimate the number of rainy weekdays at a school location, we included as a control variable $\mathbf{A}_l$, the area of the administrative unit of student i's school. The survey fixed effects, μ_c, help account for the difference in test items that were introduced to adapt the reading and mathematics tests to the context of each country. They also help use the variation of rainfall patterns across localities within the same country to identify the effect of rainy school days on the students' learning outcomes. Last, ϵ_{il} represents the unobserved heterogeneity that affects test scores at the end of the academic year.

The parameter of interest β_r, is the expected net variation of learning outcomes per standard deviation (s.d.) increase of rainy days in the administrative unit during the academic year. Since the spatial variation of rainfall patterns is determined by meteorological processes, we assumed that the variation of $\mathbf{R}_l$ across localities in the same country was exogenous to the unobserved heterogeneity ϵ_{il}. To isolate the effects of rainy days on learning outcomes that are driven by a loss of instruction time, we documented how β_r varies when we block alternative pathways through which the number of rainy days affects student learning outcomes. We focused on three such pathways. First, families who want to improve their children's learning outcomes might choose to live in administrative units with fewer rainy days during the academic year. In that case, end-of-year test scores would be lower (and, conversely, the likelihood of grade repetition would be greater) in rainy localities because of residential sorting and less investment in schools and students. Second, in response to residential sorting, student and school characteristics may differ across administrative units and confound the effects of the variation of rainy days across schools. Third, students in localities with more rainy days may contribute some of their time to helping with agricultural activities and invest less effort at school.

We used $\mathbf{Y}^b_{il}$, the normalized test score at the beginning of the academic year for student i attending school in locality l to help account for the effects of residential sorting that could mediate the impact of rainy days on end-of-year learning outcomes and considered the following specification:

$$\mathbf{Y}^e_{il} = \beta_0 + \beta_r \mathbf{R}_l + \beta_y \mathbf{Y}^b_{il} + \beta_a \mathbf{A}_l + \mu_c + v_{il}. \quad (2)$$

Since start-of-year test scores are measured at the beginning of the year, we assumed that $\mathbf{Y}_{il}^{b}$ is exogenous to the unobserved heterogeneity v_{il} and we commented on the variations of the estimates of β_r across (1) and (2).

To account for the mediating effects of student and school characteristics across localities with varying amounts of rainy days during the academic year, we used a vector of student and school characteristics. The student characteristics, $\mathbf{X}_{il}$, include age in years, gender and the number of parents/caretakers who are literate for student i in locality l. The school characteristics, $\mathbf{S}_{il}$, include binary variables identifying modes of school and classroom organization like double-shift schooling, combined or multi-grade classrooms, an index of infrastructures available at the school (storage room, library, infirmary, toilets, free canteen, athletics field, electricity supply, access to free drinking water) and an index of infrastructures available in the locality (asphalt road, electricity grid connection, access to running water, middle school, high school, landline, police office, bank office) of student i in locality l. Using these additional variables, we estimated the following specification:

$$\mathbf{Y}_{il}^{e} = \beta_0 + \beta_r \mathbf{R}_l + \beta_y \mathbf{Y}_{il}^{b} + \beta_x \mathbf{X}_{isl} + \beta_s \mathbf{S}_{il} + \beta_a \mathbf{A}_l + \mu_c + \nu_{il}. \tag{3}$$

The surveys do not document if students participated in income-generating activities between the start-of-year and end-of-year tests. However, each student stated at the beginning of the academic year whether they often contributed to farm and retail work.[2] We considered that students who had already contributed to income-generating activities would be more likely to divert efforts to income-generating activities when a locality has more rainy school days. If that assumption holds and students in localities with more rainy days divert their efforts away from school, then we would expect lower end-of-year learning outcomes (a higher likelihood of grade repetition) per unit of $\mathbf{R}_l$ for students who stated that they often contributed to farm and retail work. Conversely, the expected end-of-year learning outcomes per unit of $\mathbf{R}_l$ for students who did not often contribute to income-generating activities would provide an estimate of the effect of rainy days that can be attributed to a loss of instruction time. With $\mathbf{W}_{il}$, a binary variable that is equal to one when student i in locality l declared they often contribute to farm

---

[2] In the sample, 49% of second-grade and 57% of fifth-grade students stated at the beginning of the academic year that they had contributed to farm work. The corresponding estimates for students who had already contributed to retail work are 17% on second-grade and 22% of fifth-grade students.

and retail work and zero otherwise, we estimated the following specification:

$$\mathbf{Y}^{e}_{il} = \beta_0 + \beta_r \mathbf{R}_l + \beta_{rw} \mathbf{R}_l \times \mathbf{W}_{il} + \beta_y \mathbf{Y}^{b}_{il} + \beta_x \mathbf{X}_{il} + \beta_w \mathbf{W}_{il} + \beta_s \mathbf{S}_{il} + \beta_a \mathbf{A}_l + \mu_c + \eta_{il} \quad (4)$$

We computed clustered standard errors that accounted for within-school correlation of outcomes since students in the same school share the same environment and estimated β_r and β_{rw} in (1), (2), (3) and (4).

3 Results

3.1 Main Results

The main findings of our work are presented in Table 1. We found that the end-of-year test scores of the second and fifth-grade students were on average lower in localities that experienced more rainy events during weekdays in the academic year.[3] When the competing mechanisms were accounted for, the results suggested that the expected end-of-year scores across reading and mathematics tests dropped by 0.09 s.d. for each s.d. increase of rainfall across localities for students in second grade compared to 0.04 for those in fifth grade.

A lesser effect of rainfall during school days on test scores in fifth grade is consistent with the increase by 1.96 percentage point per s.d. increase of rainy days of the expected likelihood of grade repetition across localities for students in second grade. This result indicates that the deleterious effect of rainfall on learning outcomes expands beyond lower test scores and prevents students in second grade from graduating. Consequently, students in fifth grade are selected and mostly comprised of those who benefit from an environment that is less vulnerable to disturbance induced by rainfall patterns. Furthermore, we found no evidence that more rainy days made these students more likely to repeat the grade at the end of the academic year.

The variation of the results across the different specifications was also consistent with our expectations and suggested that the effects of rainfall during school days on learning outcomes can be mediated through residential sorting (or a lower level of investment to support schooling) and the characteristics of students and schools in localities with more rainy days. We also found no evidence that the effect of rainfall on learning outcomes was mediated when effort

---

[3] The results presented in Table 1 were estimated using the sample of students that were present at the start-of-year and end-of-year tests. Students may be absent for a variety of reasons, but we found no evidence that they were more likely to be absent in localities that experienced more rainy days during weekdays in the academic year (see Table A-3).

was diverted to participating in income-generating activities. Indeed, the estimates of β_{rw} provided no evidence that the deleterious effects of rainy days on learning outcomes were higher for students who were more likely to divert their effort to income-generating activities. Other results showed that the expected end-of-year test score per s.d. increase of rainy days was lower in reading than in mathematics (see Table A-4) and suggested that the amount of time students spend interacting with their teacher may have a higher impact on the learning process for mathematical skills covered in second and fifth grades.

