

# Analysis of Migration Trends in Zimbabwe Using Mann-Kendall and Sen's Slope Tests

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**Abstract:** The movement of people into and out of the Zimbabwean borders has become a topical issue in every sector of the country. The main devastating movement is when a lot of skilled professionals leave the country to other countries in search of greener pastures without ploughing back home and left the country of origin with few or no skilled personnel to drive the economy forward. Zimbabwe is one of the developing countries that have suffered the “brain drain” for the past decades and currently there seem no solution to stop this emigration. There is no equal balance between immigrants and emigrants. In this paper, we investigate the trend analysis of Zimbabwe migration using Mann-Kendall and Sen's Slope test. We find Mann-Kendall Test imperative in the analysis of trends of migration since it most requires data which is not normally distributed and data which contains extreme values which are difficult to handle using parametric test. Firstly, we investigate the direction of the trend and then its magnitude in terms of slope. Results show that there is a significant increase in the number of migrants going out of Zimbabwe to other countries over past two decades. This is indicated by high positive magnitudes in trend or the Sen's estimator. On the other hand, there is insignificant trend of inflows from other countries into Zimbabwe over a decade from February to December, except in every January.

**Keywords:** Migration, Mann-Kendall, Trend Analysis, Sen's Slope

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## 1. Introduction

This paper develops a methodology for trend analysis of migration in Zimbabwe. Trend analysis helps to identify the net migration status not in exact figures but a close intuitive of things on the ground. Generally, our aim is to investigate the nature of migration values to determine if they increase or decrease over time. Statistically, we wish to determine the probability distribution in which migration values evolve over time. That is, describing the rate of change with respect to the change in the central tendency value of the distribution. We also discuss the magnitude of the gradient of the trend line as well as the nature and direction of it (if significant). The elementary principle of migration research has been focusing on the notion that areas differ in their

attractiveness to possible migrants. Vincent and Macleod [22] identified three extensive sets of causal variables underlying spatial choices to migrate namely; demographic variables, socio-economic variables and geographic variables. People migration in Zimbabwe is characterised by a number issues such as; tourist attraction centers, the status of the economy and the political ambiguity. It has been an area of concern to the Zimbabwean government for a decade now that its skilled workers are warmly accepted in the neighbouring countries such as South Africa, Zambia, Namibia, Botswana and Mozambique [15].

A person is being trained for at least two years but after he or she has finished training choose to work in another country, abandoning his/her own country. Human capital is expensive to acquire through training and it is known that skilled human labour is very vital for economic growth.

Hence there is need to protect such precious resources in the country. Due to economic and political instability in Zimbabwe, there are uncertain raising fears that what happened in the 1960s, 1970s and the era of 2005-2008 would haunt the country again. There was exodus of skilled personnel from the country looking for "greener pastures" elsewhere outside the borders, this is called "brain drain" [15]. Brain drain usually occurs when the country of origin has nothing or less to offer as remuneration to match expectations and standards of skilled workforce [21]. Recently the government of Zimbabwe advocated for returning skilled workers from abroad through different initiatives such as raising salaries of civil service to match regional counterparts, offer incentives to those investors who would invest in foreign currency, availing inputs to agriculture at very low interest rates, economic and political reforms, STEM promotions and others. Due to inconsistency of Zimbabwe government policies in economic and political arenas, it becomes difficult to attract anyone from overseas and regional circles. Therefore, there was a floppy in the initiatives. The education and health sectors were not spared from the draconian maneuver and were the worst hit to the extent of deploying the army to teach and mark examination scripts of both 'O' and 'A'-levels [21].

Due to economic hardships, most women and men have resorted to earn a living through trading; cross borders have increased drastically by means of the *malaicha* (transporters). The cross borders spend a day or so in the neighbouring country ordering stocks for resale back home. Immigrants we receive nowadays are mainly university students coming on vacation and tourists in areas such as Victoria Falls, Inyanga mountains, Chinhoyi caves and Great Zimbabwe ruins. Zimbabwe has lost its glamour for the past decades due to economic and political factors; and very few migrants are attracted specially to work and do business formally in the country [21]. A Zimbabwean survey was conducted and 900 skilled workers were participants. Findings were that, 57% of the sample were geared to move outside the country, while 29% had to go back home and give it a thought and only 13% were undecided about the issue (inconclusive) [21]. It was also reported in the survey that participants registered high levels of displeasure with the basic human needs such as salaries, clothing, food, education, medical services and shelter among other things like cost of living, taxation, sanitary protection and future of the children. Most Zimbabweans have always had zeal to emigrate from their country seeking for greener pastures and some as political refugees. Tevera and Crush [21] argued that about 62% of women in Zimbabwe wants to migrate to other surrounding countries, the percentage is slightly higher than men. Again, in the survey it was noted that the most age group with the passion to emigrate is the age of 25-35.

