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ASSESSMENT OF PRIMARY PRODUCTIVITY IN BURHI GANDAK RIVER AT MUZAFFARPUR, BIHAR: A COMPREHENSIVE STUDY

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Abstract:
The Burhi Gandak River near Muzaffarpur (26.1197° N, 85.3910° E) has a significant yearly fluctuation in phytoplankton primary production, as this study reveals. Three carefully chosen locations (A, B, and C) were close to Ashram Ghat and separated by 100 meters. Site B was selected as a Control site due to receiving direct urban municipal effluent to the river. For two years (2021–2022), monthly analyses were carried out. The gross primary productivity (GPP) ranged from 4.47 to 5.54 mg/hr on average; the gross primary productivity minus autotrophic respiration ranged from -0.38 to 1.01 mg/hr, and the community respiration (CR) ranged from 2.13 to 3.11 mg/hr. For both observation years, the proportion of GPP ranged from 58.44% to 75.47%, while the ratio of NPP to GPP varied from -0.16 mg/hr to 0.29 mg/hr. Growing nutrient (pollutant) levels and environmental conditions have been identified as critical elements influencing GPP, NPP, and CR in the river. A comparative analysis among the sites revealed noteworthy patterns. In the first year, sites A and B recorded an identical average GPP of 4.47 mg/hr, surpassing C (4.35). Conversely, in the subsequent year, C exhibited the highest GPP (5.54) compared to A (4.69 mg/hr) and B (5.05 mg/hr). NPP showed intriguing disparities, with the lowest value recorded at C (-0.38 mg/hr) in the first year compared to A (1.01 mg/hr) and B (0.001 mg/hr). In the second year, C demonstrated the highest NPP (0.95 mg/hr) followed by A (0.78 mg/hr) and B (0.40 mg/hr). Similarly, community respiration (CR) varied, with C registering the maximum (3.02 mg/hr) and A the minimum (2.13 mg/hr) in the initial year. In the following year, A recorded the highest (3.13 mg/hr), B (3.11 mg/hr), and C the lowest (2.98 mg/hr). The ratio of NPP to GPP peaked at A (0.28 mg/hr) in 2021 and at A (0.29 mg/hr) in 2022, with the lowest at C (-0.16 mg/hr) and B (0.11 mg/hr), respectively. The percentage of GPP displayed a range from the lowest at C (69.46%) to the highest at A (75.47%) in the first year and from the lowest at C (58.44%) to the highest at A (66.86%) in the subsequent year. This research underscores the dynamic interplay of environmental factors and pollutant levels influencing phytoplankton primary production at selected sites. The findings contribute to a nuanced understanding of the ecological dynamics and effect of pollutants in the Burhi Gandak River different sites.
Keywords: Ashram Ghat, Monthly variation, Muzaffarpur, phytoplankton primary production.

Introduction:

Water is vital for the existence of organisms, serving as a crucial necessity. Numerous aquatic life forms, ranging from microscopic plankton to considerable aquatic animals, inhabit water environments (Wehr & Descy 1998, Das, panda, 2010, Wu et al. 2014). While Earth has abundant water, only a small fraction is suitable for use (Dooge 1984). Phytoplankton diversity is a major component of aquatic ecosystems, indicating the wealth of river ecology and reflecting the pollution level in surface waters due to both point and non-point sources, which can alter the structure of phytoplanktonic populations (Pinckney et al. 1998, Schaffner et al. 2009). The diversity of the phytoplankton community showed variation in productivity. Productivity is characterized as variability in the pace at which biomass is produced over a designated period (Dash et al, 2011).

Measuring primary productivity provides insights into the autotrophic Carbon compound in a given area over time and reveals the operational characteristics of the river (Odum, 1971). Photosynthesis constitutes the essential mechanism driving primary production in ecosystems (Singh & Singh, 1999). The chlorophyll-containing structures harness solar energy, transforming it into chemical energy through the absorption of water and carbon dioxide from the surroundings, ultimately producing carbohydrate molecules (Mishra & Saksena, 1992). GPP, NPP, and CR were analyzed as the key factors in the study of river primary productivity. Gross primary productivity refers to the total rate at which photosynthetic organisms, such as algae, capture and convert solar energy into chemical energy through photosynthesis within a specified area and period. It is a key metric for understanding the primary production of an ecosystem and the energy available for subsequent trophic levels (Wetzel &Ward, 1996, Finlay 2011, Pace et al. 2021). Net primary productivity in a freshwater ecosystem refers to the rate at which primary producers, typically plants and algae, capture and store energy through photosynthesis, minus the energy lost through respiration (Pace et al. 2021, Randerson et al. 2001). Community respiration in aquatic systems is the combined cellular respiration of all organisms within a community, involving the consumption of oxygen and the release of carbon dioxide. (Smith Jr 1973, Crossey & La Point, 1988).

