Impact of Climate Change on Rainfall Erosivity in Nigeria

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ORIGINAL RESEARCH

Abstract— Nigeria, like many other countries, is vulnerable to the effects of climate change. This study investigated the effects of climate change on rainfall erosivity in Nigeria. Changes in rainfall patterns, such as increased intensity or duration, can significantly affect erosivity. In this study, rainfall data spanning a period of 62 years, obtained from the website archive of the Climate Research Unit-Time Series v4.3 (CRU-TS v4.3) from the University of East Anglia, United Kingdom, were used to compute rainfall erosivity indices for 46 selected stations in Nigeria, across five agroecological zones of Nigeria. The processed rainfall data for the selected locations were used to develop rainfall erosivity map for Nigeria. The erosivity map developed was compared with the one produced in 2005. Values of rainfall erosivity indices ranged from 30.92 (indicating low erosion risk) in Benin City to 85.81 (signifying very severe erosion risk) in Potiskum. Notably, the Southwest agroecological zone, previously categorized as having low erosion risk, has now transitioned to moderate erosion risk zone. Meanwhile, the Southeast and Central agroecological zones persist in the moderate erosion risk category, while the Northwest and Northeast agroecological zones are predominantly classified as severe erosion risk zones. Findings of this study can improve understanding of the threats posed by climate change to Nigerian soils. This information will help in developing strategies to mitigate soil erosion and ensure sustainable land management practices.

Keywords—Agroecological zone, Climate change, Fournier index, Rainfall erosivity, Soil erosion.

1 INTRODUCTION

Climate change, a variation in climate patterns, such as long-term shift in temperatures and weather patterns that continue to occur for a long time, usually decades or more (Dash & Maity, 2023) is a widespread and impactful global phenomenon, manifests in various ways across the planet. One significant consequence of climate change is the observable trend of heightened precipitation patterns within a warmer climate (Obiora-Okeke et al., 2021). This increase in rainfall, influenced by rising global temperatures, subsequently amplifies the erosive potential of rainfall, a phenomenon known as rainfall erosivity. Thus, the interplay between climate change and increased precipitation contributes to the exacerbation of soil erosion processes, underscoring the intricate relationship between environmental factors and their effects on Earth's systems. (Uber et al., 2023). Climate change encompasses alterations in climatic conditions, including prolonged shifts in temperatures and weather patterns, which persist over extended Periods, typically spanning decades or more.

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Section A- AGRICULTURAL ENGINEERING & RELATED SCIENCES

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This phenomenon impacts humanity on a global scale, posing significant threats to human health and well-being. The escalation of extreme temperatures, intensified occurrences of floods and droughts, and heightened levels of air pollution are among the perilous consequences attributed to climate change (Dash & Maity, 2023, Demir et al., 2023). As these changes unfold, they not only endanger human lives but also pose formidable challenges to ecosystems, economies, and societal structures worldwide.

Soil erosion is a major factor of concern that limits land productivity globally. It is a land degradation process that can affect food production, biodiversity, carbon stocks and ecosystem services (Xiao et al., 2023). Its adverse effects in many parts of Nigeria has been documented and linked to volume and intensity of rainfall (Nwankwoala, et al., 2022; Ufoegbune et al., 2011). Erosion is a function of rainfall erosivity (R-factor) i.e the ability of rainfall to initiate erosion (Denis & Toyin, 2014) and soil erodibility i.e the ability of the soil to withstand climatic erosivity (Suif et al., 2018). Factors that influence rainfall erosivity includes rainfall drop Size, velocity of rain drops, duration, intensity and kinetic energy of rainfall (Ogedengbe et al., 2005).

