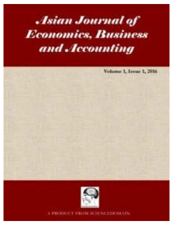

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Evaluation of Root and Tuber Crops Yield under the Changing Climatic Conditions in Kwara State, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author AAO is the general administrator of the study and corrected the designed protocol. Author ASG designed the study and wrote the protocol. Author IL wrote the proposal, supervised the data collection, wrote the first draft of the manuscript and effected all the corrections to the first draft. Author JNN cleaned the data and carried out the some analysis. Author GHMB conducted some of the data analysis. All authors read and approved the final manuscript.

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ABSTRACT

Societies which rely upon agriculture for their livelihood may face the perils of climate change, especially developing countries in the tropics and subtropics such as Nigeria in which some of the food crops are already close their peak temperature tolerance. This study was to evaluate root and tuber crops yield under the changing climatic conditions in Kwara State, located in the Guinea savannah Zone of Nigeria. Climate and crop yield data (cassava and yam) covering a period of twenty years (1995-2014) were collected from Nigerian Meteorology Agency (NIMET), Abuja and

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Kwara State Agricultural and Rural Development Office, Ilorin respectively. The data were analysed using trend analysis, Johansen's multivariate co-integration test and error correction modelling. The results show an increased in annual rainfall of about 12.42 mm/year from 1995 to 2014 with minimum temperature increasing at a faster rate compared to maximum temperature. The Augmented Dickey-Fuller test showed that climate variables were stationary at levels whiles cassava and yam yield were stationary at first differencing. The co-integration analysis and Error correction model estimates indicate that, there is at least one long-run relationship between yam yield, rainfall and temperature, whereas cassava yield, rainfall and temperature react to at least three long term equilibrium relationships. The study revealed that yam yield is affected positively by rainfall and temperature. Also, output of cassava is significantly affected by rainfall and with the expected positive sign. The study primary concludes that root and tuber crop production is climate dependent, and that the yield of yam and cassava are affected positively by rainfall and temperature.

Keywords: Climate change; root and tuber crop yield; co-integration; error correction model.

1. INTRODUCTION

Agriculture employs about 70% of the Nigeria's population at the subsistence level despite the fact that the country rely greatly on the oil industry for its budgetary revenues [1]. The country is said to be the largest producer of cassava and yam, accounting for more than 76% of Africa total output [2] with more than 90% of its been mainly used as food [3]. The crop's production is generally thought to require less labour per unit of output than other major staples and is able to grow and give reasonable yields in low fertile soils. Because it has broad uses in many industries, cassava has become an economic crop in increasing demand worldwide [4].

Today, issues of food security and crop yields feature prominently in the list of human activities [5]. Globally, the earth has over the years observed a significant increase in temperature but decreased precipitation [6]. Climate change impacts have been witnessed in several areas such as agriculture, water resources, biodiversity, and ecosystems goods and services [7,8]. Although the impact of climate change is global, for various reasons including the state of preparedness of the continent, it has been estimated that West Africa will be most vulnerable to climate change [9,10].

The issues of climate change have become very threatening, both to the sustainable development of socio-economic and agricultural activities of a nation and the totality of human existence [11]. Many countries in tropical and sub-tropical regions are expected to be more vulnerable to warming as a result of temperature increase that consequently affects marginal water balance and the agricultural sector [12]. Observations of temperature show a warming of the African continent for the last 100 years of about 0.5℃ and the rates of warming, as well as the periods of most rapid warming (1910-1930 and from 1970 upwards were similar to what can be observed globally [5]. Crop production is heavily affected by climate change through the direct impact on the biophysical factors and the physical infrastructure associated with food processing and distribution [13]. The seasonal variations in precipitation patterns and the frequency in extreme weather events may influence crop production and agricultural profitability [14-17]. Globally, the potential for food production is projected to increase in local average temperature over a range of 1-3℃, but to be decreased above this temperature. However, generally in the tropics, a change in temperature has a negative impact on food production [18].

