December, was key in the rapid melting of all snow during May. The hills of northern Wales enjoyed a snowier winter than in recent years, however, which culminated in the persistence of patches into June for the first time since 2010.

Acknowledgements

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Effect of climate variability on school attendance: a case study of Zamfara State in the semi-arid zone of Nigeria

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Introduction

The role of weather in determining important outcomes such as school attendance, truancy and absenteeism was identified several decades ago. Ellis (1973) noted that in nineteenth century England, for example, in some parts of the Fen country in North Riding, children living more than 2 miles (3km) from school were excused from compulsory schooling due to their access having been impeded by muddy cart tracks and winter snow. Apart from weather elements, there is a number of factors affecting school access, attendance and dropout rates in different parts of the globe (Pryor and Amphiah, 2003; No *et al.*, 2012), ranging from individual to institutional factors (Nicaise *et al.*, 2000; Natriello, 2002). These include culture, children with low socio-economic mobility characteristics, absence of professional role models in a community and unsupportive parents (Kailembo, 2000; Brown and Park, 2002; Boyle *et al.*, 2002; Natriello, 2002; Admassie, 2003; Traag and van der Velden, 2008; Hunt, 2008). Living in a rural or urban setting may influence the value that people attach to education, as many villagers do not consider education to be worthwhile (Pryor and Amphiah, 2003). However, some of these factors are either directly or indirectly influenced by climate.

The problems inherent in climate variability include education retardation, dropout and child labour. For instance, child labour appears to be used as a buffer for short-run economic shocks (Duryea, 1998) of the kind that follow extreme weather events, or rainfall surpluses or deficits. The diversion of school children from school to the workplace has consequences in terms of poor academic performance, threatened attendance at school and attention to schoolwork after enrolment and grade progression (Orazem and Gunnarsson, 2003; Sedlacek *et al.*, 2003).

Factors such as a lack of food, clothing, books and money to pay school fees, as well as psychological trauma, make learning difficult and often lead to high rates of school dropout in many societies (Adejuwon and Jegede, 2011). Studies have shown that school enrolment may be delayed or foregone entirely as a result of drought. Findings (2002) noted that children that are malnourished perform less well at school than the other children and conclude that the delay in school entry means delayed entry into the labour market and, hence, reduced overall earnings. Another study by Findings (2002) in February and March 2000 showed that the children affected by the drought of 1982–1984 in rural Zimbabwe, who had become young adults by the time the research was conducted, had significantly less schooling than the children in other villages who were not affected by the drought. The drought shock caused a loss of 0.4 grades of schooling and a delay of 3–7 months for an average Zimbabwean child.

Drought has resulted in poor crop yield, total crop failure, reduction in animal population, acute food shortage, increased food prices, famine and poverty in the study area in the last few decades (Apeldoorn, 1977). Mijindadi and Adegbehin (1991) noted that the drought of 1972–1973 caused a reduction in crop yield of up to 60%. This led to a reduction in quality of life and the migration of people to other villages, towns and cities where they could find succour. Consequently, the problem of drought constitutes a major threat to schooling.

In spite of the fact that drought has continued to cripple human activity in the study area, in one of the driest areas in Nigeria (Adejuwon, 2012), no research has been carried out on the effect of climate variability on school attendance (hence this study). The objectives of this study are as follows:

- to examine the variability in school attendance in the study area;
- to examine interannual rainfall and temperature variability over time in the study area;
- to identify the years of drought in the study area;
- to examine the rate of dropout of pupils from schools in the study area; and