The river of today fulfills several demands for the various towns in the area. At the same time, it absorbs urban areas' municipal wastewater, which promotes the growth of planktonic organisms. The principal aim of the observation was to appraise the degree of pollution and the relationship between primary output and specific parameters in the years 2021 and 2022. The study examines the seasonal variability of phytoplankton communities, taking into account the effects of temperature changes and rainfall patterns on their composition and abundance. It also evaluates pollution levels and primary productivity. Examining the connection between the stability of the river and the community structures at the three sites is an important aspect of the research.

Previous workers like (Likens 1975); (Naegeli et al. 1995), (Howarth et al. 1996), (Bunn et al. 1999), (Lamberti et al. 1997), (Ahmed et al. 2005), (Bott et al. 2006), (Ogbuagu & Ayoade 2011), (Barala et al. 2011), (Burford et al. 2011), (Parker et al. 2012), (Moharana et al. 2013), (Sukla et al. 2013), (Dokulil 2014), (Cui et al. 2016), (Hall Jr et al. 2015), (Sharma & Giri 2018), (Jia et al. 2019), etc were studied on primary productivity of different rivers of the world.

Study map:

This research spanned a two-year duration, encompassing the years 2021 to 2022. The study focused on three strategically chosen sites situated in close proximity to Ashram Ghat along the Burhi Gandak River bank, each positioned at a 100-meter interval from one another.

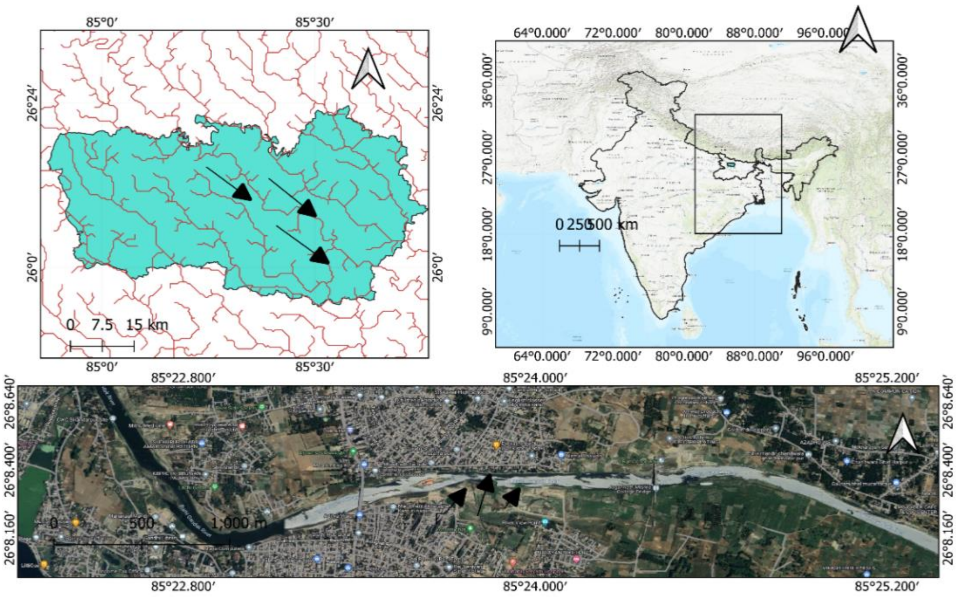

Figure 1: The above map draws in QGIS showed three sites near the Ashram Ghat at Muzaffarpur.

Material and methods:

The O_2 method was applied for the assessment of phytoplankton primary production (Gaarder & Gran, 1927). Light (transparent) and dark (blackened) bottles were filled with samples and suspended at a suitable depth for the incubation period of specified hours. Then bottles were removed, and the concentration of oxygen was measured. The initial dissolved oxygen of the water sample is also measured at the initiation of the experiment. The variation in oxygen level of the transparent and the blackened bottles is the GPP, the difference between the oxygen contents of the light and the initial bottles is the net primary production and the difference between the O_2 contents of the initial and the dark bottles in the community respiration.

$$GPP,\ O_2 mg/l/hr = DOL\text{-}DOD)/H$$

$$NPP,\ O_2\ mg/l/hr = DOL\text{-}DOI/H$$

$$CR,\ O_2 mg/l/hr = DOI\text{-}DOD)/H$$

Where,

DOI= amount of DO (mg/l) in initial bottles

DOL= amount of DO (mg/l) in the light bottles

DOD= amount of DO (mg/l) in dark bottle.

The oxygen values were multiplied by a factor of 0.375 to calculate the carbon content.

GPP, NPP or CR, mg C/l/hr= GPP, NPP or CR in mg O2/l/hr ×0.375.

Results and Discussion:

GPP exhibited the following ranges: 2.8 to 6.42 mg/hr, 3 to 6.28 mg/hr, and 2.8 to 6.2 mg/hr, maximum in April, March, and December, minimum in September at Sites A and B, and in July at Site C, average mean were 4.47 mg/hr (A and B), 4.35 mg/hr (C) in the initial year and following year GPP ranged from 2.80 to 6 mg/hr, 3.8 to 6.8 mg/hr, and 3.9 to 6.8 mg/hr, highest in April, March, June, lowest in July (A), September (B and C), average mean value were 4.69 mg/hr, 5.050 mg/hr, and 5.54 mg/hr.