According to International Fund for Agricultural Development [19], in Nigeria, about 70% of agricultural practices are rain fed making the sector more vulnerable to climate change. Numerous studies [20-23] have observed that climate variability and change have significant impacts on food production, particularly the common staple food crops grown in Nigeria. Many farmers in Kwara State of Nigeria rely on tuber crop production for their livelihood and food security. Moreover, with the increasing rate of extreme weather events, there is instability in tuber crops production which might leads to food insecurity. This study therefore seeks to assess how the output of cassava and yam vary with the changing climatic condition in Kwara State, Nigeria.

2. MATERIALS AND METHODS

The study was conducted in Zone C of Kwara State Agricultural Development Project (KWADP), Kwara State, which falls under the southern Guinea Savannah agro-ecological zone of Nigeria. Geotropically, Kwara state is located between latitudes 8° 05ˈ N to 10° 05 ˈ N and longitudes 2° 50 ˈ E to 6° 05ˈ E with an area of about 32,500 km^2 . The study area (Zone C) extends from latitude 8° 05ˈ N to 9° 05 ˈ N and longitudes 4° 20 ˈ E to 5° 5ˈ E, covering an area of about 4978.44 km^2.The area lies within a region described as tropical climate and are characterized by double rainfall maxima and has tropical wet and dry climate [24]. The raining season begins at the end of March and lasts until October with an annual rainfall ranges from 1000 mm to 1500 mm, while the dry season begins in early November and ends in early March. Temperature is uniformly high and ranges between 25℃ and 30℃ in the wet season throughout the season except in July – August when the clouding of the sky prevents direct insolation while in the dry season it ranges between 33℃ to 34℃. Relative humidity in the wet season is between 75 to 80% while in the dry season it is about 65% (NBS, 2009). The climate supports tall grass interspersed with short scattered trees, an attribute that influences the people to make farming their main occupation. Food crops produced are mostly maize, sorghum, yam, cassava, water yam and sweet potato which constitute the main staple food aside cereals [25].

Climatic data used in this study were daily rainfall amount (mm) and minimum and maximum temperatures (℃) covering a period of twenty years (1995-2014). These data were collected from Nigerian Meteorology Agency (NIMET) weather station, Ilorin, Kwara state. The data on cassava and yam yields were collected from the Kwara state Agricultural and Rural Development Office (KWADP), Ilorin. The values obtained were average yields of cassava and Yam in tons per hectare spanning a period of twenty years (1995-2014).

A number of steps were taken to establish the relationship between the tuber crop yield (Cassava and yam) and rainfall, temperature and length of raining season. Analytical tools used in this study include trend analysis, Co-integration, error correction model and Granger Causality techniques. The long-term annual trends of rainfall and temperature over the study period where examined by using trend line equation. Unit roots test were performed at both level and first difference to determine whether the individual input series are stationary or not. The unit root tests were performed using Augmented Dickey-Fuller (ADF) test to determine the stationarity of the data. According to [26], ADF test captures additional dynamics left out by Dickey-Fuller (DF) test and also normally provides accurate results.

When using non-stationary variables, a spurious regression is of concern. After the stationarity test, Co-integration between tuber crop yield (cassava and yam), rainfall and temperature were performed. Co-integration analysis help to determine the long run, dynamic relationship between two or more variables. The Johansen procedure was used to test for the number of co-integration vectors in the model due to its vector auto-regressive based and can also performs better in multivariate model [27]. The co-integration model was specified as follows:

$$Y_t = \alpha + \beta_1 R_f + \beta_2 T_{max} + \beta_3 T_{min} + e_t \quad (1)$$

Where: Y_t = cassava or yam yield in time; R_f = Annual rainfall (mm); T_{max} = Maximum temperature; T_{min}= Minimum temperature

If two variables are co-integrated, then their short-run dynamics can be described by Error Correction (Gujarati, 1995). The Error Correction Model (ECM) is specified as:

$$\Delta Y_t = a_0 + a_1 \Delta R_f + a_2 \Delta T_{max} + a_3 \Delta T_{min} + a_4 ECt + U_t \quad (2)$$

Where:

Y_t,R_f,T_{max} and T_{max} are previously defined; a_1,a_2 and a_3 are short-run effects; ECt is Error correction term; U_t is Stochastic Error term.