To mitigate against erosion, there is the need to either encourage activities that would prevent the detachment of soils by agents of erosion and / or prevent it from being washed away. Knowledge of climatic erosivity is needed so it may influence measures that would be taken to

prevent soil erosion. Change in intensity of precipitation can have direct impact on soil erosion (Pal et al., 2023; Pal & Chakrabortty, 2022). As climate change warms the atmosphere, it enhances its capacity to retain moisture, resulting in a heightened potential for extreme precipitation events (Pal & Chakrabortty, 2022). Climate change has been reported to cause a large increase in rainfall erosivity factors (Chen et al., 2023), hence the need to update current rainfall factor / erosivity map of Nigeria with more recent and spatially distributed rainfall data.
There are various attempts at estimating the rainfall erosivity indices. The most commonly used is EI_{30} (Chen et al., 2023; Denis & Toyin, 2014). Ogedengbe et al. (2005) created a rainfall erosivity map for Nigeria using the Fournier Index, patterned after that developed for Ghana by Oduro-Afriyie (1996). This index was chosen for the development of rainfall erosivity map for Nigeria because it was developed in West Africa with a similar climatic condition to that of Nigeria (Ogedengbe et al., 2005).
We investigated the effects of climate change on rainfall erosivity for Nigeria. This will guide the end users in understanding the current trend as far as rainfall erosivity in Nigeria is concerned and use the information provided as a guide for national planning and other related purposes.

2 METHODS

The rainfall erosivity map for Nigeria was developed, using the Fournier Index (Fournier, 1960). Monthly rainfall data from 46 rain gauges, spanning 62 years (1st January, 1960 to 22nd December, 2022) were selected for the calculation of rainfall erosivity in the study area, to guarantee the accuracy of the calculations. Table 1 gives a detailed overview of the selected locations. This is 11 locations and 24 years data more than the 35 years data and 38 locations used by Ogedengbe et al. (2005). The classification used is presented in Table 2. Similar to the methodology employed by Ogedengbe et al. (2005), the calculation of rainfall erosivity index for each of the 46 locations utilized the Fournier index using the relationship (Fournier, 1960)

$$C = (P_1)^2/P \text{ ……………………(1)}$$

where C, P_1 and P represent the Erosivity index, the total rainfall amount in the wettest month of the year, and total rainfall amount, respectively, in mm.
Nigeria was categorized into five (5) agroecological zones based on the classification by Shaib et al., (1997), a framework also employed by Ogedengbe et al. (2005). Erosivity index computed for each location was used to develop erosivity map for Nigeria. The Rainfall dataset used were obtained from the website archive of the Climate Research Unit-Time Series v4.3 (CRU-TS v4.3) from the University of East Anglia, United Kingdom. The CRU data span from 1901 through 2022, with an annual update on its website. Gridded monthly rainfall data from the Climate Research Unit (CRU_TS 4.3) with 0.5 by 0.5 latitude and longitude resolution over the periods 1960 - 2022 was obtained and used for the calculation of rainfall erosivity index for each of the locations. QGIS version 3.34.1 was used in developing the erosivity map for Nigeria.
The developed map was then compared with that developed in 2005 (Ogedengbe et al., 2005) and the changes in erosion risk class of each location was highlighted.

Table 1. Descriptions of Selected Locations

S/N	Location	Longitude	Latitude	Altitude	Ecological zone
1	Abeokuta	3.3333	7.1667	104.0	SW
2	Akure	5.3000	7.2833	375.0	-do-
3	Benin City	5.1000	6.3167	77.8	-do-
4	Ibadan	3.9000	7.4333	227.2	-do-
5	Ijebu Ode	3.9333	6.8333	77.0	-do-
6	Ikeja	3.3333	6.5833	39.4	-do-
7	Iseyin	3.6000	7.9667	330.0	-do-
8	Ondo	4.8333	7.1000	287.3	-do-
9	Oshodi	3.3833	6.5000	19.0	-do-
11	Oyo	3.9368	7.8430	291.0	-do-
12	Saki	3.3833	8.6667	425.0	-do-
13	Warri	5.7333	5.5167	6.1	-do-
14	Calabar	8.3500	4.9667	61.9	Southeast
15	Enugu	7.5500	6.4667	141.8	-do-
16	Ikom	8.7000	5.9667	119.0	-do-
17	Nkwelle	6.8405	6.2094	131.0	-do-
18	Ogoja	8.8000	6.6667	117.0	-do-
19	Onitsha	6.7833	6.1500	67.0	-do-
20	Owerri	7.0000	5.4833	91.0	-do-
21	Port-Harcourt	7.0167	4.8500	19.5	-do-
22	Umudike	7.5437	5.4801	121.0	-do-
23	Uyo	7.9167	5.0500	38.0	-do-
24	Yandev	9.0378	7.3602	217.0	-do-
25	Abuja	7.0000	9.2500	343.1	Central
26	Bida	6.0167	9.1000	144.3	-do-
27	Ibi	9.7500	8.1833	110.7	-do-
28	Ilorin	4.5833	8.4833	307.4	-do-
29	Jos	8.7500	9.8667	1290.0	-do-
30	Lokoja	6.7333	7.7833	62.5	-do-
31	Markurdi	8.5333	7.7333	112.9	-do-
32	Minna	6.5333	9.6167	256.4	-do-
33	Yola	12.4667	9.2333	186.1	-do-