GPP was monthly analyzed along the Burhi Gandak River over two years and showed seasonal variation and dynamic changes in photosynthetic activity. The selected three sites exhibited considerable variability in GPP values in both years, focusing on the river's dynamic nature. High value was noted in April at A site in both years but at B and C sites GPP was observed in different months described in Tables 1 and 2 and Figure 1. Mostly diversity decreased in winter due to lack of light and other important factors. However, in the primary year of observation, the higher peak was also recorded in December at the C site. This result may be due to some other factors like receiving high amounts of pollutants at that location. It was important to note that the same average value was recorded at A and B (4.47 mg/hr) respectively and less at the C site in the initial year. Whereas in the following year highest peak was observed at C sites. This indicated that pollutants traveled from B point (discharged site) to C in the following year of observation.

Gross primary production is an important tool for measuring the diversity of rivers. Many works have already been done on different rivers but less study done on Burhi Gandak. In the grassland river continuum, noted variations in Gross Primary Productivity (GPP) ranged from less than 0.3 to 9.6 grams of oxygen per square meter per day (Young, Huryn 1996). Similarly, in another study in which higher values during summer (1864.81 mg m^2 d^{-1}) and spring and lower in winter (39.80 to 393.43 mg m^2 d^{-1}) of selected area of the Gan River and Poyang Lake system (Jia et al. 2020). (Engel et al .2019) put forward the hypothesis that Gross Primary Productivity (GPP) and the biomass of phytoplankton exhibit an upward trend along the examined stretch of the river. This expectation is rooted in the hydro-morphological conditions present in the dam headwaters, which are conducive to the flourishing growth of phytoplankton.

The NPP ranged from -2.5 mg/hr to 2.90 mg/hr, -2.9 mg/hr to 2.9 mg/hr, -3.5 mg/hr to 2.35 mg/hr, the highest peak in December (A and B), November (C), lowest in April (A and B), March (C), average values were 1.01 mg/hr, 0.001 mg/hr, -0.23 mg/hr in the primary year of observation. Whereas in the secondary year, NPP varied from -3.8 mg/hr and 3.4 mg/hr, -4.40 mg/hr to 4.00 mg/hr, -4.2 mg/hr and 3.9 mg/hr, with the highest value in January (A), October (at both B and C), lowest in May, March, April and average were 0.78 mg/hr, 0.40 mg/hr, 0.95 mg/hr.

Net primary productivity between two years showed variations at different selected sites in the Burhi Gandak River. Variation in both years in the highest and lowest showed seasonal variation for example highest peak was observed in winter whereas the lowest was in summer which was described in Table 1, 2, and Figure 2. The more difference was found in the average mean in 2021. The data showed that a 1.01 mg/hr value was recorded at the A site, whereas at the B and C sites, a negligible value was observed. In the following year, the value quite increased and reached a maximum value, of 0.95 at the third site of the river. These variations were due to changes in season, anthropogenic pollutants, and other ecological factors.

The annual variations in Net Primary Productivity (NPP) in the river Birupa displayed noteworthy fluctuations across three distinct sites (S1, S2, and S3) during both 2009 and 2010 (Sukla et al, 2013). Specifically, at S1, NPP exhibited a range from 0.21 to 1.82 g C m^{-2} day-^{1} in 2009 and from 0.22 to 1.43 g C m^{-2} day^{-1} in 2010. Meanwhile, at S2, NPP showed variability from 0.57 to 1.82 g C m^{-2} day^{-1} in 2009 and continued to fluctuate within the range of 0.24 to 1.76 g C m^{-2} day^{-1} in 2010. At S3, NPP ranged from 0.21 to 1.25 g C m^{-2} day^{-1} in 2009 and exhibited variability from 0.24 to 1.76 g C m^{-2} day^{-1} in 2010.

The researcher examined 12 years (1999 to 2010) of satellite-based Net Primary Productivity (NPP) data to point out variations in the Yangtze River (Wu et al, 2014). Similarly, the rising trend in NPP in the studied river basin from 1981 to 2015, was marked by notable fluctuations (Zhang et al, 2020). Notably, the oasis area consistently showed higher NPP than the upstream mountainous region, with average annual values of 889 g C m^{-2} yr^{-1} and 659 g C m^{-2} yr^{-1}, respectively.

CR varied from -5.7 to 4.1 mg/hr, 1.10 to 5.2 mg/hr, 2.2 to 4.2 mg/hr, and 2.1 to 4.8 mg/hr, 2.1 to 4.3 mg/hr, 2.1 to 4.1 mg/hr at A, B, C site in both years. The highest peak was in December, June, May, and the minimum in June, July, and January, average values were 2.13 mg/hr, 2.95 mg/hr, and 3.02 mg/hr in the initial year whereas in the following year highest values were in May, July at A, B site but in April, October at C site, the lowest value in October, April, at A, B site but at the C site the minimum value observed in the month of march and August, average values were 3.13 mg/hr, 2.98 mg/hr, 3.11 mg/hr.