3. RESULTS AND DISCUSSION

3.1 Rainfall and Temperature Trend Analysis

The annual rainfall trend from 1995 to 2014 is shown in Fig. 1. The highest rainfall was recorded in 2014 with an amount of 1580.1 mm whereas 2001 was a year of extremely low rainfall (697.7 mm). The inter-annual rainfall variability was high from 1995 to 2002 and from 2010 to 2014, whiles from 2003 to 2009; rainfall was generally on an increased with a mean value of 1331.743 mm/yr. which was above the long term mean rainfall value (1202.39 mm/yr.). The linear trend line equation shows a slight increase [28] who found out that there was an upward trend in the mean annual rainfall amount for Ilorin from 1979 to 2008 with an R^2 value of 1.5%, 2% and 4.4% for Ilorin East, Ilorin West and Ilorin south respectively.

The results for temperature trend analysis for minimum and maximum temperature for Ilorin from 1955 to 2014 is presented in Figs. 2 and 3 respectively. The minimum temperature was between 21.1℃ (1999) to 22.3℃ (2010) with a mean value of 21.8℃. The lowest and highest annual maximum temperature were 31.6℃ (2012) and 33.3℃ (2010) respectively, whiles the mean annual maximum temperature was found to be 32.5℃. This result indicates that temperature has been increasing over the last twenty years with a noticeable warming for minimum temperature. The upward trends in temperature observed in Ilorin, Kwara State between 1995 and 2014 corroborate the findings of [29] which found out that both regional and global earth temperature trends have been on an increased over the past years.