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34	Birnin Kebbi	4.2167	12.4667	220.0	Northwest
35	Gusau	6.7000	12.1667	463.9	-do-
36	Kaduna	7.4500	10.6000	645.4	-do-
37	Kano	8.2000	12.0500	472.5	-do-
38	Katsina	7.6833	13.0167	517.6	-do-
39	Sokoto	5.2476	13.0059	350.8	-do-
40	Yelwa	4.7500	10.8833	244.0	-do-
41	Zaria	7.6833	11.1000	110.9	-do-
42	Zuru	5.2333	11.4333	393.0	-do-
43	Bauchi	9.8167	10.2833	609.7	Northeast
44	Maiduguri	13.0833	11.8500	353.8	-do-
45	Nguru	10.4667	12.8833	343.1	-do-
46	Potiskum	11.0333	11.7000	414.8	-do-

Classification Source: (Ogedengbe et al., 2005; Shaib et al., 1997)

Table 2. Classes of Erosion Risk Based on the Rainfall Erosivity Index (C)

Range of values of erosivity index (C)	Erosion risk class
<40.0	Low
40.0 – 59.9	Moderate
60.0 - 79.9	Severe
80.0 - 100.0	Very severe
>100.0	Extremely severe

Source: (Oduro-Afriyie, 1996; Ogedengbe et al., 2005)

3 RESULTS

The calculated erosivity index for each of the location are presented in Table 3, while erosivity map for Nigeria developed by Ogedengbe et al. (2005) and the one developed in this study are presented in Figures 1 and 2, respectively. Observations from the two maps are also presented in Table 4.

Table 3. Calculated erosivity index for each of the location

S/N	Location	Lon	Lat	Alt	C
1	Abeokuta	3.3333	7.1667	104.0	35.92
2	Abuja	7.0000	9.2500	343.1	50.12
3	Akure	5.3000	7.2833	375.0	45.38
4	Bauchi	9.8167	10.2833	609.7	78.37
5	Benin City	5.1000	6.3167	77.8	30.92
6	Bida	6.0167	9.1000	144.3	49.76
7	Birnin Kebbi	4.2167	12.4667	220.0	51.30
8	Calabar	8.3500	4.9667	61.9	57.02
9	Enugu	7.5500	6.4667	141.8	52.22
10	Gusau	6.7000	12.1667	463.9	81.98
11	Ibadan	3.9000	7.4333	227.2	36.83
12	Ibi	9.7500	8.1833	110.7	39.53
13	Ijebu Ode	3.9333	6.8333	77.0	58.20
14	Ikeja	3.3333	6.5833	39.4	61.02
15	Ikom	8.7000	5.9667	119.0	65.22
16	Ilorin	4.5833	8.4833	307.4	47.73
17	Iseyin	3.6000	7.9667	330.0	41.43
18	Jos	8.7500	9.8667	1290.0	59.74
19	Kaduna	7.4500	10.6000	645.4	68.51
20	Kano	8.2000	12.0500	472.5	80.82
21	Katsina	7.6833	13.0167	517.6	74.78
22	Lokoja	6.7333	7.7833	62.5	44.04
23	Maiduguri	13.0833	11.8500	353.8	67.37
24	Markurdi	8.5333	7.7333	112.9	41.39
25	Minna	6.5333	9.6167	256.4	52.84
26	Ondo	4.8333	7.1000	287.3	40.98
27	Nguru	10.4667	12.8833	343.1	70.87
28	Nkwelle	6.8405	6.2094	131.0	45.59
29	Ogoja	8.8000	6.6667	117.0	54.87
30	Onitsha	6.7833	6.1500	67.0	54.43
31	Oshodi	3.3833	6.5000	19.0	68.73
32	Oshogbo	4.4833	7.7833	302.0	42.34
33	Owerri	7.0000	5.4833	91.0	58.96
34	Oyo	3.9368	7.8430	291.0	36.38
35	Port-Harcourt	7.0167	4.8500	19.5	56.36
36	Potiskum	11.0333	11.7000	414.8	85.81
37	Saki	3.3833	8.6667	425.0	43.36
38	Sokoto	5.2476	13.0059	350.8	73.37
39	Umudike	7.5437	5.4801	121.0	55.21
40	Uyo	7.9167	5.0500	38.0	47.71
41	Warri	5.7333	5.5167	6.1	71.71
42	Yandev	9.0378	7.3602	217.0	49.72
43	Yelwa	4.7500	10.8833	244.0	58.31
44	Yola	12.4667	9.2333	186.1	38.62
45	Zaria	7.6833	11.1000	110.9	72.87
46	Zuru	5.2333	11.4333	393.0	68.06