The monthly analysis of Community respiration showed ecological diversity and pollutant effects at selected sites over two years. A higher peak was observed in a different month. Mostly in the summer season peak value was observed as mentioned in Table 1, 2, and Figure 3 but at the A site in December (2021) and at the C site in October (2022). Variations in lowest value were also recorded for example it was observed in June, July, and January (2021) and October (A), April (B), March, and August (C) respectively. Conversely, minimum CR values, occurring in different months, may indicate periods of relative environmental stability or reduced pollution. Examining the average CR values provides a broad overview. which showed the general trend of CR already described in the table i.e., maximum at C in 2021 and at B in 2022.

The difference in O_2 concentration between initial and dark treatment was used to compute the CR. For, determining the community respiration workers analyzed the variation in DOI and DOD and found values in between 2.7 to 433.6 mg C m^{-3} d^{-1} (Chen et al. 2009). The six stations examined and displayed a consistent seasonal pattern in community respiration (CR), reaching its peak during summer and hitting a minimum during winter (Dash et al. 2011). Observed community respiration levels ranged from 3.94 to 8.30 g O_2 m^{-2} d^{-1} in the western Hudson River streams and 1.39 to 6.12 g O_2 m^{-2} d^{-1} in the eastern Hudson River streams (Bott et al. 2006). In the grassland river continuum, researchers documented a spectrum of Community Respiration (CR) rates, extending from 0.7 to 9.8 *g* O_2 m^{-2} d^{-1} (Young and Huryn 1996).

NPP/GPP (table 1, 2 and Figure 3) varied from (-.44) mg/hr to .65mg/hr, (-.69) mg/hr to .78 mg/hr, (-1.00) mg/hr to .55 mg/hr, the maximum value was in October (A and B), January at C site, lowest in May, April, August, average ranged from 0.28mg/hr, 0.04 mg/hr, -0.16 mg/hr in initial year. In successive year NPP/GPP was -.61 to .92 mg/hr, -.77 to .95, -.93 mg/hr to .85 mg/hr, maximum in September, at A, C site but maximum in the month of November at B sites, lowest in March and May at A site and in the month of July at B and in the month of April C, average value was 0.29 mg/hr, 0.11 mg/hr, 0.20 mg/hr.
Photosynthetic autotrophic organisms use light and form carbon-containing compounds. These compounds are finally stored in a photosynthetic organism which is calculated by NPP/GPP (Singh & Singh 1999). Here value of NPP/GPP for two years showed significant variation. Maximum values observed in post-monsoon and pre-winter seasons were described in Table 1, 2, and Figure 4. Minimum recorded mostly in the summer season. The difference between higher and lower values showed available energy for the next trophic level of the aquatic ecosystem. Maximum average at A site but lowest at C in the initial year. Whereas in the following year, positive values were observed in comparison to the first year. Positive NPP/GPP ratios indicate that a significant proportion of the gross primary productivity is being converted into net primary productivity, while negative ratios suggest a loss of energy through processes like respiration. the lowest value in monsoon observed due to low light penetration in the Kuakhia River (Barala et al. 2013). The increased value was observed in selected sites where fewer pollutants were discharged (Janmoni et al. 2014). The ratio in river Jharahi observed varied from 0.469 to 0.799 in the initial year and 0.427 to 0.754 in the following year of observation (Pratab & Khatibullah, 2014). (Verma et al, 2012) observed that NPP/GPP was unhealthy and the value was observed in between 0.10 to 0.71.

It was also evident the percentage of GPP (table 1, 2, and Figure 5) varied considerably annually. It ranged from 38.38% to 135.39%, 27.63% to 126.82%, and 45.6% to 150%. the values reached their maximum in June (A and B), May (C), and minimum in March, July, and December. The average mean was 72.59%, 69.46%, and 75.47% in 2021. In the following year it ranged from 42.85% to 110.71%, 36.76% to 99.73%, and 33.82% to 100% with highest peaks in August, December, and September, and lowest in October, March., and June. the average mean at the three sites was 66.86%, 60.57%, 58.44%.

The data on the monthly study of % GPP at sites A, B, and C in the Burhi Gandak region over two years revealed variations in the efficiency of photosynthesis and carbon allocation within the aquatic ecosystem. The maximum peak was observed in the month of summer in the initial year whereas in the following year, the maximum value was in monsoon at A and C sites but at B site it was observed in winter (December). Lowest in different months in both years of observation. That indicates the pollution level increased at different months which was described in

Table 1, 2, and Figure 5. The average mean at B was lowest in 2021 but in 2022 the lowest was recorded at the C site due to the increased amounts of pollutants in the river Monitoring % GPP is crucial for understanding the overall health and productivity of the Burhi Gandak region. If decreases in % GPP persist, it may necessitate management actions to mitigate environmental stressors and support ecosystem resilience. Meng et al. (2020) revealed distinct drivers of GPP variations in the Heihe River Basin. Climate changes drove 65.8% of GPP changes in the upper reaches, while land use/cover changes (LUCC) contributed 75.1% in the middle and lower reaches. Monthly data from (Qin and Shen 2019) reveal that, on average, pelagic Gross Primary Productivity (GPP) in the York River was 0.7 to 2% of the ecosystem GPP, occasionally exceeding it.