A plethora of researchers of migration have examined a wide range of migration theme such as; undocumented migration, the dimensions of migration, the "brain drain", return migration, diaspora engagement, abuse of "migrants"

human rights and migrant identities [2, 7]. Analysis of migration in Zimbabwe is very complex as it involves dynamic and diverse variables. Due to this complexity, this paper wishes to explore the trend analysis of Zimbabwe migration using Mann-Kendall and Sen's Slope test. The major drivers of Zimbabwe migration are still sketch to most researchers while the bottom reason pin point to food insecurity, job insecurity and health issues [3-6].

## 2. Material and Methods

### 2.1. Data Collection

Data for this study is monthly which spans from year 2001 to 2017 June. This paper mainly focuses on two variables (time series) i.e the Total arrivals into Zimbabwe (summing up the number of immigrants, visitors from abroad and residents returning from abroad) and Total departures from Zimbabwe (summing up the number of emigrants, departing visitors and residents visiting abroad). We collected primary data from our national border posts and international airports particularly, Beitbridge border post, Chirundu border post, Nyamapanda border post, Victoria Falls border post, Plumtree border post, Mutare border post and Harare International Airport which is now Robert Mugabe International Airport through interviews and questionnaires. Most of secondary data were obtained from Zimbabwe National Statistics Agency (ZIMSTAT) and validation of our results was done at different borders and airports. Due to many missing monthly data on some of the time series, we have resorted to concentrate much on totals as a stop gage measure and we believe there is no much loss of generality especially to our conclusions.

### 2.2. Trend Detection

We applied Mann-Kendall test to detect the existence of trend in the time series. Mann-Kendall Trend test is a rank-based non-parametric technique for investigating the existence of trends in time series data. The algorithm was originally derived by [13] and [10]. According to Drapela and Drapelova [8], data points in a time series are ranked according to time, each data point is sequentially treated as a reference point and then comparison is made to all following data points. We prefer non-parametric test in this study to parametric test because it has an advantage that it does not require prior determination of the underlying probability distribution of the random variable and also the method is not affected by outliers. In fact, it does not require the data to be normally distributed [8, 9, 24]. Since the test statistic works based on the sign difference rather than on the magnitude of the data itself, it is less affected by the outlier of the data [16]. We find Mann-Kendall Test imperative in the analysis of trends of migration since it most suit data which is not normally distributed and contains extreme values which are difficult to handle using parametric test (parameter estimation may be distorted). We have noted that migration data have the above mentioned attributes mainly due to unforeseen

events such as natural hazards, famine and political quagmire.

The Mann-Kendall test possesses two important parameters used to detect the existence of trend in data. The first parameter is the significance level that shows the strength of the trend. Secondly, the slope magnitude estimate that indicates both the direction and the magnitude of the trend. We wish to test null hypothesis  $H_0$  of no trend, against the alternative hypothesis  $H_1$  of monotonic increasing or decreasing trend. The data points in the time series are ordered and individual data point is compared with all successive points. Let  $S$  be a statistic such that if a data point from a future time period is higher than a data point from a prior time period, a one will be added to it. Otherwise, a one will be subtracted from  $S$  [1, 8, 20, 24]. The M-K test statistic  $S$  is presented as:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{sgn}(\xi_j - \xi_k) \quad (1)$$

and

$$\text{sgn}(\xi_j - \xi_k) = \begin{cases} +1 & \text{if } \xi_j - \xi_k > 0 \\ 0 & \text{if } \xi_j - \xi_k = 0 \\ -1 & \text{if } \xi_j - \xi_k < 0 \end{cases} \quad (2)$$

Where  $\xi_j$  and  $\xi_k$  are monthly values in months  $j$  and  $k$ ,  $j > k$ .