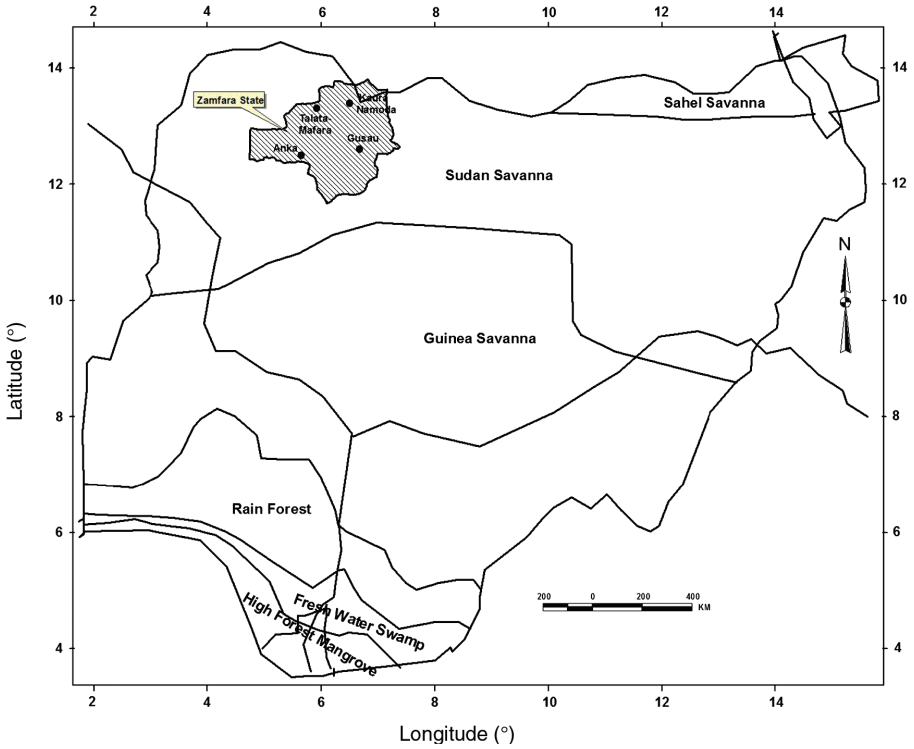

Figure 1. Ecological zones of Nigeria and study area.

Table 1

Selected primary schools in Zamfara State.

Local government	*Primary schools*
Talata-Mafara	(i) A Tunalim Primary School (ATPS), Talata-Mafara
	(ii) Dr A.M. Dogo Model Primary School (DAMDMPS), Talata-Mafara
	(iii) Yelwa Model Primary School (YMPS), Talata-Mafara
Anka	(iv) Anka Nizzamiyya Primary School (ANPS), Anka
	(v) Wuya Model Primary School (WMPS), Anka
	(vi) Anka Model Primary School (AMPS), Anka
Gusau	(vii) Jamaatul Nasirul Islam Model Primary School (JNIM PS), Gusau
	(viii) Township 1 S.M.P.S., Gusau
	(ix) Danturai Model Primary School (DMPS), Gusau
Kaura-Namoda	(x) Bashar Special Model Primary School (BSMPS), Kaura-Namoda
	(xi) Namoda Model Primary School (NMPS), Kaura-Namoda
	(xii) Mamuda Pilot Primary School (MPPS), Kaura-Namoda

- to assess the relationship between climate and school attendance.

Study area

The study area, Zamfara State, Nigeria, lies between latitude 10°N and 14°N and longitude 4°E and 8°E (Figure 1), covering an estimated land area of 38 418km^2.

It experiences a tropical climate, governed by the Intertropical Discontinuity (ITD; Obasi, 1965). The ITD marks the boundary line between two air masses – the tropical maritime (mT) air mass from the Atlantic Ocean and the dry tropical continental (cT) air mass from the Sahara Desert. The ITD migrates in a north–south direction and determines the zone of approximate penetration of the moist air masses (Lamb, 1983; Adejuwon *et al.*, 1990). The prevailing air mass at a particular period has a strong influence on the climate. Rain falls when an area is under the influence of the tropical maritime (mT) air mass, while dryness prevails when an area is dominated by the tropical continental air mass (cT). The climate exhibits a definite and marked wet and dry season. Tropical maritime air mass predominates during the wet season, while tropical continental air mass predominates during the dry season. The wet season is between June and September (Mamman, 2000).