3.2 Robustness

Even though we accounted for the area, the number of rainy days at school locations is overestimated when using data on rainfall during school days across administrative units. As a result, our methodological approach yields conservative estimates of the effect of rainy days on learning outcomes. Using rainfall during school days across administrative units is also worrisome when rainy days affect the actions of the administrative units in other ways that may affect student learning outcomes. This is the case when rainfall activities divert local resources away from primary schools toward flood mitigation or road maintenance. To test the extent to which we underestimated the effect of rainfall and to see whether we might explain away the effects of rainy days on learning outcomes with time-varying unobserved heterogeneity across administrative units, we collected GPS coordinates of the schools surveyed in Benin and Senegal and studied how learning outcomes varied with rainfall levels across locations within the same administrative unit.

For each school located using GPS coordinates, we computed the average level of daily precipitation in a buffer of 1 km around the school. Then, we counted the number of rainy school days at each school location and used the following specification to estimate their effect on learning outcomes:

$$\mathbf{Y}^{e}_{il} = \beta_0 + \beta_r \mathbf{R}_l + \beta_y \mathbf{Y}^{b}_{il} + \beta_x \mathbf{X}_{isl} + \beta_s \mathbf{S}_{il} + \mu_a + \epsilon_{il}. \tag{5}$$

The fixed effects, μ_a, helped account for the unobserved heterogeneity that affects the learning outcomes of students from the same administrative unit during the academic year. The questionnaires used in Senegal did not allow us to measure how likely each student tested was to repeat the grade. Therefore, we restricted the estimation of the effect of the number of rainy school days on grade repetition on the students tested and surveyed in Benin.

The results are reported in Table 2 and confirm the main results described earlier. We found that expected end-of-year test scores decreased by 0.21 s.d. for each s.d. increase of rainy days for students in second grade. Their likelihood to repeat their grade is also 11 percentage points higher. While these effects are stronger than reported in Table 1 – and confirm that specification (3) produces conservative estimates of the effects of rainy days – we found no noticeable effects on students in fifth grade.

If rainy school days affect learning outcomes by reducing instruction time, we would expect that rainy days during weekends or summer break would have little to no effect on end-of-year test scores or likelihood of grade repetition. Using the specification (5), we reproduced the results of Table 2 and found no evidence that rainy days on weekends or during the summer break impacted student learning outcomes (see Table A-8).

3.3 Heterogeneity

At the country level, we found that the expected end-of-year test scores were often lower per unit of s.d. increase of rainy days except in Congo and Madagascar (see Fig. 1). Across all the countries, the deleterious effects of rainfall during the academic year were also higher for students in second grade. We found no evidence of a gender-differentiated effect of rainfall during school days on student learning outcomes (see Table A-5). However, we found that the impact of rainfall during school days on test scores decreased with student age (see Table A-6). This could suggest that older students are less likely to miss school on rainy days than their younger siblings. We also observed that the effects of rainfall during weekdays were more significant for students who had achieved higher scores at the start-of-year test (see Table A-7). This suggests that the disruption of instruction time induced by rainfall may affect all the students. In regression to the mean, with less instruction time, students who achieved higher test scores initially saw their score decrease the most by the end of the year.

3.4 Mechanisms

To test the mechanisms through which rainfall disturbs learning outcomes, we created a set of indicators of absenteeism and completion of the official curricula. These were derived using responses to the surveys administered to the teachers and the principals at the time of the end-of-year test in certain countries.[4] Then, we used the specification of Eq. (3) to study how the

---

[4] The questions on absenteeism were not included in the survey administered to teachers and principals in Cameroon. Consequently, we excluded Cameroon from the sample used to produce the estimates reported in

number of rainy days affected the number of school days missed by each teacher, as reported by the principal; the number of students who were on average absent in each classroom; and the likelihood of completion of the official curricula in mathematics and reading by the teacher. The results reported in Table 3 suggest that the expected number of school days missed by the teachers over a month increases by 0.06 s.d. per s.d. increase of rainy days. Teachers were also less likely to complete the curricula in reading and mathematics. We found no strong evidence that the average number of absent students increases with rainy school days.

4 Conclusion

Considering the context of a warming climate with varied rainfall patterns and intensity, this paper studies some of the hidden costs that rainy school days impose on learning outcomes at primary school. The results contribute to economic studies of the returns of instruction time. Existing studies report moderate to high returns of the length of the academic year on labor outcomes. In the United States of America (USA) and Germany, Card and Krueger (1992) and Pischke (2007) find evidence of persistent positive effects of the length of the academic year on labor market outcomes. In Argentina, Jaume and Willén (2019) find that teacher strikes in primary school have persistent long-run effects on earnings. Furthermore, a growing body of studies has documented the effects of instruction time on academic achievement (see Aucejo and Romano, 2016; Barrios-Fernández and Bovini, 2021; Cattaneo et al., 2017; Goodman, 2015; Huebener et al., 2017; Marcotte, 2007; Marcotte and Hemelt, 2008; Rivkin and Schiman, 2015; Thompson, 2021) with potential deleterious effects of an increase in instruction time on student mental health (see Marcus et al., 2020).

Given its topical coverage, this paper expands the work of Marcotte (2007); Marcotte and Hemelt (2008) and Goodman (2014) who studied the effect of snowfall on student' performance in the United States. In Maryland and Colorado, Marcotte (2007) and Marcotte and Hemelt (2008) find that students who took exams in years with snowfall performed significantly worse on the academic assessments than their peers in the same school who took the exams in other years. In Massachusetts, Goodman (2015) finds that school closings caused by extreme snowfall have little impact on student achievement whereas absences due to moderate snowfall cause a sharp reduction in math achievement. Considering that the number of school days lost to school closings was limited in Massachusetts, the results from Goodman

---

Table 3.

(2015) suggest that teachers and schools can mitigate the adverse effects of the disruption of instructional time but have more issues with absences that affect different students at different times. These conclusions echo the results of Aucejo and Romano (2016) who find that, in North Carolina, the increase in achievement from extending the school calendar is lower than the reduction in achievement due to absenteeism.

This paper finds that rainfall activities during school days have deleterious effects on student test scores and contribute to grade repetition by reducing the amount of instruction time for a sample of countries in Sub-Saharan Africa. Detailed analyses suggest that teacher absenteeism increases with rainfall, whereas the likelihood the official curricula will be completed decreases. These results echo the findings of learning losses associated to school closures during the COVID pandemic in low and middle income countries (see UNICEF et al., 2022). They also suggest that while learning poverty was highest pre-pandemic in Sub-Saharan Africa, schoolchildren have lower test scores during rainy school days when their teacher is absent. The negative effects of rainfall are strongest for math achievement and penalize the youngest students the most. However, some countries are more resilient than others to the disruption of instruction time caused by rainfall during the academic year. This presents an opportunity for future research to study and identify the factors that contribute to making some countries more resilient than others to the loss of instruction time due to rain. Alternatively, it may be worth studying if regional calendars that reduce the number of rainy school days help reduce the inequality of instruction time across administrative units and improve enrollment and learning outcomes.