A positive  $S$  shows a monotonic upward trend whereas negative value of  $S$  shows a monotonic downward trend [11, 18]. The distribution has mean  $E(S) = 0$  and variance  $\sigma^2$  given as:

$$\sigma^2 = \{n(n-1)(2n+5) - \sum_{j=1}^p t_j(t_j-1)(2t_j+5)\} \frac{1}{18} \quad (3)$$

where  $p$  is the number of the tied groups in the data set and  $t_j$  is the number of data values in the  $j^{\text{th}}$  tied group. The statistic  $S$  is roughly normal distributed provided that the Z-transform is employed:

$$Z_c = \begin{cases} \frac{S-1}{\sigma} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sigma} & \text{if } S < 0 \end{cases} \quad (4)$$

Where  $Z_c \sim N(0,1)$ . A positive value of  $Z_c$  indicates an upward trend whereas its negative value indicates a downward trend. Alternatively, the trend is considered significant if  $Z_c$  appears greater than  $Z_{\alpha/2}$  where  $\alpha$  represents the significance level [1, 14, 17].

### 2.3. Magnitude of Trend

The Sen's slope test was used to estimate the magnitude of trend in time series data. This test was developed by Sen in 1968 [19]. It is used to predict the magnitude of the trend, sometimes called the Sen's estimator. A set of linear slopes is computed as: follows:

$$d_k = \frac{x_j - x_i}{j - i}, \quad k = 1, 2, \dots, n; \quad 1 \leq i < j \leq n \quad (5)$$

where  $d$  is the slope at time  $k$ ,  $X$  are data points at time  $i$  and  $j$ ,  $n$  is the number of data points. Sen's slope is then computed as the median from all slopes:  $b = \text{Median } d_k$ . The intercepts are computed for each time step  $t$  as:

$$a_t = X_t - b * t \quad (6)$$