Rainfall amount varies from 675 to 1000 mm. Compass direction is recorded as north, south, west, east etc. Due to Inter-Tropical Discontinuity (ITD), rainfall decreases in amount from southern Nigeria to Northern Nigeria. High relative humidity is experienced during the wet season, while low humidity of about 30% is experienced in the dry season (Oboli, 1967). During January to April, mean values are close to 20 or 25%. Diurnal values may fall from 50% at dawn to 10% in the afternoon. This is characteristic of the dry and dust-laden northeast trade wind known as the 'Harmattan', which blows from the Sahara Desert under cloudless but dusty conditions. This period is marked by very low temperatures and the prevalence of thick fog of alarming intensity.

The mean annual temperature is between 26 and 30°C (Mistry, 2000). The extreme diurnal and seasonal temperature range is affected by seasonal and latitudinal variations. The highest temperatures are normally in the hot season, during March to April, while the minimum temperatures are usually recorded in November to February.

Methodology

Data collection

School enrolment and attendance data for 12 primary schools were retrieved from the archives of the Local Government Education Authorities (LGEA) at Gusau, Kaura-Namoda, Anka and Talata-Mafara in Zamfara State. Three primary schools were selected from each LGEA (Table 1) using a purposive sampling technique, while the LGEA was selected using a systematic sampling technique. Only schools that were established prior to (and including) 1970 were selected for the study, for reasons of data uniformity and homogeneity.

Purposive and systematic sampling techniques were employed in this study, and each method has its advantages. Purposive sampling enables a researcher to reach a targeted sample quickly, and provides researchers with the justification for making generalisations from the sample that is being studied, whether such generalisations are theoretical, analytic and/or logical in nature. Qualitative research designs can involve multiple phases, with each phase building on the previous one. In such instances, different types of sampling technique may be required at each phase. Purposive sampling is useful in these instances because it provides a wide range of non-probability sampling techniques for the researcher to draw on.

Systematic sampling is advantageous and preferred over simple random sampling because it is straightforward, it ensures that the population will be evenly sampled, and it is better suited to covering a wide study area. Systematic samples are relatively easy to construct, execute, compare and understand, and also provide researchers and statisticians with a degree of control and a sense of process. Clustered selection, a phenomenon whereby randomly chosen samples are uncommonly close together in a population, is eliminated in systematic sampling. The greatest strength of a systematic approach is its low risk factor.

Climate (rainfall and temperature) data were collected from the archive of the Nigerian Meteorological Agency (NIMET; Oshodi, Lagos State) from 1970 to 2006. The data were collected for Gusau station – the only synoptic station in the state.

Data analysis

Data were analysed using descriptive statistics such as total and mean. School attendance was subtracted from school enrolment to calculate dropout. Bivariate (Pearson) Correlation and the Pearson product-moment correlation coefficient were used to establish the relationship between climate and school attendance. Correlation was analysed using the Statistical Package for the Social Sciences (SPSS). The coefficient of determination was calculated to examine the extent to which climate determined school attendance. The standardised rainfall anomaly index (SAI) was used to determine the year-to-year deviation of rainfall and temperature from the mean. It can be expressed as follows:

$$SAI = \frac{X - \bar{X}}{\sigma}$$

where X is the annual rainfall/temperature for a particular year, $\bar{X}$ is the mean annual rainfall/temperature for the period covered by the data, and σ is the standard deviation.

Results

Figure 2 shows the annual rainfall and mean annual temperature anomaly in Zamfara State from 1970 to 2006. Rainfall was extremely low during the droughts of 1970, 1984, 1987 and 1990, at 633, 675, 686 and 697mm respectively. These measurements were far less than the average rainfall amount of 907mm in the entire area. However, temperatures of 33.6, 34, 33.4 and 34.3°C, respectively, were recorded during these periods. The drought occurrences correspond to the periods of below-average rainfall and above-average temperature.