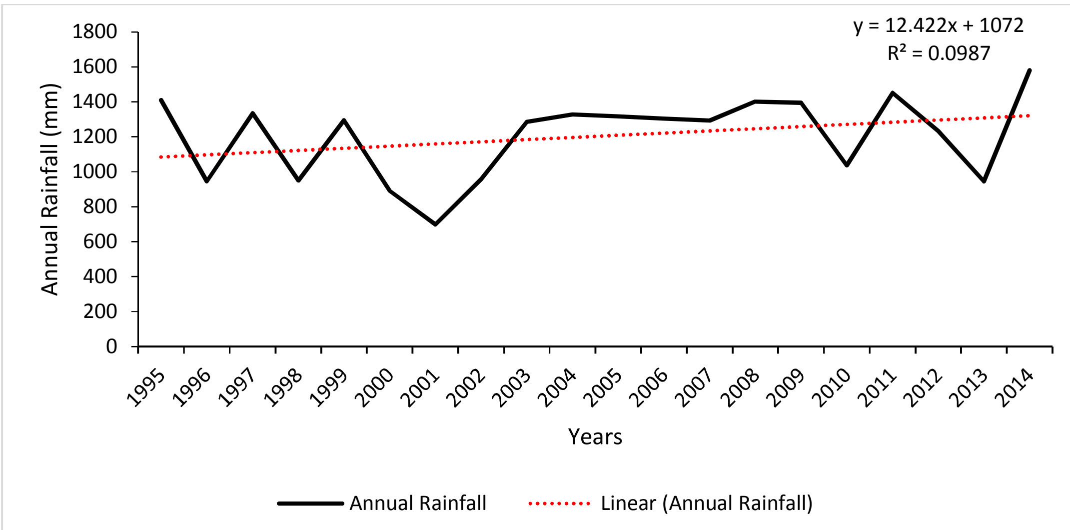

Fig. 1. Annual rainfall series and trend line for Ilorin from 1975 to 2014

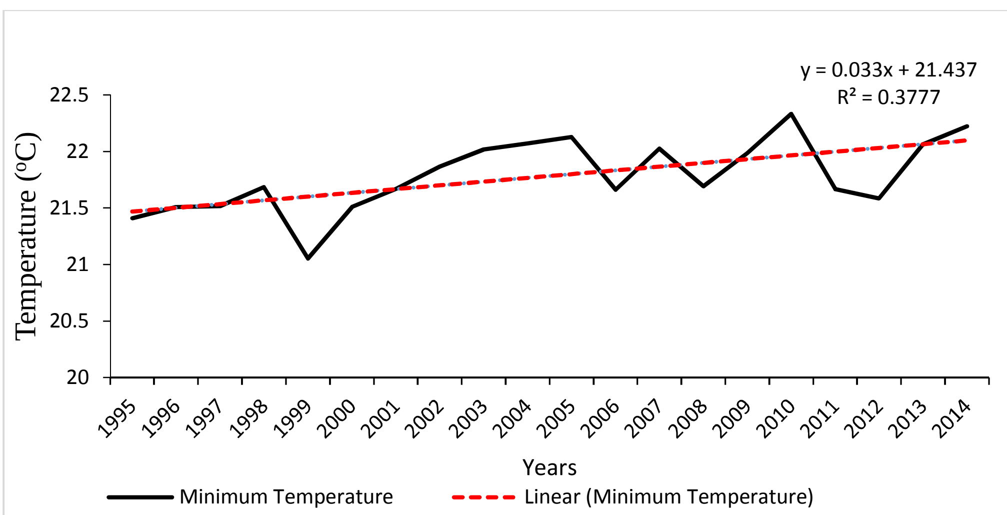

Fig. 2. Annual minimum temperature trend for Ilorin from 1995 to 2014

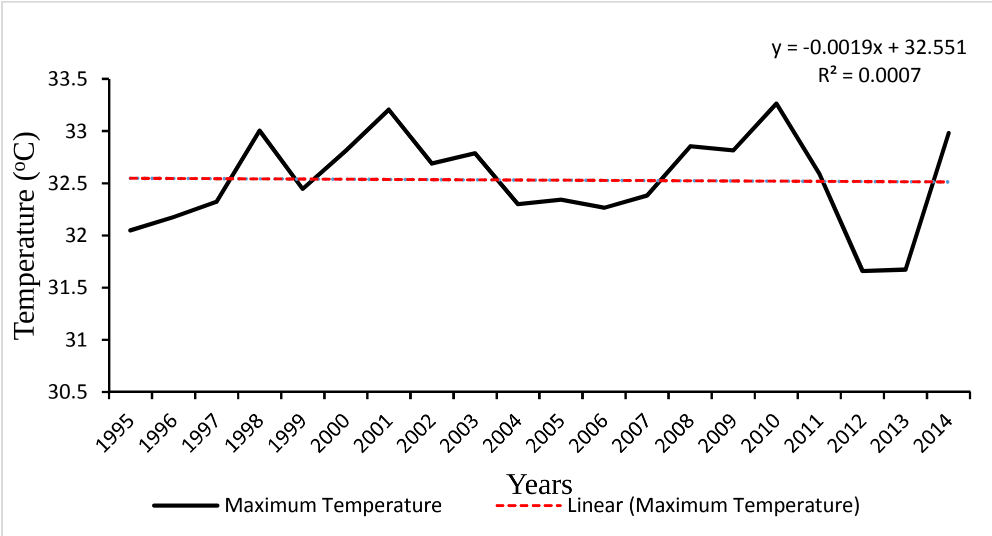

Fig. 3. Annual maximum temperature trend for Ilorin from 1995 to 2014

3.2 Trend Analysis of Tuber Crop Yield

Fig. 4 shows the pattern and Inter-annual variations in yields of cassava and yam in Ilorin from 1995 to 2014. Both yam and cassava recorded their highest yield per hectare in the year 2014. The highest yield recorded by yam was 14.63 tonnes/ha and that of cassava was 17.65 tonnes/ha. This may be due to the increase in rainfall during that year. The lowest yield for yam (10.86 tonnes/ha) was recorded in the year 2003 and the lowest yield for cassava (8.78 tonnes/ha) was recorded in the year 1997. There was inter annual variation in both yam and cassava yields from 1991 to 2002. The trend in yam yields then increased gradually from 2003 to 2014. Cassava recorded a sharp increase in yield from 2005 to 2008 and then a linear trend increased from 2009 to 2014.

3.3 Empirical Results of Augmented Dickey-Fuller and Co-integration Tests

The unit root tests, with intercept only, were applied to the study's four time series (rainfall, minimum and maximum temperature, cassava and yam yields). The empirical results of ADF tests are reported in Table 1. The results showed that all the variables exhibited a unit root at except the maximum temperature which was stationary at levels, hence the null hypothesis were not rejected for those variables. The test was then applied to the first differentiated variables with results indicating the rejection of the null hypothesis at all cases. Thus, rainfall, minimum temperature, cassava and yam yields are integrated in order one, I (1).