and the corresponding intercept is also the median of all the intercepts. The upper and lower limits of the confidence interval of the Sen's slope are also calculated by this function [14, 17, 19]. The positive Sen's slope estimate shows an upward increasing trend, while a negative estimate indicates a downward decreasing trend [23]. Furthermore, the value of Sen's slope estimate shows also the magnitude of the trend, either increasing or decreasing.

## 3. Results and Discussions

### 3.1. Total Arrivals

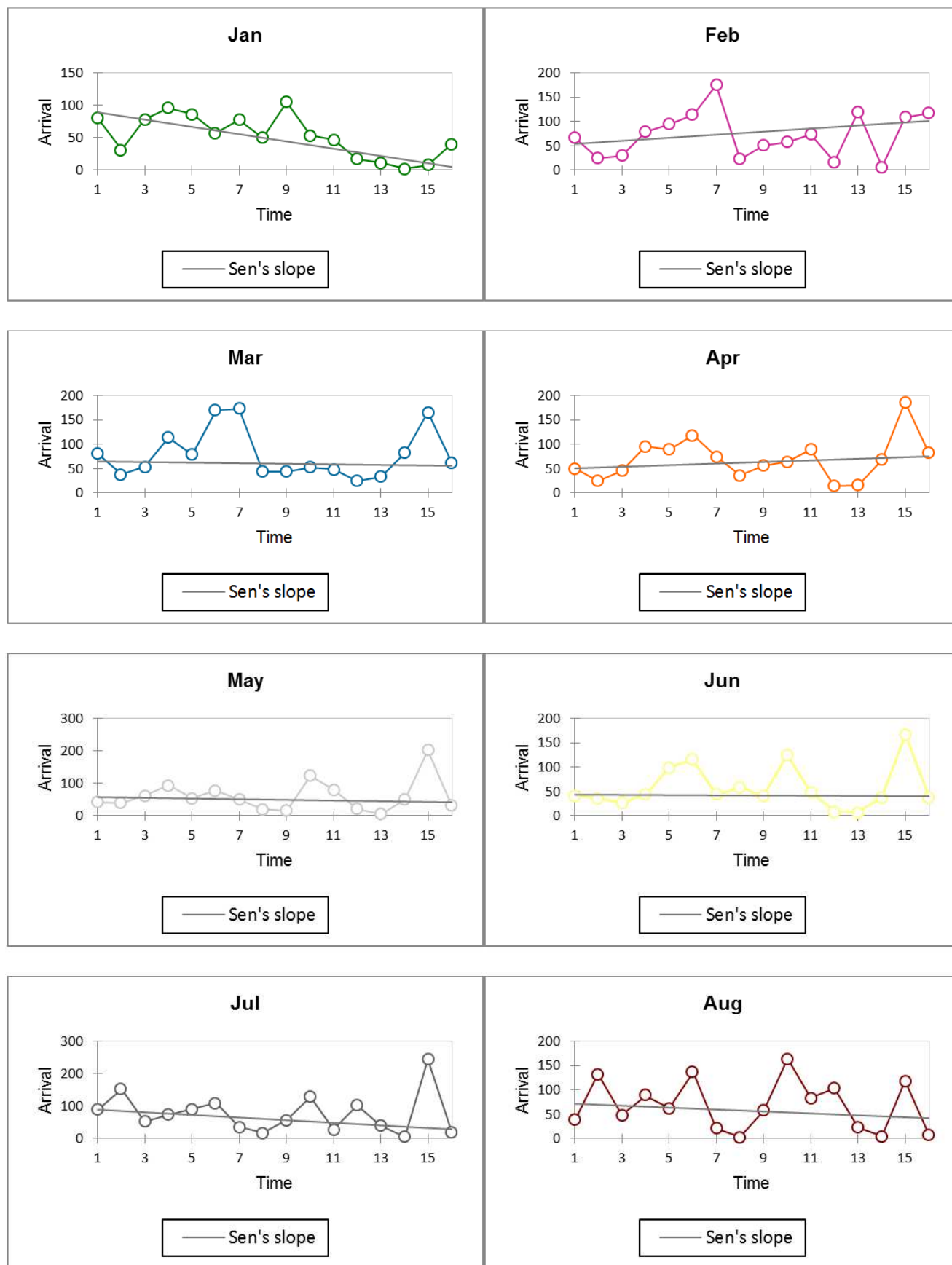
We analysed data to investigate the presence of trend in each month from year 2001 to year 2017 e.g. January 2001 to January 2017, February 2001 to February 2017 and so on. There is an insignificant increase or decrease in the number of migrants coming to Zimbabwe especially from February to December. Only January has a significant decrease in total arrivals, indicated by a significant decreasing monotonic trend of magnitude -5.664, see Table 1 and a  $p$ -value less than the significant value ( $\alpha = 0.05$ ). Our analysis shows that there is no statistically significant trend of total arrivals from February to December for the period 2001 to 2017, rather there is an insignificant upward trend in February and April, with the remaining months experiencing insignificant downward trend (Kendall's tau and Sen's slope in Table 1; Figure 1). This indication is emphasised by the Sen's slope estimates which are considerably very low. Time series (months) with statistically significant trends are indicated by two stars (\*\*), conversely months with no significant trends are indicated by (NS) (Table 1).