School attendance across the study area varied from 39 pupils at JNIMPS, Gusau in 1970 to 4880 pupils at TIMPS, Gusau in 2006 (Figure 3). Pupil dropout varied from 1 pupil in JNIMPS, Gusau (in 1972, 1973, 1978 and 2000), AMPS, Anka (in 1996), and NMPS, Kaura-Namoda (in 1999), to 220 pupils at ANPS, Anka in 1990. School attendance was generally low (39–694 pupils) at WMPS, Anka, JNIMPS, Gusau and MPPS, Kaura-Namoda, in comparison to other schools (Figure 4). The initial increase in school attendance at TIMPS, Gusau, DAMDMPS, Talata-Mafara and NMPS, Kaura-Namoda grew much larger from 1985 to 2006, varying between 1000 and 4880 pupils. BSMPS, Kaura-Namoda is the only school at which attendance was larger than 1000 pupils throughout the period of study. All three schools in Anka (WMPS, AMPS and ANPS) experienced low attendance in 1973, 1984, 1990, 1991, 1995 and 1997 due to drought. However, the rest of the schools experienced a steady increase in attendance. The number of years in which pupil dropout occurred varied from 13 to 37 years (Table 2). The total attendance for schools in the study area over the whole period of study varied from 7901 pupils at WMPS, Anka to 80 726 at TISMPS, Gusau, while the dropout totals varied from 326 pupils at BSMPS, Kaura-Namoda to 2452 pupils at DAMDMPS, Talata-Mafara. The total percentage dropout of pupils during the period of study ranged from 0.5% at TISMPS, Gusau to 9.28% at WMPS, Anka (Table 3).

The results of bivariate correlation analysis for rainfall and school attendance in Zamfara State are shown in Table 4. Rainfall had a significant positive ($P \leq 0.05$, $P \leq 0.01$) relationship with school attendance for eight schools. The correlation coefficient varied

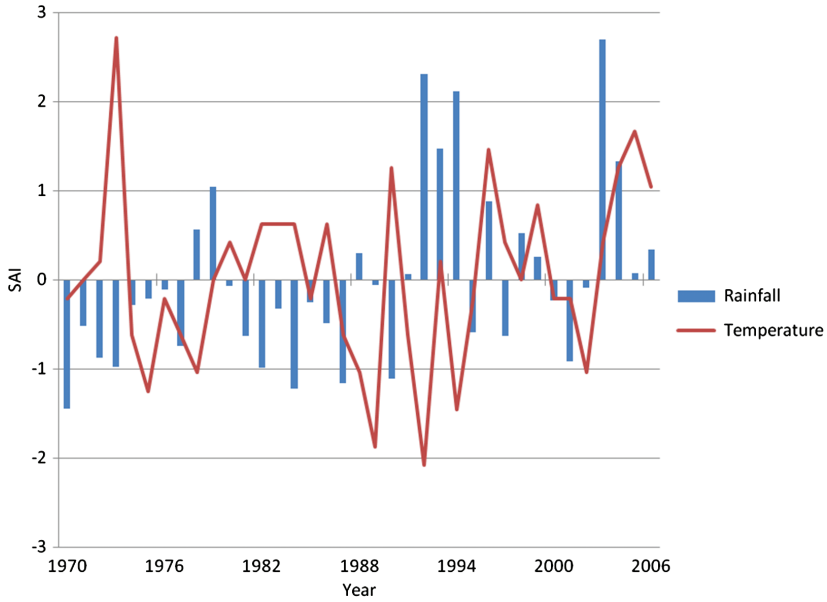

Figure 2. Annual rainfall and temperature anomaly for Gusau.