References

Angrist, N., S. Djankov, P. K. Goldberg, and H. A. Patrinos (2021). Measuring human capital using global learning data. *Nature 592*(7854), 403–408.

Aucejo, E. M. and T. F. Romano (2016). Assessing the effect of school days and absences on test score performance. *Economics of Education Review 55*, 70 – 87.

Barrios-Fernández, A. and G. Bovini (2021). It's time to learn: School institutions and returns to instruction time. *Economics of Education Review 80*, 102068.

Card, D. and A. B. Krueger (1992, February). Does School Quality Matter? Returns to Education and the Characteristics of Public Schools in the United States. *Journal of Political Economy 100*(1), 1–40.

Cattaneo, M. A., C. Oggenfuss, and S. C. Wolter (2017). The more, the better? the impact of instructional time on student performance. *Education Economics 25*(5), 433–445.

Funk, C., P. Peterson, M. Landsfeld, D. Pedreros, J. Verdin, S. Shukla, G. Husak, J. Rowland, L. Harrison, A. Hoell, and J. Michaelsen (2015). The climate hazards infrared precipitation with stations - a new environmental record for monitoring extremes. *Scientific Data 2*(150066), 1 –21.

Goodman, J. (2014). Flaking Out: Student Absences and Snow Days as Disruptions of Instructional Time. NBER Working Papers 20221, National Bureau of Economic Research, Inc.

Goodman, J. (2015). In defense of snow days: students who stay home when school is in session are a much larger problem. *Education Next 15*(3), 64–70.

Huebener, M., S. Kuger, and J. Marcus (2017). Increased instruction hours and the widening gap in student performance. *Labour Economics 47*, 15–34. EALE conference issue 2016.

Jaume, D. and A. Willén (2019). The long-run effects of teacher strikes: Evidence from Argentina. *Journal of Labor Economics 37*(4), 1097–1139.

Marcotte, D. E. (2007). Schooling and test scores: A mother-natural experiment. *Economics of Education Review 26*(5), 629–640.

Marcotte, D. E. and S. W. Hemelt (2008). Unscheduled School Closings and Student Performance. *Education Finance and Policy 3*(3), 316–338.

Marcus, J., S. Reif, A. Wuppermann, and A. Rouche (2020). Increased instruction time and stress-related health problems among school children. *Journal of Health Economics 70*, 102256.

Nordman, C. J., S. Sharma, and N. Sunder (2022). Here comes the rain again: Productivity shocks, educational investments, and child work. *Economic Development and Cultural Change 70*(3), 1041–1063.

Pischke, J.-S. (2007). The impact of length of the school year on student performance and earnings: Evidence from the German short school years. *Economic Journal 117*(523), 1216–1242.

Rivkin, S. G. and J. C. Schiman (2015). Instruction Time, Classroom Quality, and Academic Achievement. *Economic Journal 0*(588), 425–448.

Thompson, P. N. (2021). Is four less than five? Effects of four-day school weeks on student achievement in Oregon. *Journal of Public Economics 193*, 104308.

UNESCO (2019). New methodology shows that 258 million children, adolescents and youth are out of school. *Fact Sheet 56*, 1–16.

UNICEF, World Bank, UNESCO, USAID, FCDO, and Bill & Melinda Gates Foundation (2022). The state of global learning poverty: 2022 update. Technical report, UNICEF: United Nations Children’s Fund.

Table 1: Effects of the number of rainy days on test score and likelihood of grade repetition

	End-of-year test score				Grade repetition			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Panel A: Second-grade students								
Number of rainy days (β_r)	-0.143***	-0.102***	-0.091***	-0.098***	3.326***	2.392***	1.960***	2.220**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.72)	(0.71)	(0.73)	(0.93)
× student worked (β_{rw})				0.023				-0.515
				(0.02)				(0.99)
$\beta_r + \beta_{rw}$				-0.075***				1.705**
				(0.02)				(0.85)
Number of students	20,140	20,140	20,140	20,140	14,224	14,224	14,224	14,224
Panel B: Fifth-grade students								
Number of rainy days (β_r)	-0.130***	-0.050***	-0.043***	-0.060***	2.086***	0.392	0.135	-0.638
	(0.02)	(0.01)	(0.01)	(0.02)	(0.79)	(0.79)	(0.81)	(1.06)
× student worked (β_{rw})				0.037**				0.897
				(0.02)				(1.08)
$\beta_r + \beta_{rw}$				-0.023				0.259
				(0.02)				(0.91)
Number of students	19,584	19,584	19,584	19,584	13,262	13,262	13,262	13,262
Area and country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Start-of-year test score	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Student and school characteristics	No	No	Yes	Yes	No	No	Yes	Yes

Note: The table shows estimates of the expected end-of-year score in mathematics and reading per s.d. increase of rainy days during the school year. For a selected number of countries the surveys included complementary information that allowed us to identify students who were likely to repeat the grade. Hence, the column "Grade repetition" reports estimates of the expected likelihood of grade repetition per s.d. increase of rainy school days. For each outcome, column (1) reports estimates of β_r obtained with the specification of Eq. (1), column (2) reports the estimates of β_r from Eq. (2) and column (3) the estimates of β_r from Eq. (3). Column (4) reports the estimates of β_r and β_{rw} from Eq. (4). The standard errors are clustered at the classroom level and are reported in parentheses. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table 2: Effects of the number of rainy days on test scores and likelihood of grade repetition using variation of rainfall patterns within administrative units

	End of year test score			Grade
	Reading	Math	Average	Repetition
Panel A: Second-grade students				
Number of rainy days	-0.109	-0.191**	-0.213**	10.751**
	(0.09)	(0.09)	(0.10)	(4.60)
Number of students	3,593	3,593	3,593	1,701
Panel B: Fifth-grade students				
Number of rainy days	0.089	-0.008	0.021	8.546
	(0.07)	(0.07)	(0.06)	(5.60)
Number of students	3,699	3,699	3,699	1,822
Administrative unit fixed effects	Yes	Yes	Yes	Yes
Start-of-year test score	Yes	Yes	Yes	Yes
Student and school characteristics	Yes	Yes	Yes	Yes

Note: The table shows the estimates of the average effect of one standard deviation variation of rainy days during the school year in a 1 km radius around each school on the standardized end-of-year test scores (in reading, mathematics, and the average score for both subjects) and the likelihood that the student will repeat the grade according to the teacher. The sample used in this estimation is restricted to the students surveyed in Benin and Senegal where we were able to precisely locate each school using their GPS coordinates. The coefficients reported correspond to the estimates of β_r in Eq. (3). The estimation of the average effect of rainy days on the likelihood of grade repetition is limited to the sample of students surveyed in Benin where teachers were asked this question.