Table 1. Summary of M-K and Sen's slope test results for Total arrivals.

Series\Test	Kendall's tau	p-value	Sen's slope
Var1	1,000	< 0,0001	1,000
Jan **	-0,533	0,005	-5,664
Feb (NS)	0,117	0,558	3,161
Mar (NS)	-0,059	0,787	-0,477
Apr (NS)	0,092	0,652	1,667
May (NS)	-0,059	0,787	-0,924
Jun (NS)	-0,017	0,964	-0,216
Jul (NS)	-0,200	0,300	-4,146
Aug (NS)	-0,100	0,620	-1,978
Sep (NS)	-0,133	0,499	-2,862
Oct (NS)	-0,151	0,443	-2,764
Nov (NS)	-0,209	0,279	-3,063
Dec (NS)	-0,250	0,192	-3,258

We suggest that Zimbabwe's economic hardships and political instability have a positive contribution to low turn up of migrants into the country. Our results in Table 1 and Figure 1 are also confirmed in [12], that there is insignificant increase

in the number of migrants in the country for a decade due to some economic and political factors.



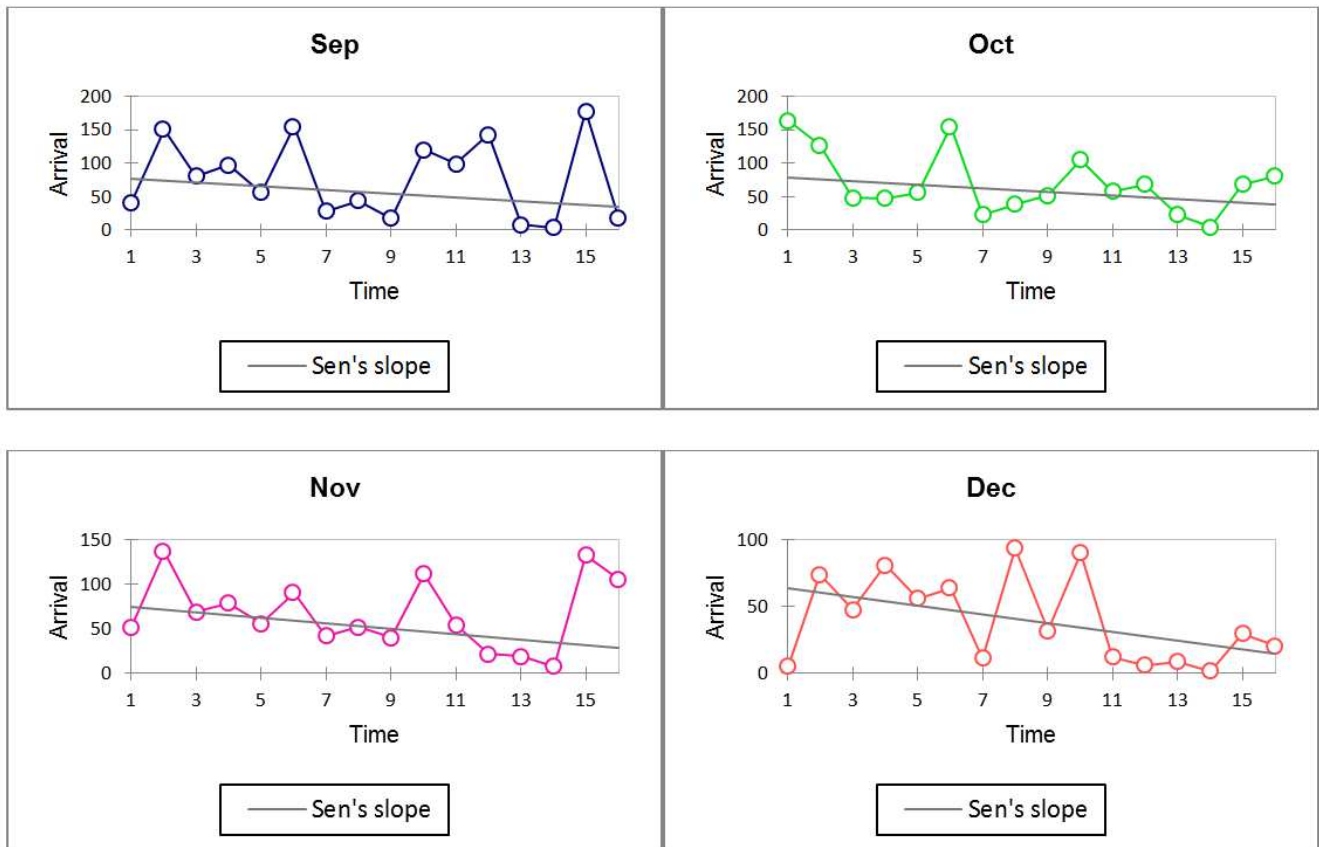


Figure 1. Trend analysis of Total arrivals depicting Sen's slope.