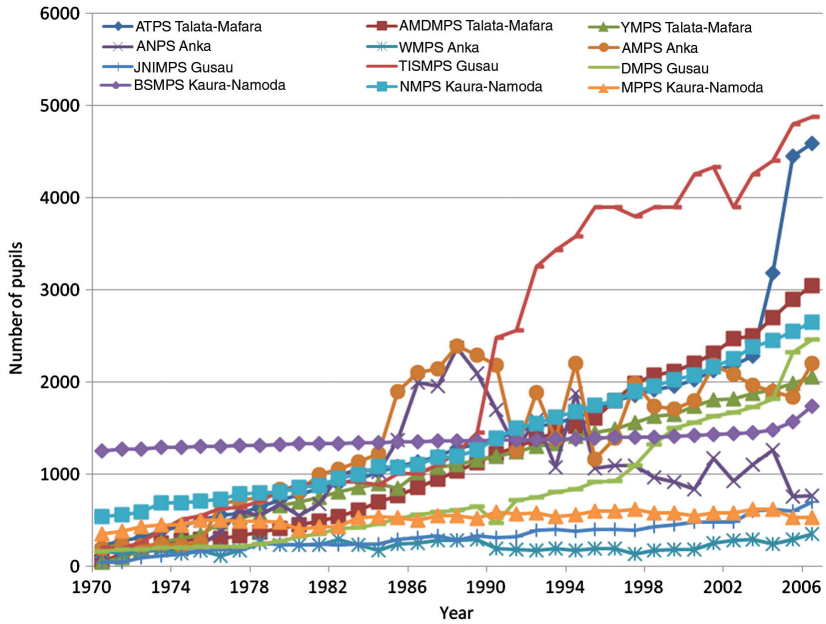

Figure 3. School attendance in Zamfara State, Nigeria.

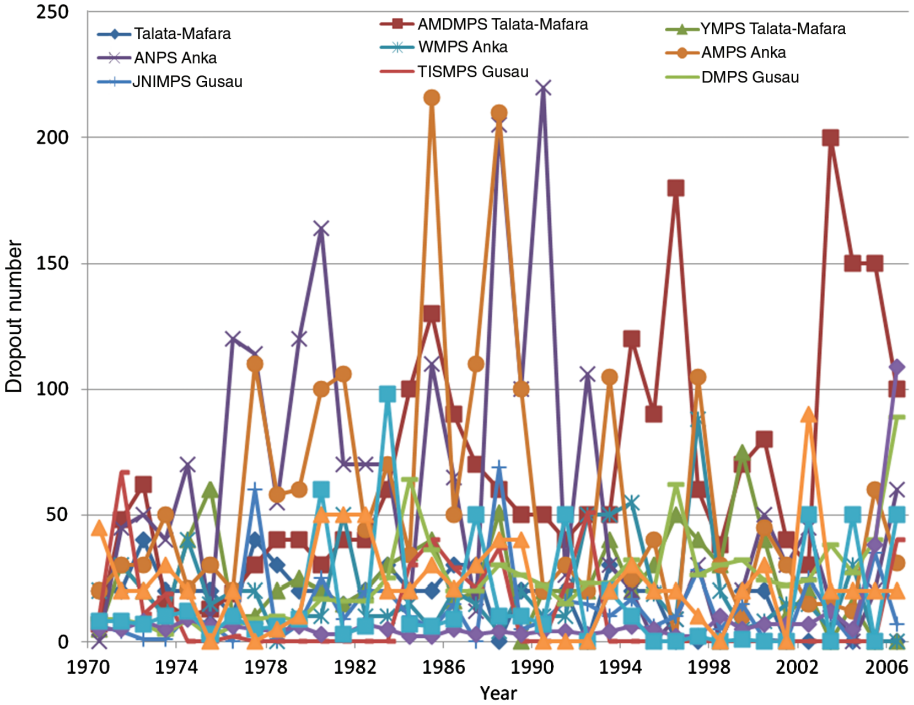

Figure 4. Dropout of pupils in primary schools in Zamfara State, Nigeria.

