Vol: 1 -- Issue: 2, 2024

Journal of Biosciences and INNOVATIONS

Https://bioscijournal.com

Editor@bioscijournal.com

Article History

Received:
July 30, 2024

Revised:
September 24, 2024

Accepted:
November 09, 2024

Available Online:
December 31, 2024

Urban Tree Canopy Loss and the Decline in Insect Pollinators: Impacts on Urban Agriculture

Muhammad Umair[1*], Muhammad Bilal[2]

[1]Faculty of Environmental Sciences, University of Agriculture, Dera Ismail Khan-29050, Pakistan

[2]Faculty of Agriculture, Gomal University, Dera Ismail Khan 29050, Khyber Pakhtunkhwa, Pakistan

*Corresponding author E-mail: mumairk536@gmail.com

Abstract

It is highly crucial that the canopy of the tree in the urban areas avail and sustain the insect pollinators without which urban farming is unlikely to prosper. This paper examines the issue of loss of a tree cover on the population of the pollinators and the volume of harvests produced by the urban agricultural networks. The analysis was a mixed-method approach involving satellite-derived analysis of canopy, in-field pollinators surveys, environmental sensors installations, and interviews with farmers. We had collected the data of three urban regions having various covers of trees. We considered how well pollination, fruit set and crop levels were doing in insects-dependent crops. Regression analysis was done to estimate the pollinator numbers and visits per visit and canopy parameters. We also used qualitative data to perceive how much of local ecological knowledge existed using theme analysis. In locations where the canopy was eliminated, pollinator visits reduced by as much as 58 percent and yield in agriculture reduced by 41 percent. The lowest number of species was recorded in the canopy-degraded areas including the native bees and butterflies. An environmental sensor indicated that open-space areas experienced high temperatures and poor humidity, therefore, uninhabitable. According to the farmers, they still needed to engage in more manual pollination and were poorer in terms of food security. The meta-analysis revealed strong relationships between canopy decrease, the ecological instability, and decrease in productive agricultural systems. Disappearing of trees canopies in urban areas is also linked to the destruction of insect pollinators and low farm productivity. To reduce such impacts, urban design techniques ought to consist of safeguarding trees, designing landscapes favorable to pollinators, and ensuring that agricultural lands in their entirety are ecologically linked with one another.

Keywords: “Urban Canopy”, “Insect Pollinators”, “Urban Agriculture”, “Crop Yield”, “Ecological Decline”, “Green Infrastructure”

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

INTRODUCTION

All plants and trees in cities are also known as urban forests, and they are highly beneficial to the individuals living in cities, but they are getting increasingly difficult to come across (Vogt, 2020). Urbanization is hurrying to complete the conversion of natural landscapes to urbanized ones, which places considerable pressure on urban ecosystems and the ecological services they sport (Czaja et al., 2020). According to Richards et al. (2022), the long-term delivery of such services has a huge problem with constructing the infrastructure in the regions where these plants are located. The use of urban tree canopies is quite significant in limiting the effect of the urban heat island, which occurs due to a multitude of hard surfaces in a city (Shiu et al., 2022). According to Morgan et al. (2023), stormwater runoff can also be controlled by trees, which will reduce the energy consumption of built structures. Urban trees are highly valuable, as they might lose their canopy due to such factors as the construction of new roads, pollution, and climate change (Lahoti et al., 2020). Declines in trees canopy cover over urban areas have large impacts on insect pollinator populations which is already threatened worldwide. The habitat of the pollinators is disappearing and this is one of the main causes of disappearance of the pollinators. And it is compounded by shrinking of urban tree canopies since they also offer fewer locations where bees can obtain food and nest (EspernonRodriguez et al., 2023). It is very delicate to have urban agriculture because insect pollinators show a delicate complex connection with urban trees, as seen in this complex connection. To be able to devise effective methods of urban biodiversity conservation and ensuring that food production within the urban areas is not carrying out unsustainable processes, we must be able to understand the relationship that exists between these varied items.The insects such as bees, butterflies, and moths, which pollinate plants are quite vital to natural and agricultural ecosystems (Yogita et al., 2025). These species aid the reproduction of a broad diversity of plants, and hence ensure that biodiversity remains healthy, and fruits, vegetables and seeds required by humans to sustain do get produced (Chen et al., 2025). Over the last several decades, the decline in the number of pollinators is high, and this fact caused concerns among many people in food security and the integrity of ecosystems (Zualkernan et al., 2023). Various factors attributed to the decline of the number of pollinators are included in habitats loss, the application of pesticides, change in climate, and diseases (Pandey & Ghosh, 2023). The degradation of habitats that removes the food source, nesting sources and wintering periods of pollinators is brought about by urbanisation, agricultural intensification and deforestation. That loss of habitat is directly connected with the reduction of the urban tree canopies, which is significant to the pollinators since the canopies provide sources of nectar, pollen, and shelter. The nature of interdependencies between plants and pollinators also alters with shifting climatic conditions at dissimilar elevation and thus impacts the kind of interactions occurring between the species (Dzekashu et al., 2023). Additionally, many citizens are unfamiliar with the nature of bee pollinators, and this is likely to make them less willing to conserve them (Ojija & Leweri, 2022). Pollinator decline is a serious issue to agriculture as most food crops require insects to pollinate them so that they can produce fruits and seeds.