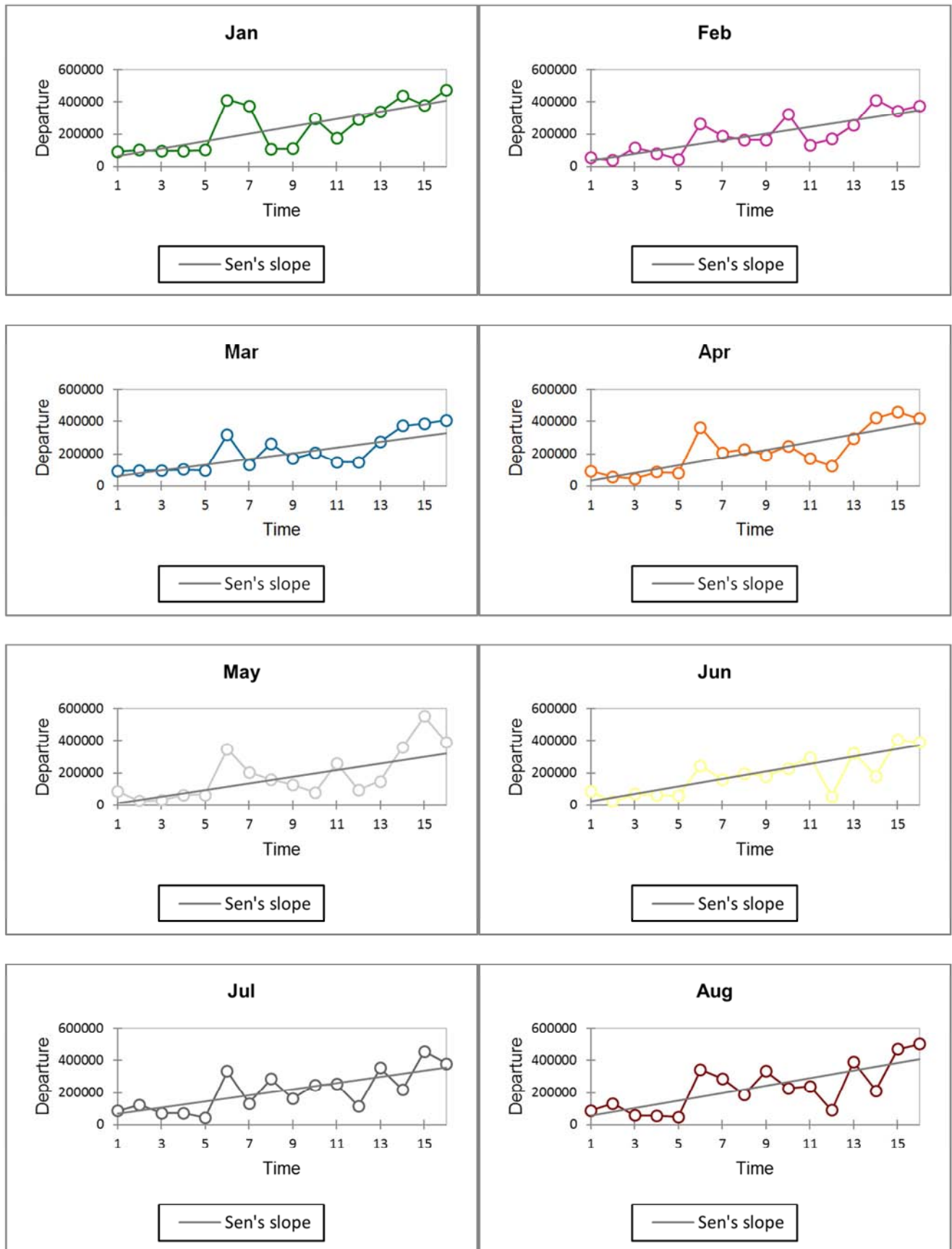
### 3.2. Total Departures / Exit Migrants

Total departures comprise of residents visiting abroad, emigrants and departing visitors. Generally, our main focus is on migrants who cross the Zimbabwean boarder to other countries, regional or international. The results (Table 2) point out that there is an influx of migrants going out of the country either for a short visit or long visits or seeking permanent residence in other countries. There is increasing monotonic trends in all of the months from January to December, with October and December registering the highest as indicated by highest magnitudes (Sen's slope) of more than 24 000 (Table 2; Figure 2). The p-values are less

than the significance level ( $\alpha = 0.05$ ) in all the time series (months). In this regard  $H_0$  (no trend) is rejected in favour of the alternative hypothesis. All time series with two stars (\*\*) (Table 2) have significant monotonic trends. The population of able bodied mainly skilled and unskilled men and women are leaving the country for greener pastures in other countries. We could have shown that 20-30 and 31-40 age groups are the most affected and are leaving the country through some graphical representation but due to limited data we just make assumptions in this paper. Anyway, graphs in Figure 2 are unequivocally presenting multitudes of Zimbabweans migrating to other countries any time of the month mainly South Africa.

Table 2. Summary of M-K and Sen's slope test for Total departures.

Series/Test	Kendall's tau	p-value	Sen's slope
Var1	1,000	< 0,0001	1,000
Jan **	0,667	0,000	22802,056
Feb **	0,617	0,001	20725,036
Mar **	0,700	0,000	17980,538
Apr **	0,567	0,003	23988,938
May **	0,567	0,003	20465,111
Jun **	0,533	0,005	23108,625
Jul **	0,517	0,006	19055,522
Aug **	0,467	0,013	23409,159
Sep **	0,483	0,010	14186,313
Oct **	0,683	0,000	24581,042
Nov **	0,467	0,013	17337,083
Dec **	0,583	0,002	35702,893