Given that the climate variables and crop yield are integrated of the same order one, a co-integration test was then performed. Before performing the Johansen test of co-integration, the lag number for the model was determined. Based on the LI selection criteria, lag number 2 was used for the co-integration test. The Johansen co-integration results which indicate the number of co-integrating vectors among yam yield, rainfall, minimum and maximum temperature are presented in Table 2. The trace statistics indicates the rejection of null hypothesis at r =1, hence, the existence of one co-integrating equation between the variables, whiles the maximum eigenvalue test also indicates the rejection of the null hypothesis at r =0. The results from both tests therefore indicate that, there exist a long run relationship between yam, rainfall and minimum and maximum temperature.

The results of Co-integration test for cassava, rainfall, minimum and maximum temperature is presented in Table 3. The trace and maximum eigenvalue tests were used to determine the number of co-integrated vectors. Both test indicated the existence of long run relationship between the variables. The trace statistics indicates the existence of three co-integration equations between the variables at 5% significant level. The findings therefore indicate the existence of a long run relationship between cassava yield, rainfall, minimum and maximum temperature.

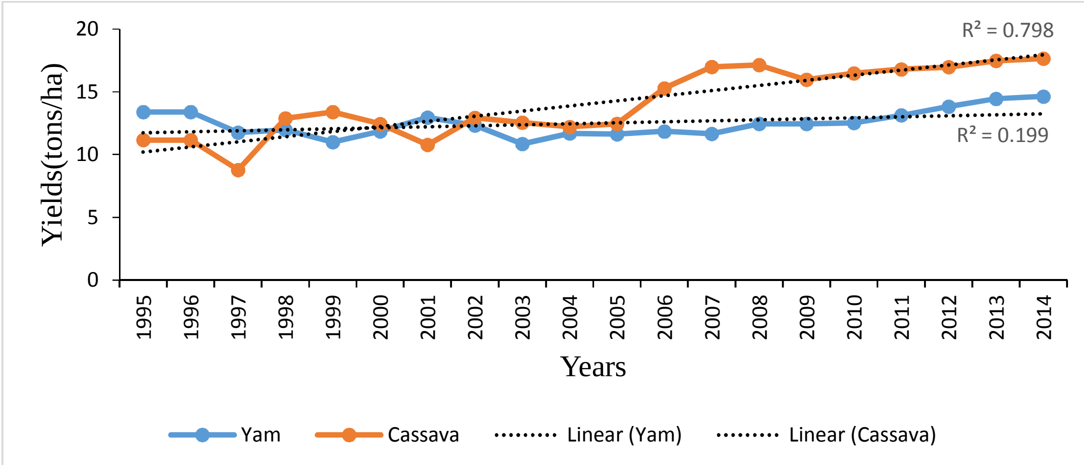

Fig. 4. Annual variation in the yield of yam and cassava in Ilorin (1995 to 2014)

Table 1. Results of unit root test (Augmented Dickey-Fuller) from 1995 to 2014

Variable	Levels	1st difference	Order
Annual rainfall	-2.102	-4.208**	I(1)
Minimum temperature	-1.933	-4.169**	I(1)
Maximum temperature	-3.649**	-3.284**	I(0)
Yam yield	-1.976	-4.131**	I(1)
Cassava yield	-3.239	-4.780**	I(1)

*Critical value: 5% = -3.000, **Represents significant at 5% level*

Table 2. Johansen co-integration test results

Rank (r)	Trace			Maximum eigenvalue	
	Eigenvalue	Statistics	5% critical value	Statistics	5% value
0	---------	58.4590**	47.21	27.5666**	27.07
1	0.80241	30.8924**	29.68	16.9445	20.97
2	0.63092	13.9479	15.41	10.4127	14.07
3	0.45801	3.53.2	3.76	3.5352	3.76
4	0.18776	....	……..	………	……

*r indicates the number of co-integrating relationship, ** indicates rejection at the 95% critical values, model type: A model with unrestricted constant*