Variation in the standard deviation of primary production showed diversity dispersion in Burhi Gandak river. In 2021, the SD of GPP ranged from 1.08 to 1.13, indicating moderate variability among sites, while 2022 showed decreased SD (0.85 to 0.97), suggesting a more consistent GPP pattern. SD of NPP displayed distinct temporal dynamics, with 2021 exhibiting higher variability (1.99 to 2.54) compared to 2022 (2.79 to 3.43). Conversely, the SD of CR in 2021 showed substantial variability (2.55 to 0.47), whereas, in the second year, values decreased (0.89 to 0.73), signifying more uniform carbon respiration patterns. Noteworthy variations in NPP/GPP ratios were observed in 2022 (0.43 to 0.68), reflecting differences in energy conversion and utilization efficiency among ecosystems. %GPP standard deviations indicated a shift in 2022 (16.37% to 22.71%) from the relatively stable values in the initial year (28.10% to 29.98%).

Table 1: Primary Productivity in 2021

	GPP			NPP			CR			NPP/GPP			%of GPP		
Month	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
January	5.1	5	4.21	2.35	2.83	2.3	3.5	2.8	2.2	0.46	0.57	0.55	68.62	56	52.25
February	4.53	4.52	5	2.43	-2.41	2.1	2.1	2.9	3.2	0.54	-0.53	0.42	46.35	59.95	64
March	5.21	6.28	5.48	2.21	-2.5	-3.5	2	3.2	2.8	0.42	-0.40	-0.64	38.38	50.95	51.09
April	6.42	4.21	4.8	-2.51	-2.9	-2.8	2.5	3.1	2.7	-0.42	-0.69	-0.52	38.94	73.63	56.25
May	5.01	5.82	2.8	-2.22	-2.7	-1.4	2.8	2.1	4.2	-0.44	-0.46	-0.50	55.88	36.08	150
June	4.21	4	3.2	-1.8	-2	1	-5.7	5.2	3.1	-0.43	-0.49	-0.25	135.39	126.82	96.87
July	3.81	3.98	2.8	2	-1.8	-2	3.3	1.1	2.9	0.52	-0.45	-0.71	86.69	27.63	103.57
August	3.21	3.61	3.2	1	1.9	-3.2	2.1	3.5	2.8	0.53	0.53	-1.00	65.42	96.95	87.5
September	2.8	3	4.2	1.5	1.5	-2	2.6	2.9	3.2	0.54	0.50	-0.48	92.85	96.66	76.19
October	3.1	3.2	5.1	2	2.5	2.3	3.1	3.2	3.1	0.65	0.78	0.45	100	100	60.78
November	4.8	4.9	5.2	2.3	2.7	2.35	3.2	2.9	3.2	0.48	0.55	0.45	66.66	59.8	61.53
December	5.4	5.1	6.2	2.9	2.9	2.1	4.1	2.5	2.8	0.54	0.57	0.34	75.93	49.01	45.6
Average	4.47	4.47	4.35	1.01	0.001	-.23	2.13	2.95	3.02	0.28	0.04	-0.16	72.59	69.46	75.47
SD	1.08	1	1.13	1.99	2.54	2.44	2.55	.95	.47	.43	.58	.56	28.10	29.73	29.98

Table 2: Primary productivity in 2022

	GPP			NPP			CR			NPP/GPP			%of GPP		
Month	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
January	5.21	6	6	3.41	3.2	2.48	2.3	3.1	3.8	0.65	0.53	0.41	44.23	51.66	63.33
February	4.8	5.4	5.4	2.8	2.9	3.2	2.2	2.9	2.9	0.58	0.53	0.59	45.83	53.75	53.7
March	5.6	6.8	5.8	-3.4	-4.4	2.8	2.4	2.5	2.1	-0.61	-0.65	0.48	42.88	36.76	36.2
April	6	4	4.7	-2.8	2.9	-4.2	2.7	2.1	4.1	-0.47	0.73	-0.93	45	52.5	87.23
May	4.9	5.4	6.5	-3.8	2.3	-2.6	4.8	2.6	3.2	-0.61	0.43	-0.40	77.41	48.15	49.23
June	3.8	5.3	6.8	1.7	-3.1	-2.3	3.9	3.5	2.3	0.35	-0.58	-0.34	79.59	66.03	33.82
July	2.8	5.4	5.8	-1.5	-4.2	-3.5	3.5	4.3	2.5	0.39	-0.77	-0.60	92.1	79.62	43.1
August	3.1	4.9	4.8	2	-2.8	2.3	3.1	2.9	2.1	0.71	-0.57	0.48	110.71	59.18	43.75
September	4.9	3.8	3.9	2.3	-2.5	3.3	2.5	2.5	3.9	0.92	-0.66	0.85	80.64	65.78	100
October	5.2	5.6	4.8	2.3	4	3.9	2.1	2.9	4.1	0.47	0.71	0.81	42.85	51.78	85.41
November	4.8	4.2	6.2	3.1	3.98	3.2	3.9	2.6	2.8	0.60	0.95	0.52	75	61.9	45.16
December	5.2	3.81	5.8	3.2	2.5	2.8	4.1	3.8	3.5	0.52	0.66	0.48	66.12	99.73	60.34
Average	4.69	5.05	5.54	0.78	0.40	0.95	3.13	2.98	3.11	0.29	0.11	0.20	66.86	60.570	58.44
SD	.97	.94	.85	2.79	3.43	3.09	.89	.62	.73	.54	.68	.6	22.71	16.37	21.63