C = Rainfall Erosivity Index

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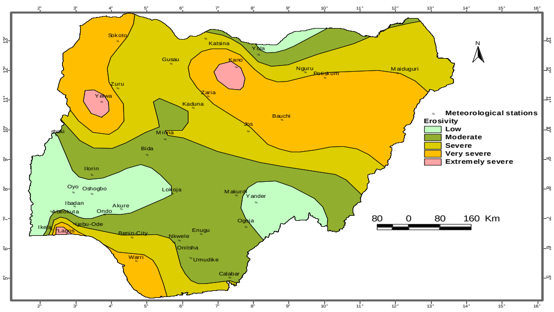

Fig. 1. Erosivity map of Nigeria developed using mean monthly rainfall erosivity indices with rainfall data between 1945 and 1980, as well as 1994 and 1999.¶Source: Ogedengbe et al., (2005).

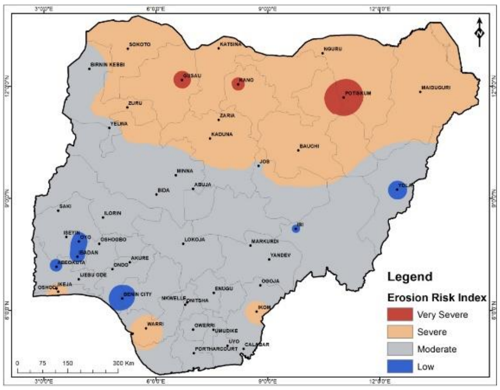

Fig. 2. Erosivity map of Nigeria developed using mean monthly rainfall erosivity indices obtained from rainfall data between 1st January 1960 to 22nd December 2022

Table 4. Comparison between erosivity map developed by Ogedengbe et al. (2005) and that from the present study.

Ecological	Initial (Ogedengbe et al., (2004)	Current Study
SW	Largely in low erosion risk zone. Ijebu Ode, up to Benin City lie in severe erosion risk class; Warri area in very severe, while other part of coaster region of Lagos lies in extremely severe erosion risk.	Largely in moderate erosion risk zone; with Benin City, Abeokuta, Oyo, and Ibadan in low erosion risk; and the coaster area of Warri and lagos in severe erosion risk class.
SE	Largely lie in moderate erosion risk class, with places around Yandev in low erosion risk class and places towards the coast in severe erosion risk class.	Largely in moderate erosion risk class, with places around Ikom in severe erosion risk class.
Central	Predominantly moderate, with places around Jos lying in severe erosion risk zone.	Predominantly in moderate erosion risk class, with places around Ibi and Yola in low erosion risk class.
NW	Range from severe (places around Kaduna, Zuru, Gusau, and Katsina) to very severe (areas around Sokoto to places around Yelwa) while Yelwa and Kano lie in extremely severe erosion risk.	Predominantly in severe erosion risk class, with places around Birnin Kebbi and Yelwa in moderate erosion risk class and while Gusau and Kano areas are in very severe erosion risk class.
NE	Largely lies between severe (in places above Maiduguri and Potiskum) and very severe erosion risk (Bauchi, Zaria, around Kano, Potiskum and Maiduguri)	Predominantly in severe erosion risk class, with places around Potiskum in very severe erosion risk class.