Table 2

Summary of years with dropout of pupils in schools in Zamfara State.

Schools	*Years with dropout of pupils*
ATPS Talata-Mafara	26: 1970–1987, 1989–1991, 1994–1995, 1999–2000
DAMDMPS Talata-Mafara	37: 1970–2006
YMPS Talata-Mafara	33: 1970–1988, 1990–2002, 2004
ANPS Anka	33: 1971–1994, 1996–1997, 1999–2003, 2005–2006
WMPS Anka	34: 1970–1976, 1978–2004
AMPS Anka	37: 1970–2006
JNIMPS Gusau	33: 1970–1975, 1977–1986, 1988–2000, 2002–2003, 2005–2006
TISMPS Gusau	13: 1970–1973, 1976, 1984–1988, 1991–1992, 2006
DMPS Gusau	37: 1970–2006
BSMPS Kaura-Namoda	37: 1970–2006
NMPS Kaura-Namoda	29: 1970–1991, 1993–1994, 1997, 1999, 2002, 2004, 2006
MPPS Kaura-Namoda.	30: 1970–1974, 1976, 1978–1989, 1993–1997, 1999–2000, 2002–2006

from 0.349 for ATPS, Talata-Mafara to 0.496 for JNIMPS, Gusau. The extent to which rainfall significantly determined school attendance varied from 12.18% at ATPS Talata-Mafara to 24.60% at JNIMPS, Gusau. However, rainfall is not significantly related to school attendance at either the 95 or the 99% level of confidence in schools at Anka.

Discussion

The results show that school attendance across the study area varied from 39 to 4880 pupils over the period of study. Dropout varied from 1 to 220 pupils, while the pupil dropout percentage ranged from 0.5 to 9.28%. The results also show that school attendance is low during drought and high when there is enough rain. Dropout was highest during the drought years of 1984, 1987 and 1990 in most schools in the study area. Farmers were able to confirm the drought years when interviewed, as 96.4% of them maintained that the drought had a significant impact on their crops (Adejuwon, 2012). Apeldoorn (1977) noted that the drought of 1970–1973 seriously affected the area. The drought was so severe that people started migrating to areas where they could find succour (New Nigerian Newspaper, 26 November 1973; 15 December 1973). The drought caused a reduction in crop yield of up to 60%, as well as the loss of between 1.5 and 1.8 million livestock animals, which is about 20% of the total livestock population in the whole of northern Nigeria (Mijindadi and Adegbehin, 1991). The *Daily Times* of 17 January 1974 reported that many pupils abandoned schools in towns and villages and joined their parents in search of food in areas not affected by drought. A consequence of this is that children who migrate from rural to urban areas may encounter difficulties in continuing their education and may be forced to work to help their family recover the costs of moving. Migrant families may not be able to afford school fees, schools that are overcrowded may refuse to take migrant children due to lack of capacity, and children who are new to a school may also experience discrimination (UNICEF, 2011).

Similarly, the drought of 1984 (remembered in the study area as the year of Buhari – the then head of state in Nigeria) was devastating in nature. Another severe drought, that started in Yobe and Borno States in northeastern Nigeria in 1990 (Adejuwon, 2005), spread across the whole of northern Nigeria. These droughts resulted in a high rate of dropout of pupils, not only in the drought years but also the subsequent years. For instance, the 1970 drought led to a high dropout of pupils from schools in 1971 at YMPS, Talata-Mafara, WMPS, Anka, AMPS, Anka, TISMPS, Gusau, and in 1972 at ATPS, Talata-Mafara, DAMDMPS, Talata-Mafara and ANPS, Anka. Similarly, the dropout at DAMDMPS, Talata-Mafara, ANPS, Anka, AMPS, Anka and JNIMPS, Gusau, during the droughts of 1984, 1987 and 1990 extended to the following year for each school. This is due to the fact that the drought's effects extend beyond the year of their occurrence. However, the drought that caused low attendance in 1990 at DMPS, Gusau, JNIMPS, Gusau and WMPS, Anka did not result in a high rate of dropout. A high rate of dropout was only recorded at JNIMPS, Gusau a year after. While dropout occurred irregularly across a number of years at most schools, it occurred consistently for the 37 years under consideration at DAMDMPS, Talata-Mafara, AMPS Anka, DMPS Gusau and BSMPS Kaura-Namoda.