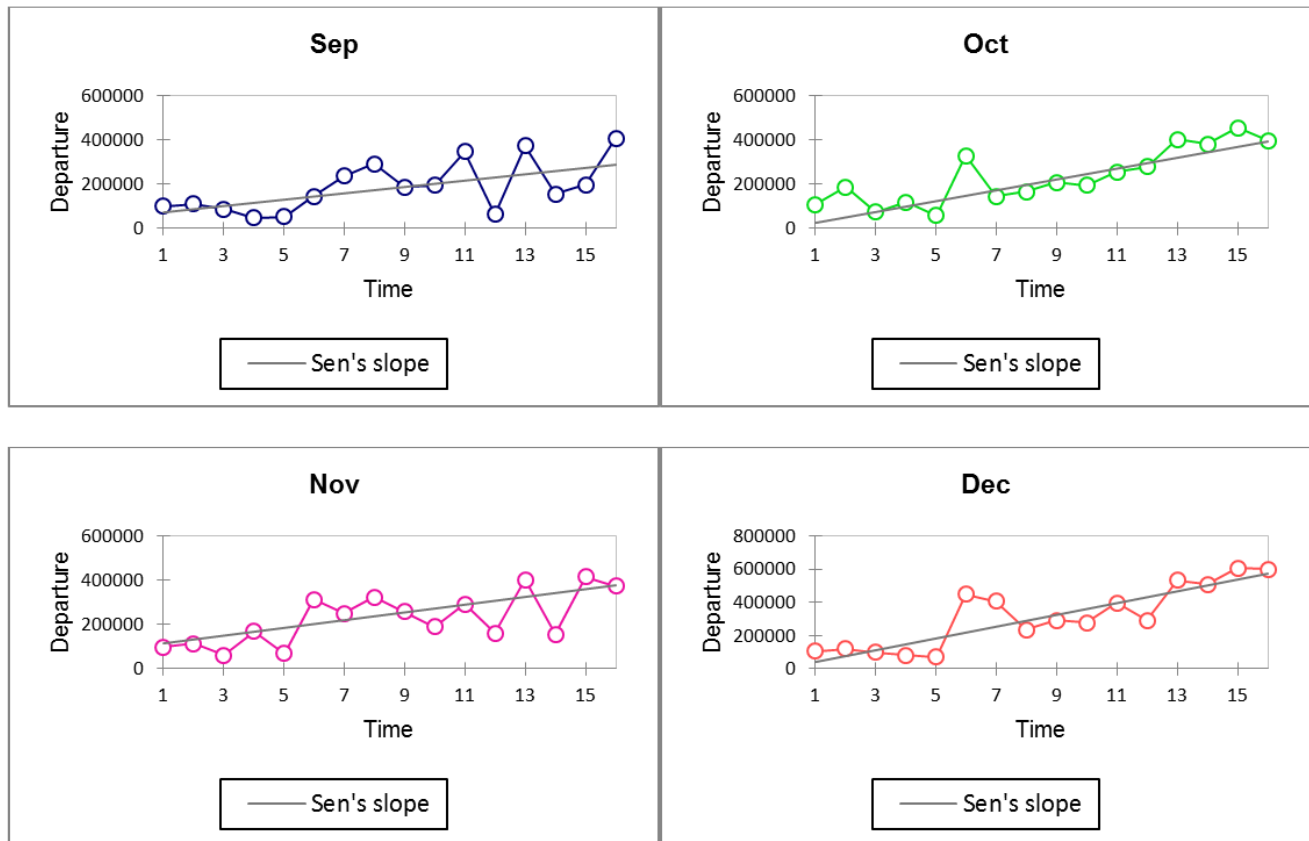


Figure 2. Trend analysis of Total arrivals depicting Sen's slope.

## 4. Conclusion

Migration in Zimbabwe has characterised the instability of the economy and political ambiguity. More people are migrating out of the country than we receive immigrants and visitors. The trend analysis on migration performed and displayed in this paper show that we have a monotonic decreasing trend in migrants coming in through Zimbabwean borders and international airports and a monotonic increasing trend in migrants going out of the country. What it means in plain senses is that Zimbabwe is no longer attracting more visitors and emigrants from abroad due to unprecedented events and systems beyond its capacities. On another hand, more migrants are moving out of the country for undisclosed reasons in this paper than yester years. In general, we are losing more able-bodied (skilled workers) to other countries each month and year than we used to previously. Coercive measures by the government to return skilled labour could not work and the best way to curb the high rates of skilled labour migration lies in addressing the economic fundamentals of the country which will ultimately improve living standards.