Table 3. Johansen co-integration test results

Rank (r)	Trace			Maximum eigenvalue	
	Eigenvalue	Statistics	5% critical value	Statistics	5% value
0	--------	105.1035**	47.21	62.6871**	27.07
1	0.97496	42.4163**	29.68	25.7346**	20.97
2	0.77993	16.6817**	15.41	12.2979	14.07
3	0.51490	4.3839**	3.76	4.3839	3.76
4	0.22731	....	……..	………	……

*r indicates the number of co-integrating relationship, ** indicates rejection at the 95% critical values, model type: A model with unrestricted constant*

Since the variables are co-integrated, Error Correction Model (ECM) was performed for each co-integrating vector. The results for ECM for yam are presented in Table 4. The results indicate that yam yield is affected positively by rainfall and minimum and maximum temperature.

Table 4. Error correction model estimates for yam

Variable	Coefficient	Standard error	z-Statistics	Probability
Rainfall	0.0002325	0.0008291	0.28	0.779
Minimum temperature	1.499247**	0.6468595	2.32	0.020
Maximum temperature	0.988787**	0.4085495	2.42	0.016
ECt	-0.3822151	0.1126588	-3.31	0.001
Constant	0.1645479	0.1918406	0.86	0.391
R^2= 0.67; Prob (Lagrange multiplier test) = 0.1119 Prob (Jarque Bera test) = 0.70525				

*ECt denotes Error correction term; ** denotes significant at 5% level*

Table 5. Error correction model estimates for cassava

Variable	Coefficient	Standard error	z-Statistics	Probability
Rainfall	0.002967**	0.00142	2.09	0.037
Min. temperature	2.572355	1.43805	1.79	0.074
Max. temperature	0.829539	0.97434	0.85	0.395
ECt	-1.884992	0.41045	-4.59	0.000
Constant	-0.000135	0.34926	-0.01	1.000
R^2= 0.81; Prob (Lagrange multiplier test) = 0.8834 Prob(Jarque Bera test) = 0.7967				

*ECt denotes Error correction term; ** denotes significant at 5% level*

The coefficient of rainfall (0.0002325) indicates a positive relationship between rainfall and yam yield. This means that an increase in rainfall during the growth period of yam tends to stimulate an increase in yam yield, whereas a reduction in rainfall will decrease yam yield in that particular year. The positive coefficient of minimum temperature (1.499247) and maximum temperature (0.988787), significant at 5% level indicates that, a change in these variables turn to change the yield of yam. The R^2 value of indicates that about 67% of variation in the yield of yam is explained by the combined effects of rainfall, minimum and maximum temperature. The coefficient on the error correction term (ECt) which measures adjustments towards long-run equilibrium has the expected sign and was significant at 5% level. The Lagrange multiplier test with a probability value of 0.1119 indicates no serial auto correlation between the variables and the residual were also normally distributed for all variables as indicated by Jarque Bera test with a probability value of 0.70525. The result of the diagnostic test therefore indicates that the model is accepted.

The results of error correction model for that of cassava are presented in Table 5. The results showed a positive relationship between rainfall (0.0029677) and cassava, significant at 5% level indicating that an increase in rainfall increases cassava yield in that particular year. The coefficient of minimum and maximum temperature indicates a positive relationship between cassava yield and temperature but not significant. The coefficient of determination (R^2) of cassava is 0.81, indicating that the independent variables explain 81% of the variations in the cassava yield. Both Lagrange multiplier test and Jarque Bera test were also performed as diagnostic check to verify the model and the results indicates that there was no autocorrelation and the residuals are also normally distributed at 5% level. This result agrees with earlier studies [21,30] conducted in different parts of Nigeria, which found out that rainfall amount and temperature are positively related with the yield of cassava.

4. CONCLUSION

This study concludes that there is an increasing in temperature trend in Ilorin from 1995 to 2015 with minimum temperature increasing at a faster rate compared to maximum temperature. Rainfall on the other hand has been observed to be of an increased but with higher inter annual variability within some years. During the period of 1995 to 2015, yam yield is affected positively by rainfall and temperature clearly suggests the large dependence of cassava and yam production on climate in Kwara state, Nigeria. The meteorological stations and Kwara State Agricultural Development Project (KWADP) agents should assist farmers in monitoring the current climate condition and provision of improved crop varieties and other adaptation measures to increase productivity.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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