Bivariate (Pearson) Correlation established a relationship between climate and school attendance in the study area. There is no significant relationship between temperature and school attendance for all schools, though the relationship is positive in nine schools and negative in three schools. This indicates that temperature is not a determinant of school attendance in Zamfara State. The correlation coefficients of the relationship between rainfall and school attendance for the 12 schools are positive, but only 8 gave values that are significant at the 95 and 99% confidence levels. This implies that an increase in the annual rainfall over the period of consideration increases school attendance. Conversely, the annual rainfall

Table 3

Total percentage dropout of pupils in Zamfara State, Nigeria.

Schools	*Total attendance*	*Total dropout*	*Percentage dropout*
ATPS Talata-Mafara	52 700	595	1.13
DAMDMPS Talata-Mafara	44 689	2452	5.49
YMPS Talata-Mafara	40 101	907	2.26
ANPS Anka	36 915	2186	6.73
WMPS Anka	7901	733	9.28
AMPS Anka	51 251	2063	4.03
JNIMPS Gusau	11 985	484	4.04
TISMPS Gusau	80 726	379	0.5
DMPS Gusau	29 453	891	3.03
BSMPS Kaura-Namoda	50 782	326	0.64
NMPS Kaura-Namoda	51 136	577	1.13
MPPS Kaura-Namoda.	20 495	841	4.10

Table 4

Bivariate correlation (R) and coefficient of determination (R^2) for annual rainfall and school attendance, and for mean annual temperature and school attendance in the Sokoto-Rima River Basin.

	Rainfall		*Temperature*	
School	*R*	*R^2*	*R*	*R^2*
A Tunalim PS, Talata-Mafara	0.349[a]	12.18	0.280	7.84
DR. A.M. Dogo MPS, Talata-Mafara	0.413[a]	17.06	0.193	3.72
Yelwa MPS, Talata-Mafara	0.433[b]	18.75	0.127	1.61
Anka NPS, Anka	0.243	5.90	−0.258	−51.6
Wuya MPS, Anka	0.136	1.85	0.040	0.16
Anka MPS, Anka	0.316	9.99	−0.094	−18.8
JNIMPS, Gusau	0.496[b]	24.60	0.156	2.43
Township 1 S.M.P.S, Gusau	0.474[b]	22.47	0.156	2.43
Danturai MPS, Gusau	0.351[a]	12.32	0.238	5.66
Bashar Special MPS, Kaura-Namoda	0.321	10.30	0.255	6.50
Namoda MPS, Kaura-Namoda	0.434[b]	18.84	0.190	3.61
Mamuda Pilot PS, Kaura- Namoda	0.487[b]	23.72	−0.010	−2.00

[a]R is significant at 0.05 level ([a]$\alpha \leq 0.05$).
[b]R is significant at 0.01 level ([b]$\alpha \leq 0.01$).

is not significantly related to school attendance in Anka, in the western part of the study area. Hence, rainfall does not have such a strong effect on school attendance in this area.