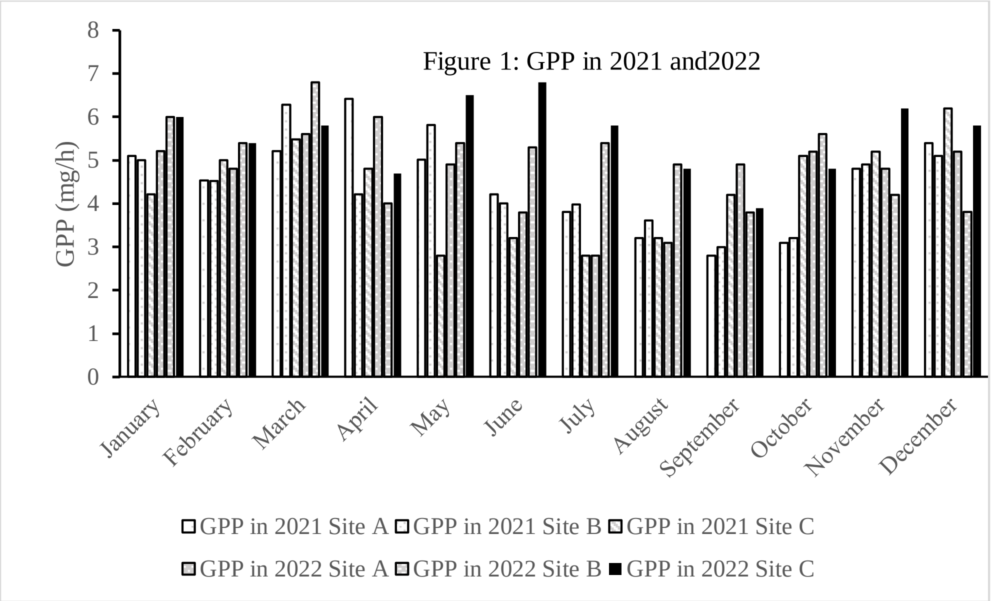

Figure 1: showed monthly variation in GPP at three sites (A, B, C) in both years of observation periods.

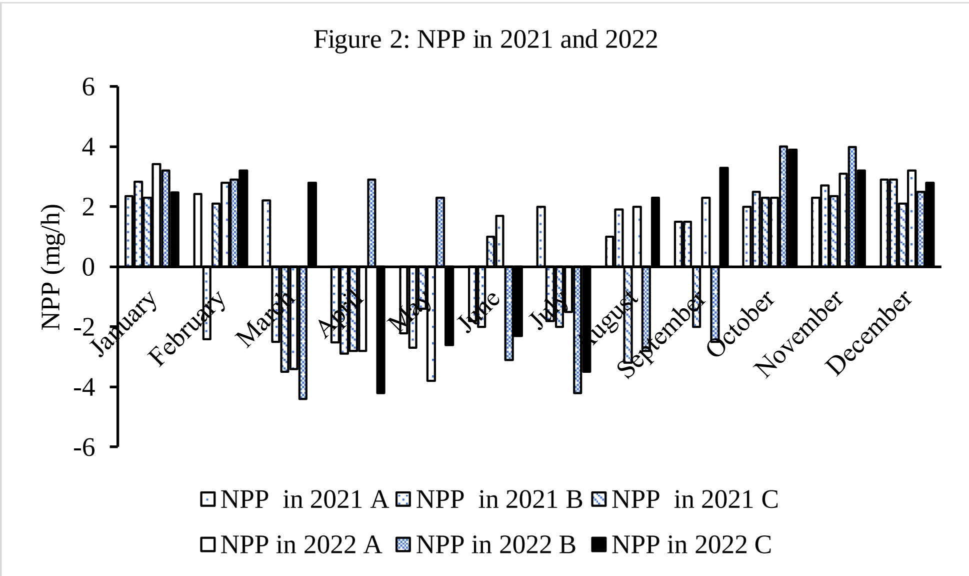

Figure 2: showed monthly variation in NPP at three sites (A, B, C) in both years of observation periods.