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4 DISCUSSION

The erosivity index ranges from 30.92 (indicating a low erosion risk) in Benin City to 85.81 (signifying a very severe erosion risk) in Potiskum. Notably, the Southwest agroecological zone, previously categorized as predominantly low erosion risk zone according to Ogedengbe et al. (2005), has transitioned to a moderate erosion risk zone. Meanwhile, the Southeast and Central agroecological zones persist in the moderate erosion risk category, while the Northwest and Northeast agroecological zones are largely classified as severe erosion risk areas. Given the significant influence of climate change on these erosivity patterns, mitigating the erosivity class of these regions presents a considerable challenge. However, proactive measures can be taken to address soil erosion. Strategies aimed at reducing the kinetic energy of raindrops to prevent soil particle detachment, as well as measures to impede the transport of detached soil particles, are essential.

The soils within the Southwest agroecological zone exhibit a diverse range of compositions, including sandy loam, sandy clay and clay loam (Nkwunonwo et al., 2020). Moreover, this region is characterized by a variety of soil types, encompassing rainforest, savannah and wetland soils. In contrast, the Southeast agroecological zone is predominantly characterized by rainforest soils, while the Central, Northwest and Northeast agroecological zones are predominantly composed of savannah soils (Nkwunonwo & Okeke, 2013).

In terms of drainage patterns, the soils in the Southwest and Southeast agroecological zones primarily exhibit well-drained characteristics, with patches of poorly drained soils along the coastal areas. On the other hand, the soils in the Central agroecological zones are predominantly poorly drained. In contrast, the soils in the Northwest and Northeast zones display a combination of moderately, poorly and well-drained characteristics (Nkwunonwo & Okeke, 2013).

Ezemonye & Emeribe (2012) reported rainfall erosivity indices in Southeast Nigeria as ranging from very low to very high levels of erosivity. In the present study, with the exception of areas around Yandev exhibiting low erosivity indices, the majority of locations in Southeast agroecological zones are classified under moderate erosion risk. However, areas situated below Port-Harcourt fall into the severe erosion risk category. These are likely due to climate change effect. To mitigate the adverse effects of erosion, practices that would conserve the soil and discourage transportation of soil particles via erosion should be encouraged. Planting of cover crops, cultivation across slope, mulching, afforestation and other sustainable agricultural practices should be encouraged. Furthermore, dangerous practices such as bush burning and deforestation, which exacerbate erosion and contribute to greenhouse gas emissions should be strongly discouraged. By advocating for these proactive measures, communities can safeguard soil health, mitigate erosion risks, and foster environmental resilience in the face of climate change challenges.

5 CONCLUSION

The developed erosivity map for Nigeria showed a large variation compared to that developed by Ogedengbe et al. (2005), this variation can be attributed to the impacts of climate change. Notably, none of the agroecological zones lies majorly in low erosion risk category. The Southwest and southeast agroecological zones are primarily categorized under moderate erosion risk, although certain areas within them exhibit severe erosion risk. The Northwest and northeast regions are predominantly classified as severe erosion risk areas. Given these alarming trends, urgent land management measures should be introduced to mitigate erosion problems in all parts of Nigeria. There is also the need to discourage practices that would aggravate the release of greenhouse gases into the atmosphere, thereby mitigating climate change. By addressing both erosion and climate change mitigation strategies simultaneously, Nigeria can work towards fostering sustainable land management practices and enhancing environmental resilience nationwide.

REFERENCES

Chen, F., Hu, H., Pan, D., Wang, J., Zhang, H., & Pan, Z. (2023). Distribution Characteristics of Rainfall Erosivity in Jiangsu Coastal Areas. *Agronomy*, *13*(7). https://doi.org/10.3390/agronomy13071829

Dash, S. S., & Maity, R. (2023). Effect of climate change on soil erosion indicates a dominance of rainfall over LULC changes. *Journal of Hydrology: Regional Studies*, *47*(April), 101373. https://doi.org/10.1016/j.ejrh.2023.101373

Denis, M. K. A., & Toyin, A. O. (2014). Estimation of soil erodibility and erosivity of rainfall patterns in Njala land resource area of southern Sierra Leone. *Research Journal of Agricultural Sciences*, *5*(2), 163–167.