Moreover, the extent to which rainfall significantly determined school attendance varied from 12.18 to 24.60%. This is an indication that there are other factors affecting school attendance in the study area. Culture is a major factor affecting school attendance. Hofstede (2001) defined culture as a set of shared attitudes, values, goals, and practices that characterise an institution, organisation or group. The culture of the study area and some other parts of northern Nigeria encourages early marriage for girls and early independent life for boys. Girls are given away in marriage at ages as early as 11 years. For this reason, most girls are not allowed to go to school, and if they are allowed, they are withdrawn at a tender age. Early independent life is another part of the culture that affects school attendance. In 2008, an education officer at the Anka Local Government Education Authority related the case of a primary school pupil whose father assisted in marrying two wives. The decision to enrol and keep a child in school involves parental beliefs and expectations about the value of schooling (Akresh, 2008). However, these problems become more pronounced during drought periods.

Conclusion

This study has shown the following: school attendance varied from 39 to 4880 pupils; dropout varied from 1 to 220 pupils; the percentage of total dropout of pupils ranged from 0.5 to 9.28%; the number of years in which pupil dropout occurred varied from 13 to 37 years; dropout affected WMPS Anka more than other schools; school attendance is low during drought and high when there is enough rain; and dropout was highest during the drought years of 1984, 1987 and 1990 at most schools. The study has also revealed that temperature is not significantly related to school attendance, while rainfall had a positive significant relationship with school attendance at $p \leq 0.05$, $p \leq 0.01$ at most schools, and the extent to which rainfall significantly determined school attendance varied from 12.18 to 24.60%. The reason(s) why the relationship between rainfall and school attendance for all schools in Anka was not statistically significant is unknown and remains a matter for further research.

The consequences of decreasing rainfall for sustainable development include reduced school attendance, high rate of dropout, and setback in the education of children. Current climate scenarios predict that the driest regions of the world will become even drier, signalling a risk of persistence of drought in many arid, semi-arid and dry sub-humid areas, with greater and sustained negative impacts. The solution lies in policymakers delivering a prompt response to drought threat in terms of regularities in distribution and early arrivals of relief materials, free feeding programs and free education. The accurate prediction of anomaly years will enhance better drought planning in the study area.

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Letters

Readers are encouraged to submit letters for possible publication. Letters can be submitted either electronically through the system used for articles, by email attachment to weather@wiley.com or by post, as shown on the Contents page. The Letters Editor reserves the right to edit any letter.

The Halo Wheel

When the sun is partially hidden by clouds or other objects – distant mountains, for example – light and dark rays are sometimes seen coming out from the position of the sun. The light rays are air which is sunlit by the radiation through openings in the clouds or mountain range, and the dark rays are shaded air. The rays are called crepuscular rays and are parallel; however, due to perspective they are seen as divergent.

Sometimes, especially at low sun altitude, the rays enter the part of the sky which is opposite the sun. Due to perspective the rays will now be seen converging towards the antisolar point and are called anticrepuscular rays. If this optical phenomenon is combined with a rainbow, a so-called rainbow wheel arises, a rainbow with 'spokes'. The phenomenon is seldom seen. Some observations are reported on the internet.

An optical phenomenon related to the rainbow wheel may possibly arise in the circular 22° halo with a number of 'spokes' formed by crepuscular rays. I have tried in vain to find some observational report of this atmospheric–optical, combined phenomenon, suitably named the 'halo wheel', and I have not been lucky enough to observe it first-hand. Even if the 22° halo is normally a more common phenomenon than the rainbow – except in the Tropics, perhaps – its more discreet appearance leads it to be disregarded. A possible situation for the formation of the phenomenon may be when a layer of cirrostratus clouds belonging to an approaching warm front glides in over the observational area above which disconnected cumulus clouds have remained. The spoke system of the wheel may sometimes be strengthened by a vertical light column and a horizontal parhelic circle within the halo ring. Compared with the rainbow wheel, the halo wheel may be found at higher sun levels and thus be more wheel-like. In addition, crepuscular rays are more common and often more strongly developed than anticrepuscular rays.

Could the origin of Sun wheels in the Scandinavian rock-carvings from the Bronze Age possibly be inspired by halo observations, perhaps including the halo wheel?

Maybe it is time to start looking for, and perhaps to photograph, the halo-wheel.

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