## References

- [1] Blain, G. C. (2013). The Mann-Kendall test: the need to consider the interaction between serial correlation and trend. *Acta Scientiarum. Agronomy*, 35 (4), pp. 393-402.
- [2] Bloch, A. (2006). Emigration from Zimbabwe: Migrant Perspectives *Social Policy & Administration* 40 (1): 67-87.
- [3] Chikanda, A. (2004). The emigration potential of skilled Zimbabwean: Perceptions, current migration patterns, trends and policy responses. Unpublished Master's thesis, University of Zimbabwe.
- [4] Chikanda, A. (2007). Skilled Health Professionals' Migration and Its Impact on Health Delivery in Zimbabwe, *Journal of Ethnic and Migration Studies* 32 (4): 667-80.
- [5] Chikanda, A. (2008). The Migration of Health Professionals from Zimbabwe, In J. Connell (ed) *The International Migration of Health Workers*, (New York and London: Routledge), pp. 110-28.
- [6] Chikanda, A. (2011). The Engagement of the Zimbabwean Medical Diaspora, *SAMP Policy Series No. 55*, Cape Town.
- [7] Crush, J., & Tawodzera, G. (2016). Migration and Food Security: Zimbabwean Migrants in Urban South Africa. *AFSUN Food Security Series*, (23).
- [8] Drápel, K., and Drápelová, I. (2011). Application of Mann-Kendall test and the Sen's slope estimates for trend detection in deposition data from Bílý Kříž (Beskydy Mts., the Czech Republic) 1997–2010. *Beskydy*, 4 (2): 133–146.
- [9] Gavrilov, M. B., Tošić, I., Marković, S. B., Unkašević, M., Petrović, P. (2016). Analysis of annual and seasonal temperature trends using the Mann-Kendall test in Vojvodina, Serbia, *Quarterly Journal of the Hungarian Meteorological Service*, 120 (2), pp. 183–198.

- [10] Kendall, M. G., (1975). Rank correlation methods. Charles Griffin, London.
- [11] Luo, Y., Liu, S., Fu, S. F., Liu, J., Wang, G., Zhou, G. (2008). Trends of precipitation in Beijiang River Basin, Guangdong Province, China. *Hydrological Processes*, 22: 2377–2386.
- [12] Makoni, T., Murwendo, T. D., Mawonike, R., Chipumuro, M. (2019). Modelling and forecasting Zimbabwe's immigrants using SARIMA models. *African Journal of Hospitality, Tourism and Leisure*, Volume 8 (1), pp. 1-8.
- [13] Mann, H. B., (1945). Nonparametric tests against trend. *Econometrica* 13, 245–259.
- [14] Mondal, A., Kundu, S., Mukhopadhyay, A. (2012). Rainfall trend analysis by mann-Kendall test: a case study of North-Eastern part of Cuttack District, Orissa. *International Journal of Geology, Earth and Environmental Sciences* ISSN: 2277-2081.
- [15] OECD (2004). Trends In International Migration: Sopemi 2003 Edition – ISBN 92-64-01944-8.
- [16] Onoz, B. and Bayazit, M., (2003). The Power of Statistical Tests for Trend Detection. *Turkish J. Engineer. Environ. Sci.* 27, 247–251.
- [17] Pohlert, T. (2018). Non-Parametric Trend Tests and Change-Point Detection. Accessed online on the website: <http://creativecommons.org/licenses/by-nd/4.0/>
- [18] Salmi, T., Maata, A., Antilla, P., Ruoho-Airola, T., Amnell, T. (2002). Detecting trends of annual values of atmospheric pollutants by the Mann–Kendall test and Sen's slope estimates – the Excel template application Makesens. Finnish Meteorological Institute, Helsinki, Finland, 35 pp.
- [19] Sen, P. K. (1968). Estimates of the regression coefficient based on Kendall's tau. *Journal of the American Statistical Association*, 63: 1379–1389.
- [20] Shahid, S. (2011). Trends in extreme rainfall events of Bangladesh. *Theoretical and Applied Climatology*, 104: 489–499.
- [21] Tevera, D. S., and Crush, J. (2003). The new brain drain from Zimbabwe. Southern African Migration Project (SAMP).
- [22] Vincent, C., and Macleod, B (1974). An application of Network theory to migration analysis. *Canadian studies in Population*, Vol 1, pp. 43-59.
- [23] Xu, Z., Liu, Z., Fu, G., Chen, Y. (2010). Trends of major hydro climatic variables in the Tarim River basin during the past 50 years. *J Arid Environ*, 74 (2): 256–267.
- [24] Yadav, R., Tripathi, S. K., Pranuthi, G., Dubey, S. K (2014). Trend analysis by Mann-Kendall test for precipitation and temperature for thirteen districts of Uttarakhand, 164 Trend analysis for precipitation and temperature in Uttarakhand. *Journal of Agrometeorology* 16 (2): 164-171.