Ezemonye, M., & Emeribe, C. (2012). Rainfall Erosivity in Southeastern Nigeria. *Ethiopian Journal of Environmental Studies and Management*, *5*(2), 112-122–112–122. https://doi.org/10.4314/EJESM.V5I2.1

Fournier, F. (1960). *Climat et érosion : la relation entre l'érosion du sol par l'eau et les précipitations atmosphériques*.

Nkwunonwo, U. C., Okeke, F. I., Ebinne, E. S., & Chiemelu, N. E. (2020). Free, open, quantitative and adaptable digital soil map data and database for Nigeria. *Data in Brief*, *31*(June), 105941. https://doi.org/10.1016/j.dib.2020.105941

Nkwunonwo, U., & Okeke, F. (2013). GIS-based production of digital soil map for Nigeria. *Ethiopian Journal of Environmental Studies and Management*, *6*(5). https://doi.org/10.4314/ejesm.v6i5.7

Nwankwoala, H.O, Igbokwe, T., & and Orluchukwu, J. . (2022). *Nwankwoala et al., 2022.pdf* (pp. 30–38). Journal of e-Science Letters. https://doi.org/http://dx.doi.org/10.46890/SL.2022.v03i02.005

Obiora-Okeke, O. A., Adewumi, J. R., & Ojo, O. M. (2021). Impact of Climate Change on Runoff Prediction in Ogbese River Watershed. *FUOYE Journal of Engineering and Technology*, *6*(4), 392–396. https://doi.org/10.46792/fuoyejet.v6i4.721

Oduro-Afriyie, K. (1996). Rainfall erosivity map for Ghana. *Geoderma*, *74*(1–2), 161–166. https://doi.org/10.1016/S0016-7061(96)00054-7

Ogedengbe, K., Akintola, O., & Idowu, O. (2005). Development Of Rainfall Erosivity Map For Nigeria. *Global Journal of Pure and Applied Sciences*, *11*(2). https://doi.org/10.4314/GJPAS.V11I2.16495

Pal, S. C., & Chakrabortty, R. (2022). *Climate Change Impact on Soil Erosion in sub-tropical Environment*. *22*(November), 140. https://doi.org/10.1007/978-3-031-15721-9

Pal, S. C., Chakrabortty, R., Towfiqul Islam, A. R. M., Roy, P., Chowdhuri, I., Saha, A., Islam, A., Costache, R., & Alam, E. (2023). Land use and climate change-induced soil erosion mapping in a sub-tropical environment. *Geomatics, Natural Hazards and Risk*, *14*(1). https://doi.org/10.1080/19475705.2023.2270129

Shaib, B., Aliyu, A., Bakshi, J. S., & Nigeria. Department of Agricultural Sciences. (1997). *Nigeria : National agricultural research strategy plan 1996-2010*. Department of Agricultural Sciences, Federal Ministry of Agriculture and Natural Resources,.

Suif, Z., Razak, M. A. A. A., & Ahmad, N. (2018). Predicting of soil erosion with regarding to rainfall erosivity and soil erodibility. *AIP Conference Proceedings*, *1930*(February). https://doi.org/10.1063/1.5022948

Uber, M., Haller, M., Brendel, C., Hillebrand, G., & Hoffmann, T. (2023). *Past , present and future rainfall erosivity in Central Europe based on convection-permitting climate simulations*. *May*, 1–30.

Ufoegbune, G. C., Bello, N. J., Ojekunle, Z. O., Orunkoye, a R., Eruola, a O., & Amori, a a. (2011). Rainfall Erosivity Pattern of Ogun River Basin Area (Nigeria) using Modified Fournier Index. *European Water*, *35*(July 2015), 23–29.

Xiao, Y., Yin, S., Yu, B., Fan, C., Wang, W., & Xie, Y. (2023). The most extreme rainfall erosivity event ever recorded in China up to 2022: the 7.20 storm in Henan Province. *Hydrology and Earth System Sciences*, *27*(24), 4563–4577. https://doi.org/10.5194/hess-27-4563-2023