The standard errors are clustered at the school level and are reported in parentheses. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table 3: Effects of the number of rainy days on absenteeism and the likelihood the curricula will be completed

	Absenteeism indicators		Curricula completed	
	Teachers	Students	Reading	Math
Panel A: Second grade				
Number of rainy days	0.061**	-0.014	-2.038**	-2.951***
	(0.03)	(0.03)	(0.99)	(0.93)
Number of classrooms	1,427	1,427	1,427	1,427
Panel B: Fifth grade				
Number of rainy days	0.035	0.056	-1.871*	-2.430**
	(0.03)	(0.04)	(1.06)	(1.01)
Number of classrooms	1,371	1,371	1,371	1,371
Area and country fixed effects	Yes	Yes	Yes	Yes
Start-of-year test score	Yes	Yes	Yes	Yes
Student and school characteristics	Yes	Yes	Yes	Yes

Note: The table shows estimates of the effect of rainy school days on different variables associated with the amount of instruction time supplied at school. The column on teacher absenteeism reports the estimated s.d. change in the number of school days missed by each teacher per s.d. increase of rainy days. The column on student absenteeism reports the estimated s.d. change in the number of absent students per s.d. increase of rainy days. The last two columns under the headings "Curricula completed" report the expected percentage points change of the likelihood that a teacher will complete the reading and mathematics curricula per s.d. of rainy days.

The standard errors are clustered at the school level and are reported in parentheses. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

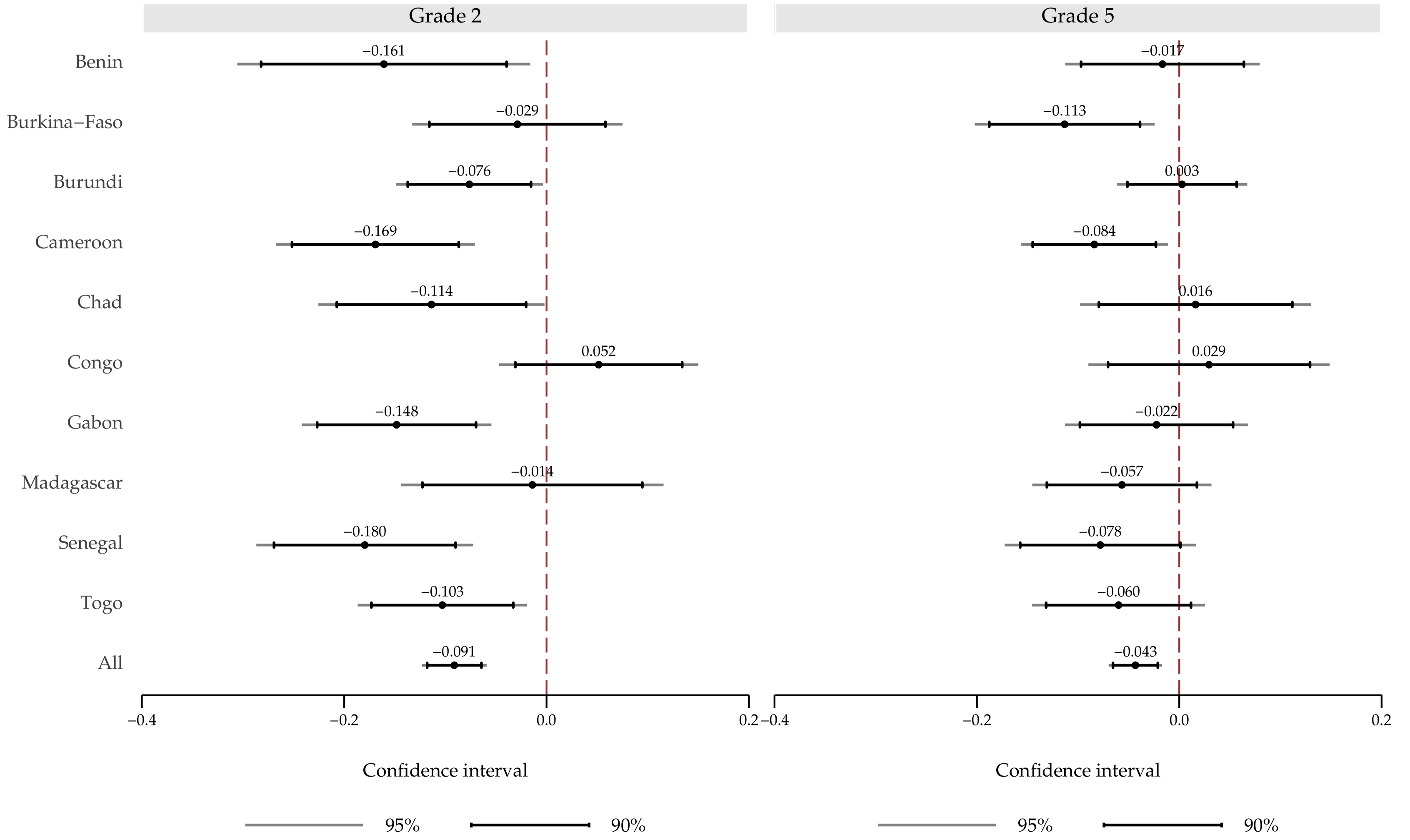


Fig. 1: Average effects of rainy days on average test scores across grades and countries This figure shows how the expected end-of-year test scores across reading and mathematics per unit of s.d. increase of rainy days vary across country for students in second and fifth grade.

Table A-1: Summary of data used in this study

Country	Years	Sample characteristics			Number of rainy days							
		Number of schools	Number of students: Second grade	Number of students: Fifth grade	obs.	min	p25	p50	mean	p75	max	sd
Benin	2004-05	145	2,034	2,098	61	53	70	79	79.6	88	121	14.1
Burkina-Faso	2006-07	175	2,289	2,327	42	45	61	68	69.3	77	101	13.6
Burundi	2008-09	180	2,694	2,625	89	42	48	50	50.7	53	65	4.4
Cameroon	2004-05	174	2,427	2,361	112	21	87	113.5	101.5	129	153	36.4
Chad	2009-10	169	2,454	1,988	43	22	45	63	62.4	77	100	19.7
Congo	2006-07	140	2,052	1,958	32	95	141	150.5	149.7	161.5	177	17.1
Gabon	2005-06	142	1,981	2,022	29	60	75	79	77.8	82	89	6.7
Madagascar	2004-05	180	2,677	2,215	56	32	91	110.5	104.8	119.5	151	25.2
Senegal	2006-07	159	2,201	2,140	38	0	38	46	45.9	53	81	16.1
Togo	2009-10	179	2,651	2,578	33	57	81	99	94.4	109	124	19.0
All	2004-10	1,643	23,460	22,312	535	0	53	77	82.4	109	177	34.5

Note: The table reports the characteristics of available PASEC surveys and spatial variability of rainfall across Sub-Saharan Africa. Column *min* reports the smallest number of days with rainfall measured at the lowest administrative unit during the academic year for each survey. Column *p25* shows the number of rainy days at the local level for the 25% of locations with the lowest number of rainy days where a school was surveyed. Column *p75* shows the minimum number of rainy days at the local level for the 25% locations with the most rainy days surveyed. Lastly, column *max* shows the maximum number of rainy days at the local level for each country.