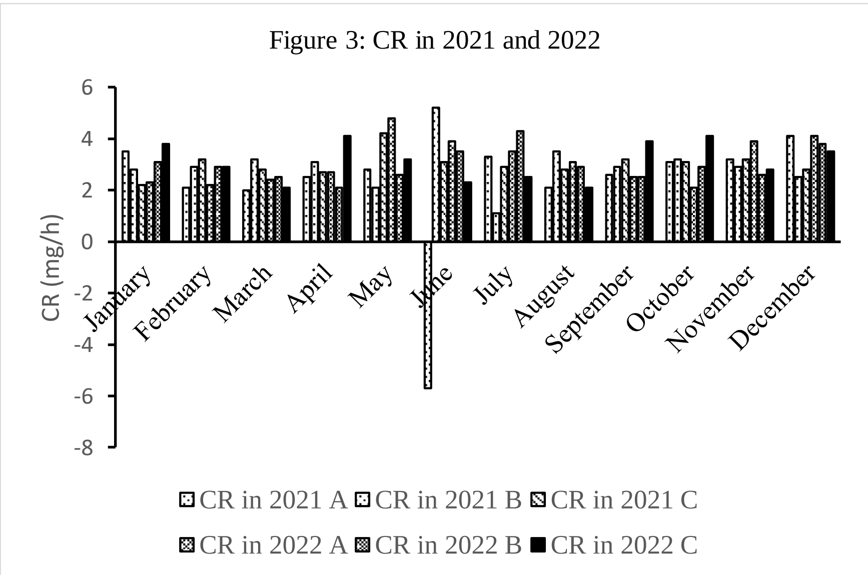

Figure 3: showed monthly variation in CR at three sites (A, B, C) in both years of observation periods.

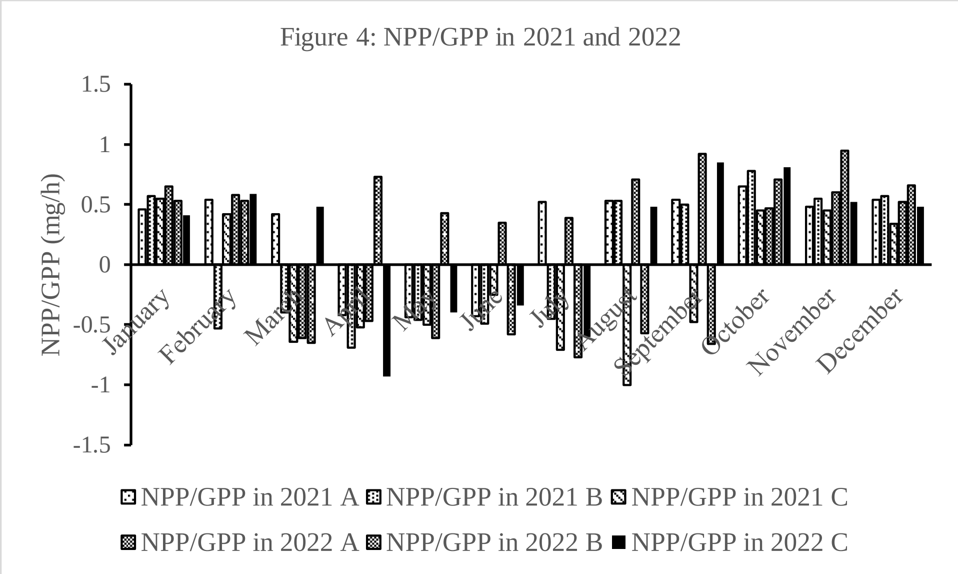

Figure 4: showed monthly variation in NPP/GPP at three sites (A, B, C) in both years of observation periods.

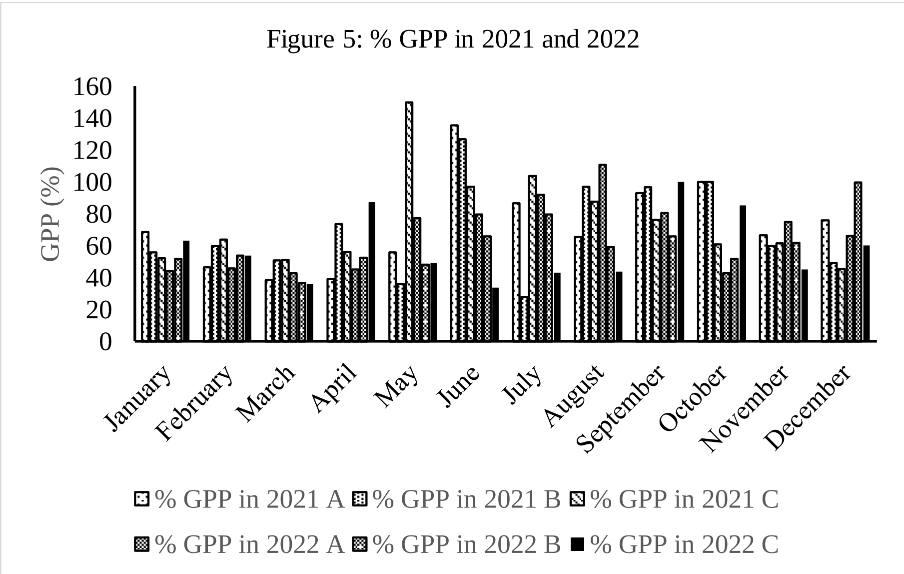

Figure 5: showed monthly variation in % of GPP at three sites (A, B, C) in both years of observation periods.