Table A-2: Descriptive statistics of key variables

	Second grade					Fifth grade				
	Obs	Min	Mean	s.d.	Max	Obs	Min	Mean	s.d.	Max
Reading score										
- *start-of-year*	23,460	0	20.4	22.4	100	22,312	0	24.2	16.9	100
- *end-of-year*	20,140	0	32.5	24.4	100	19,584	0	25.9	17.7	100
Mathematics score										
- *start-of-year*	23,460	0	29.6	28.0	100	22,312	0	31.1	21.2	100
- *end-of-year*	20,140	0	32.6	24.1	100	19,584	0	28.6	18.7	100
Average score										
- *start-of-year*	23,460	0	25.0	24.0	100	22,312	0	27.6	17.9	97.4
- *end-of-year*	20,140	0	32.5	23.2	100	19,584	0	27.2	17.0	100
Student attrition	23,460	0	0.14	0.35	1	22,312	0	0.12	0.33	1
Student will repeat the grade	14,224	0	23.8	42.6	100	13,262	0	28.7	45.3	100
Student has dropped out	14,224	0	2.86	16.7	100	13,262	0	2.84	16.6	100
Student has repeated a grade	23,460	0	0.46	0.50	1	22,312	0	0.55	0.50	1
Age in years	23,460	4	8.27	1.69	18	22,312	4	11.9	1.82	21
Student is a girl	23,460	0	0.48	0.50	1	22,312	0	0.46	0.50	1
Number of school literate parents										
- *none*	23,460	0	0.37	0.48	1	22,312	0	0.39	0.49	1
- *one*	23,460	0	0.30	0.46	1	22,312	0	0.32	0.46	1
- *two*	23,460	0	0.33	0.47	1	22,312	0	0.29	0.46	1
Child work										
- *agricultural activities*	23,333	0	0.49	0.50	1	22,162	0	0.57	0.50	1
- *retail and services*	23,248	0	0.17	0.38	1	22,087	0	0.22	0.41	1
Teacher absence in days	1,599	0	2.99	5.85	153	1,538	0	2.74	5.64	153
Number of absent students	1,427	0	5.04	7.65	98	1,371	0	4.00	7.57	98
Curricula was completed in:										
- *Reading*	1,599	0	10.4	30.5	100	1,538	0	8.65	28.1	100
- *Mathematics*	1,599	0	10.3	30.4	100	1,538	0	9.69	29.6	100
School and classroom organization										
- *single-shift*	1,599	0	0.57	0.50	1	1,538	0	0.62	0.48	1
- *multi-grade*	1,599	0	0.096	0.29	1	1,538	0	0.10	0.30	1
- *double-shifting*	1,599	0	0.33	0.47	1	1,538	0	0.28	0.45	1
Infrastructure index										
- *locality*[a]	1,599	0	0.53	0.42	2	1,538	0	0.54	0.41	2
- *school*[b]	1,599	-0.44	0.35	0.46	2	1,538	-0.44	0.35	0.46	2
Number of rainy days	527	0	82.6	34.7	177	517	0	82.9	34.6	177

Note: The table presents descriptive statistics of the main variables considered in this study. The statistics reported under the heading “Second grade” refer to the sub-sample of students from the second grade. Under the heading “Fifth grade” we report the statistics from the sub-sample of fifth-grade students.

[a] The infrastructure index at the locality level was constructed based on a list of infrastructures and services available near the school. The list includes roads, electrification, water supply networks, high schools, health-care centers, telephone lines, police stations and banks.

[b] The infrastructure index at the school level is a composite index based on the availability of the following infrastructures within the school: kiosks, libraries, nurseries, canteens, toilets, playgrounds, athletics fields, electricity, and water supply networks.

Table A-3: Effects of the number of rainy days on presence at end-of-year tests

	Second grade			Fifth grade		
	(1)	(2)	(3)	(1)	(2)	(3)
Number of rainy days	0.001 (0.005)	-0.000 (0.005)	-0.003 (0.005)	0.004 (0.005)	0.002 (0.005)	-0.002 (0.005)
Number of students	23,460	23,460	23,460	22,312	22,312	22,312
Area and country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Start-of-year test score	No	Yes	Yes	No	Yes	Yes
Student and school characteristics	No	No	Yes	No	No	Yes

Note: The table shows estimates of the effect of one standard deviation variation of rainy weekdays on the likelihood that students will take the end-of-year tests. This allows us to check if presence at the end-of-year tests is affected by rainfall patterns during school days. We provide different estimates of the effect on the sample of students in second and fifth grades in separate columns using the specifications outlined in Eq. (1), (2), (3) and (4). Column (1) reports the estimates obtained with the specification of Eq. (1), column (2) corresponds to the estimates from Eq. (2) and column (3) the estimates from Eq. (3).

The standard errors are clustered at the classroom level and are reported in parentheses. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table A-4: Effects of the number of rainy days on end-of-year test scores in reading and mathematics

	Reading			Math		
	(1)	(2)	(3)	(1)	(2)	(3)
Panel A: Second-grade students						
Number of rainy days	-0.139*** (0.02)	-0.089*** (0.02)	-0.078*** (0.02)	-0.105*** (0.02)	-0.100*** (0.02)	-0.088*** (0.02)
Number of students	20,140	20,140	20,140	20,140	20,140	20,140
Panel B: Fifth-grade students						
Number of rainy days	-0.115*** (0.02)	-0.049*** (0.02)	-0.039*** (0.01)	-0.148*** (0.02)	-0.081*** (0.02)	-0.074*** (0.02)
Number of students	19,584	19,584	19,584	19,584	19,584	19,584
Area and country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Start-of-year test score	No	Yes	Yes	No	Yes	Yes
Student and school characteristics	No	No	Yes	No	No	Yes

Note: The table shows estimates of the expected end-of-year test score for each subject (reading or mathematics) per standard deviation increase of rainy days during the school year. For each outcome, column (1) reports the estimates of β_r obtained with the specification of Eq. (1), column (2) reports the estimates of β_r from Eq. (2) and column (3) the estimates of β_r from Eq. (3).

The standard errors are clustered at the classroom level and are reported in parentheses. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table A-5: Effect of the number of rainy school days by student gender

	End of year test score			Grade
	Reading	Math	Average	Repetition
Panel A: Second-grade students				
Number of rainy days	-0.080***	-0.077***	-0.087***	1.720**
	(0.02)	(0.02)	(0.02)	(0.80)
× student is a girl	0.005	-0.023*	-0.009	0.522
	(0.01)	(0.01)	(0.01)	(0.69)
Number of students	20,140	20,140	20,140	14,224
Panel B: Fifth-grade students				
Number of rainy days	-0.034**	-0.070***	-0.039***	0.129
	(0.02)	(0.02)	(0.01)	(0.88)
× student is a girl	-0.011	-0.008	-0.009	0.014
	(0.01)	(0.01)	(0.01)	(0.82)
Number of students	19,584	19,584	19,584	13,262
Area and country fixed effects	Yes	Yes	Yes	Yes
Start-of-year test score	Yes	Yes	Yes	Yes
Student and school characteristics	Yes	Yes	Yes	Yes

Note: The table shows estimates of the expected end-of-year test score (in reading, mathematics, and the average score of both subjects) and the likelihood that the student will repeat the grade per s.d. increase of rainy days during the school year and gender. Each column corresponds to an estimation where the end-of-year test score and the likelihood that the student will repeat the grade are regressed on the number of rainy school days at school locations interacted with a binary variable that is equal to one for girls and zero for boys while controlling for various characteristics of students and their schools as in Eq. (4). The standard errors are clustered at the school level and are reported in parentheses. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table A-6: Effect of the number of rainy days by student age

	End of year test score			Grade
	Reading	Math	Average	Repetition
Panel A: Second-grade students				
Number of rainy days	-0.237***	-0.230***	-0.244***	1.511
	(0.06)	(0.06)	(0.06)	(2.18)
× age in years	0.019***	0.017***	0.018***	0.055
	(0.01)	(0.01)	(0.01)	(0.25)
Number of students	20,140	20,140	20,140	14,224
Panel B: Fifth-grade students				
Number of rainy days	-0.261***	-0.244***	-0.190***	-3.146
	(0.07)	(0.07)	(0.06)	(3.13)
× age in years	0.019***	0.014**	0.012***	0.279
	(0.01)	(0.01)	(0.00)	(0.27)
Number of students	19,584	19,584	19,584	13,262
Area and country fixed effects	Yes	Yes	Yes	Yes
Start-of-year test score	Yes	Yes	Yes	Yes
Student and school characteristics	Yes	Yes	Yes	Yes

Note: The table shows estimates of the expected end-of-year test scores (in reading, mathematics, and the average score of both subjects) and the likelihood that the student will repeat the grade per s.d. increase of rainy days during school year and age of the student. Each column corresponds to an estimation where the end-of-year test scores and the likelihood of grade repetition are each regressed on the number of rainy days around school locations during the academic year interacted with age (in years) of the student while controlling for various characteristics of students and their schools as in Eq. (4). The standard errors are clustered at the school level and are reported in parentheses. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table A-7: Effect of the number of rainy school days on end-of-year learning outcomes by initial level of academic performance

	End-of-year test score			Grade
	Reading	Math	Average	Repetition
Panel A: Second-grade students				
Number of rainy days	-0.048**	-0.051**	-0.060**	2.306*
	(0.02)	(0.02)	(0.02)	(1.31)
× 2nd quartile start-of-year score	-0.005	-0.012	0.004	-1.057
	(0.02)	(0.02)	(0.02)	(1.34)
× 3rd quartile start-of-year score	-0.035	-0.063**	-0.041	0.211
	(0.03)	(0.02)	(0.03)	(1.42)
× 4th quartile start-of-year score	-0.071**	-0.046	-0.071**	-0.369
	(0.03)	(0.03)	(0.03)	(1.41)
Number of students	20,140	20,140	20,140	14,224
Panel B: Fifth-grade students				
Number of rainy days	-0.017	-0.088***	-0.044**	0.849
	(0.02)	(0.02)	(0.02)	(1.42)
× 2nd quartile start-of-year score	-0.001	0.041*	0.019	-0.603
	(0.02)	(0.02)	(0.02)	(1.46)
× 3rd quartile start-of-year score	-0.013	-0.020	0.001	-0.287
	(0.02)	(0.03)	(0.02)	(1.60)
× 4th quartile start-of-year score	-0.115***	-0.001	-0.067**	-0.941
	(0.03)	(0.03)	(0.03)	(1.77)
Number of students	19,584	19,584	19,584	13,262
Area and country fixed effects	Yes	Yes	Yes	Yes
Start-of-year test score	Yes	Yes	Yes	Yes
Student and school characteristics	Yes	Yes	Yes	Yes

Note: The table shows estimates of the expected end-of-year score in reading, mathematics, and the average score of both subjects per s.d. increase of rainy school days by level of start-of-year test scores. The column "Grade repetition" reports the estimates of the expected likelihood of grade repetition per s.d. increase of rainy school days by levels of start-of-year test scores. Each column corresponds to an estimation where the end-of-year test score and the likelihood of grade repetition are regressed on the number of rainy school days at school locations interacted with binary variables that identify different quartiles of start-of-year test scores while controlling for various characteristics of students and their schools as in Eq. (4). The standard errors are clustered at the school level and are reported in parentheses. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table A-8: Effects of the number of rainy days during weekends and the previous summer break on test scores and likelihood of grade repetition

	End of year test score			Grade
	Reading	Math	Average	Repetition
Panel A: Second-grade students				
Number of rainy days in 1km buffer during:				
- *holidays*	0.165	0.184	0.153	-39.579*
	(0.13)	(0.13)	(0.13)	(20.89)
- *weekends*	0.062	-0.075	-0.017	1.918
	(0.06)	(0.06)	(0.06)	(8.41)
Number of students	3,593	3,593	3,593	1,701
Panel B: Fifth-grade students				
Number of rainy days in 1km buffer during:				
- *holidays*	-0.169	-0.018	-0.108	-13.307
	(0.11)	(0.15)	(0.11)	(21.09)
- *weekends*	0.029	0.018	0.022	12.386
	(0.05)	(0.05)	(0.04)	(8.03)
Number of students	3,699	3,699	3,699	1,822
Administrative unit fixed effects	Yes	Yes	Yes	Yes
Start-of-year test score	Yes	Yes	Yes	Yes
Student and school characteristics	Yes	Yes	Yes	Yes

Note: The table shows the estimates of the average effect of one standard deviation variation of rainy days during the past summer break (July to mid-August) or during weekends of the school year in a 1 km radius around each school on the standardized end-of-year test scores (in reading, mathematics, and the average score of both subjects) and the likelihood that students will repeat the grade according to the teacher. The sample used in this estimation is restricted to the students surveyed in Benin and Senegal where we were able to precisely locate each school using their GPS coordinates. The coefficients reported correspond to the estimates of β_r in Eq. (3). The estimation of the average effect of rainy days on the likelihood of grade repetition is limited to the sample of the students surveyed in Benin where teachers were asked this question.

The standard errors are clustered at the school level and are reported in parentheses. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table A-9: Effect of the number of rainy days by student participation in retail or farm work

	End of year test score			Grade
	Reading	Math	Average	Repetition
Panel A: Second-grade students				
Number of rainy days	-0.080***	-0.081***	-0.098***	2.220**
	(0.02)	(0.02)	(0.02)	(0.93)
× student worked	0.002	0.040**	0.023	-0.515
	(0.02)	(0.02)	(0.02)	(0.99)
Number of students	20,140	20,140	20,140	14,224
Panel B: Fifth-grade students				
Number of rainy days	-0.044**	-0.084***	-0.060***	-0.638
	(0.02)	(0.02)	(0.02)	(1.06)
× student worked	0.040**	0.031	0.037**	0.897
	(0.02)	(0.02)	(0.02)	(1.08)
Number of students	19,584	19,584	19,584	13,262
Area and country fixed effects	Yes	Yes	Yes	Yes
Start-of-year test score	Yes	Yes	Yes	Yes
Student and school characteristics	Yes	Yes	Yes	Yes

Note: The table shows how the estimates of the average effect of one standard deviation variation of rainy days during the school year on the standardized end-of-year tests scores (in reading, mathematics, and the average score of both subjects) and the likelihood that the student will repeat the grade vary depending on whether the student had already con- tributed to retail or farm work in the past. Each column corresponds to an estimation where student end-year test scores and the likelihood of grade repetition are regressed on the number of rainy days around school locations during the academic year interacted with a binary variable that is equal to one for students who participated to farm and retail work in the past and zero for those who did not.