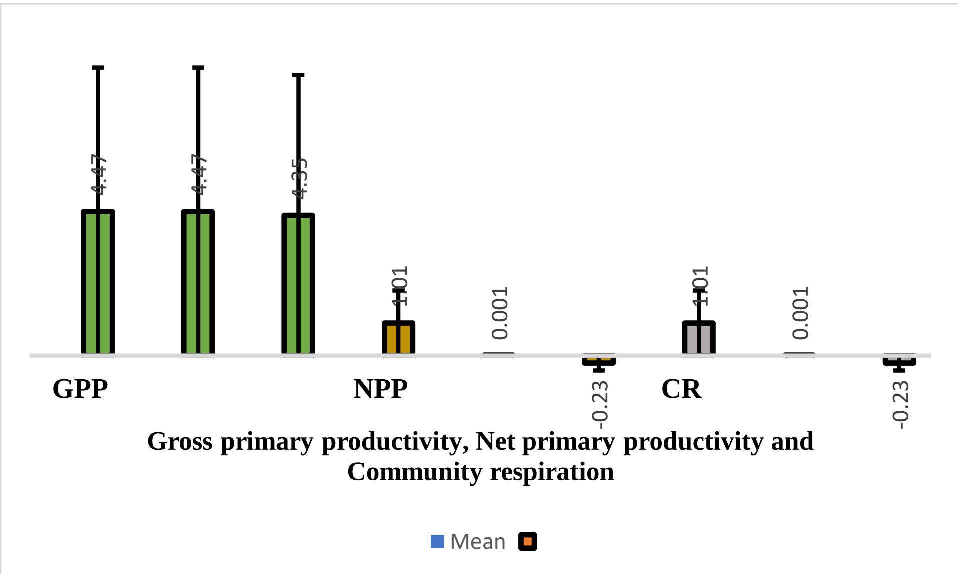

Figure 6: showed SD at three sites in 2021

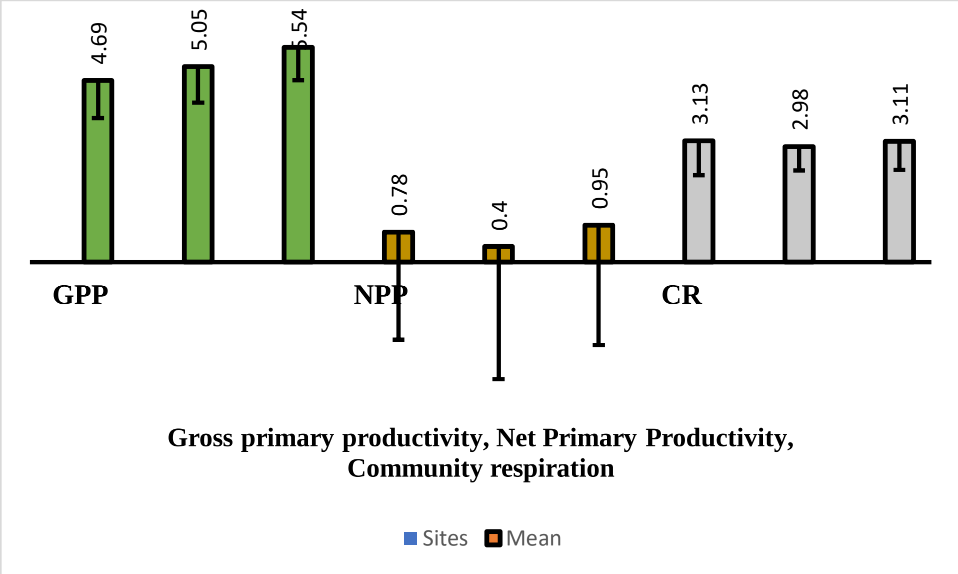

Figure 7: showed SD at three sites in 2022

Conclusion:

Ultimately, the analysis shows that Gross Primary Productivity (GPP) showed similar trends in the two years, peaking in April and March at locations A and B. Interestingly, location C showed a variance, with the highest GPP being recorded in May of the subsequent year and December of the first year. When looking at net primary productivity (NPP), there were clear seasonal differences. At locations A and B, December was the top month for NPP; at location C, however, the peak occurred in November 2021 and covered the months of January, November, and October 2022. Time variations were shown using the Community Respiration (CR) analysis. The highest levels of CR were recorded in May, July, and October of 2022, whereas they peaked in December, June, and May of 2021. These results emphasize the dynamic character of both CR and primary productivity, stressing the importance of particular locations and temporal elements within the ecosystem under study. Variations in the distribution of carbon and the use of energy within the ecosystem are indicated by the NPP/GPP and the percentage of gross primary productivity (% GPP), which offer additional insights into the effectiveness of primary production. The observed fluctuations laid the groundwork for comprehending the interactions between environmental variables and the metabolic activities of the biological community, as well as offering insightful information about the seasonal dynamics of ecological processes. Besides, this study also showed the relationship between selected sites and the effect of pollutants that move from a specific site (B) to other sites.

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