The standard errors are clustered at the school level and are reported in parentheses. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

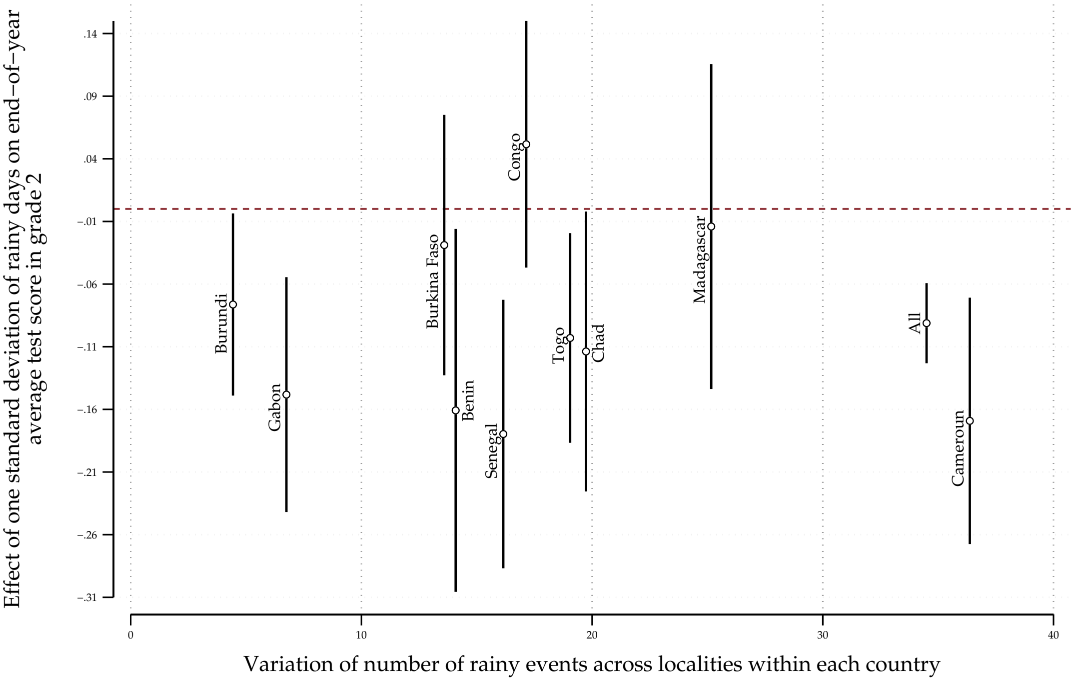


Fig. A-1: Average effect of a rainy school day on student test scores across countries in second grade. This figure shows how the expected end-of-year test scores across reading and mathematics per unit of s.d. increase of rainy days vary across countries for students in second grade.

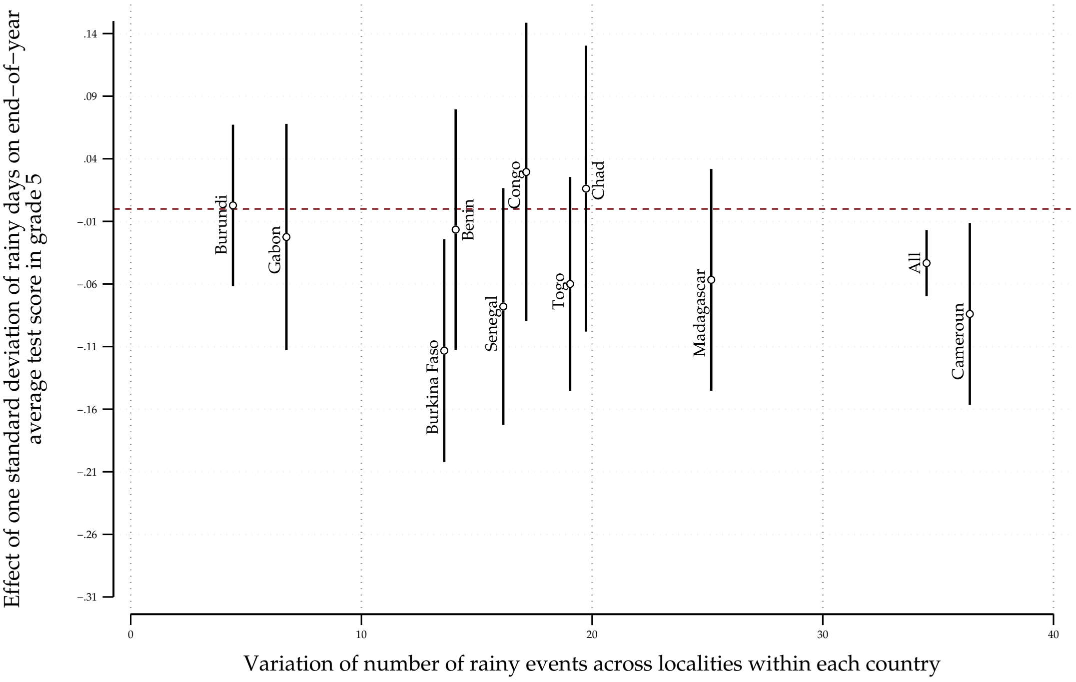
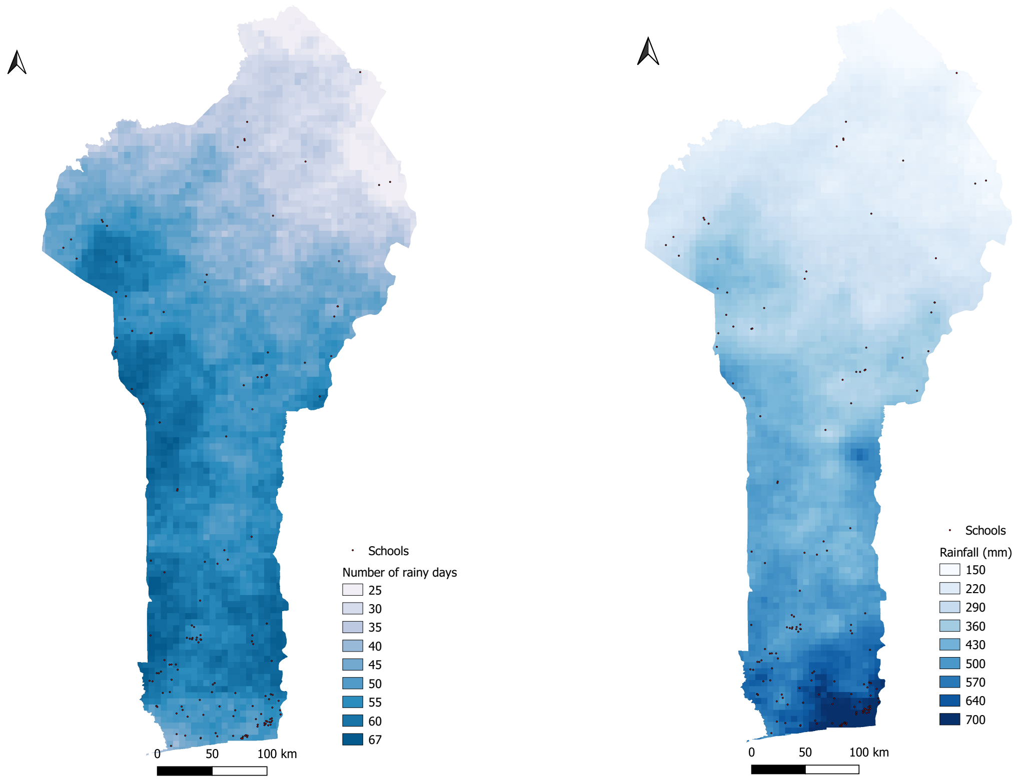


Fig. A-2: Average effect of a rainy school day on student test scores across countries in fifth grade. This figure shows how the expected end-of-year test scores across reading and mathematics per unit of s.d. increase of rainy days vary across countries for students in fifth grade.

S1 Measuring Rainfall at School Location

To measure daily precipitation in the neighborhood surrounding each school surveyed by PASEC, we used high-resolution maps of daily rainfall data collected by the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS). CHIRPS' data sets combine observations of cold cloud derived from satellites, rain gauge measurements from stations, and models of rainfall to produce detailed maps of daily precipitation for pixels with a size of 0.05°(approximately 5 km) since 1981 (see Funk et al., 2015, for more details). Combining the daily maps over a given academic year, it is possible to produce a detailed account of the number of rainy days during school days for each pixel of 25 km^2 (see Fig. A-3 for a visual representation of rainfall activities across Benin during school days in the academic year 2004-05 using daily maps produced by CHIRPS).



(a) Number of rainy days

(b) Rainfall

Fig. A-3: Rain activities during school days in the academic year 2004–05 in Benin. This figure describes the variation of the number of rainy days and total rainfall at local level across Benin for the academic year 2004–05.

Matching the detailed maps of daily precipitation from CHIRPS with the coordinates of each school successfully located, we were able to estimate the number of rainy days for the pixel where each school is located. To account for rainfall variation across pixels for schools located near adjacent pixels, we associated the average level of precipitation estimated for a buffer of neighboring pixels to each school the average level of precipitation estimated for a buffer made of neighboring pixels. Hence, our approach appropriately reports on rainfall events occurring in the neighborhood of near each school during the academic year.

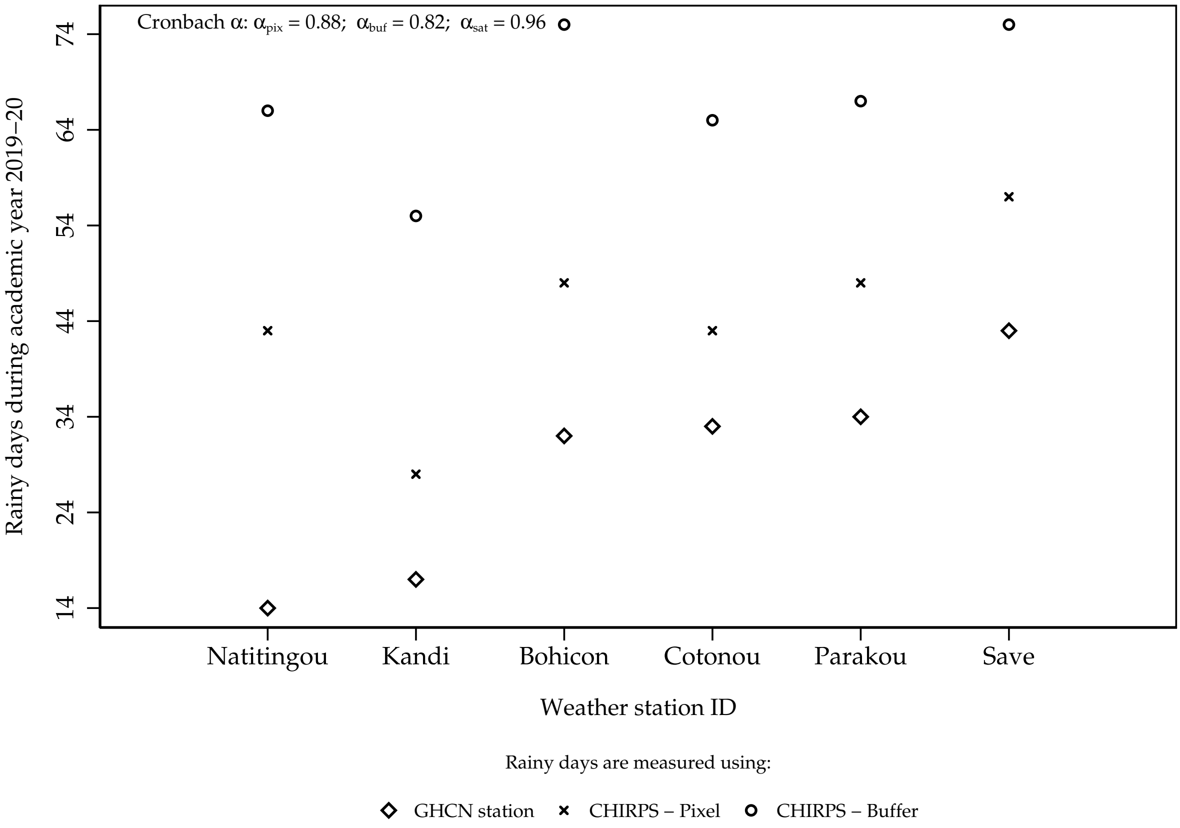


Fig. A-4: Number of rainy days during the academic year 2019–20 reported by CHIRPS and weather stations. This figure represents how the number of rainy days estimated using CHIRPS at the site of meteorological stations differ from the number of days recorded by the stations for the academic year 2019–20 for which we had comparable data sets.

To address concerns that spatial variation of rainfall produced by CHIRPS can fail to capture spatial variation of rainfall observed on the ground, we compared how the number of rainy days during the academic year 2019–20 at six (of the eight) meteorological stations throughout Benin varies when we estimate it using CHIRPS or the observations reported by rain gauges installed at each station. Since rainfall measurements reported by CHIRPS are recorded for each 25 km^2 pixel, they are likely to include precipitations near the station that did not reach the station. Hence, we may expect that the number of rainy days reported by CHIRPS for the pixel or the buffer where the station is located might systematically be greater than the number of rainy days measured based on the rain gauge measurements available for the station. This expectation was vindicated by the data (see Fig. A-4). We also found that the three measures had a high level of internal consistence, and the ranking of stations depending on the number of rainy days did not show much variation from one method to another. The internal consistency (the Cronbach's alpha) between the number of rainy days reported by the stations and the number of rainy days reported by CHIRPS at the pixel level is 0.88 whereas the internal consistency between the number of rainy days reported by the stations and the number of rainy days reported at the buffer level by CHIRPS is estimated at 0.82.