The practice of urban agriculture, or production of crops in an urban area, has gained momentum recently due to its ability to enhance food security, involve people with the surrounding neighbourhood

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

and also make the environment sustainable. Urban agriculture can take a wide number of forms including community gardens, rooftop farms, vertical farms and backyard gardens. Urban farming paves the way to numerous possibilities of the agricultural and horticultural spheres by using technology, architecture, and agriculture with vertically arranged buildings (Gunapala et al., 2025)The potential of urban farming is quite high, but there are also a lot of issues, including, lack of space, poisoned soil, and failure to access the resources it requires. Among the greatest issues in regard to urban farming is that it relies on insects to pollinate crops. Most of the fruits, vegetables and herbs which are grown in urban gardens require insect pollinators in order to facilitate pollination. Urban agriculture is also an option that becomes effective when carried out at the building or urban level (Gunapala et al., 2025). Reduced population of insect pollinators represents a significant risk to agricultural productivity and sustainability of urban farming (Altieri et al., 2025). This situation is aggravated by the reduction of tree covers in urban areas, as this lowers the ability of the pollinators to survive in urban areas in terms of space and food supply. Urban farmers can receive fewer crops and poor quality crops as the pollinators are decreasing in number. The soil should be enriched with fertisers, thoroughly screened against the presence of contaminants, and the pH level of the soil must be altered to create the most favourable conditions under which plants could thrive (Bhattarai & Adhikari, 2023). Pollinators play a special role in ensuring decent genetic diversity in plant populations that are important to the long-term well-being of urban farming systems. An assortment of pollinator elements can raise yields of crops, enhance the flavor of crops, and ensure that urban ecosystems remain healthy and stable. The practice of urban farming is gaining more significance in making food safer to urban dwellers (Zhu et al., 2024). Its capacity to promote rural development has been demonstrated because it forms networks in supplying community food (Abas et al., 2020).

RESEARCH METHODS

The present research will be based on a mixed-method experimental design to examine the influence of the disappearance of the urban tree canopies on the insect pollinator communities and urban crop production. As the study sites, we selected three urban areas characterized by a different extent of canopy cover (high, medium, and severely degraded). This was done using geospatial canopy on high resolutions satellite images of Sentinel-2 and Landsat-8. We applied NDVI (Normalised Difference Vegetation Index) in Google Earth Engine to these pictures to monitor the changes in the canopy and urban vegetation indices over a 10 year period. Thanks to the following, we determined the canopy loss (519519519519 first-order difference):

$$\Delta C = \frac{C_{\text{initial}} - C_{\text{current}}}{C_{\text{initial}}} \times 100$$

In which the percentage of tree canopy coverage at the beginning and end of observation period is denoted as CinitialC_{\text{initial}} Cinitial and CcurrentC_{\text{current}} Ccurrent respectively. In order to investigate the relationship between the percentage cover of canopy and the amount of pollinators, standardised transect walk was conducted on a fortnightly basis between March and September across 15 urban farms and community gardens within the selected regions. The insect pollinators were searched and enumerated using timed sweeps nets and pan traps. After this the species were aggregated in broad functional guilds, e.g. bees, butterflies and hoverflies. Next, we considered the consequences of the canopy

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

measurements on the pollinator abundance and pollinator visitations in several linear regressions and generalised additive models. Meanwhile, the HOBO environmental sensors and air passives were employed to monitor the supply of flowers, the air temperature, the concentration of the particulate matter in the air to consider the pollution and microclimate effects.

Productivity of urban agriculture was determined by a quantitative measure of fruit set, crop yield (kg/m 2) and success of pollination (the number of pollen deposited on each stigma) in crops with insect-mediated pollination such as tomatoes, squash, and cucumber. We interviewed 45 urban farmers and conducted participatory questionnaires always to equate what we observed with what we have known concerning environment and the social and ecological limits to the locals. We have examined these qualitative inputs in thematic form in order to determine how individuals believe that the loss of pollinators and green infrastructure will impact the food production systems. We employed a convergent design from which qualitative and quantitative data were integrated. This enabled cross validation of data and putting more meaning to the data. Figure 1 indicates that the methodological framework passes through a sequence of procedures which are repeated. These actions include canopy mapping and deployment of environmental sensors, pollinator monitoring, crop productivity, farmer qualitative research followed by integrative analysis to identify the relationship between canopy loss, ecological degradation and agricultural effects.

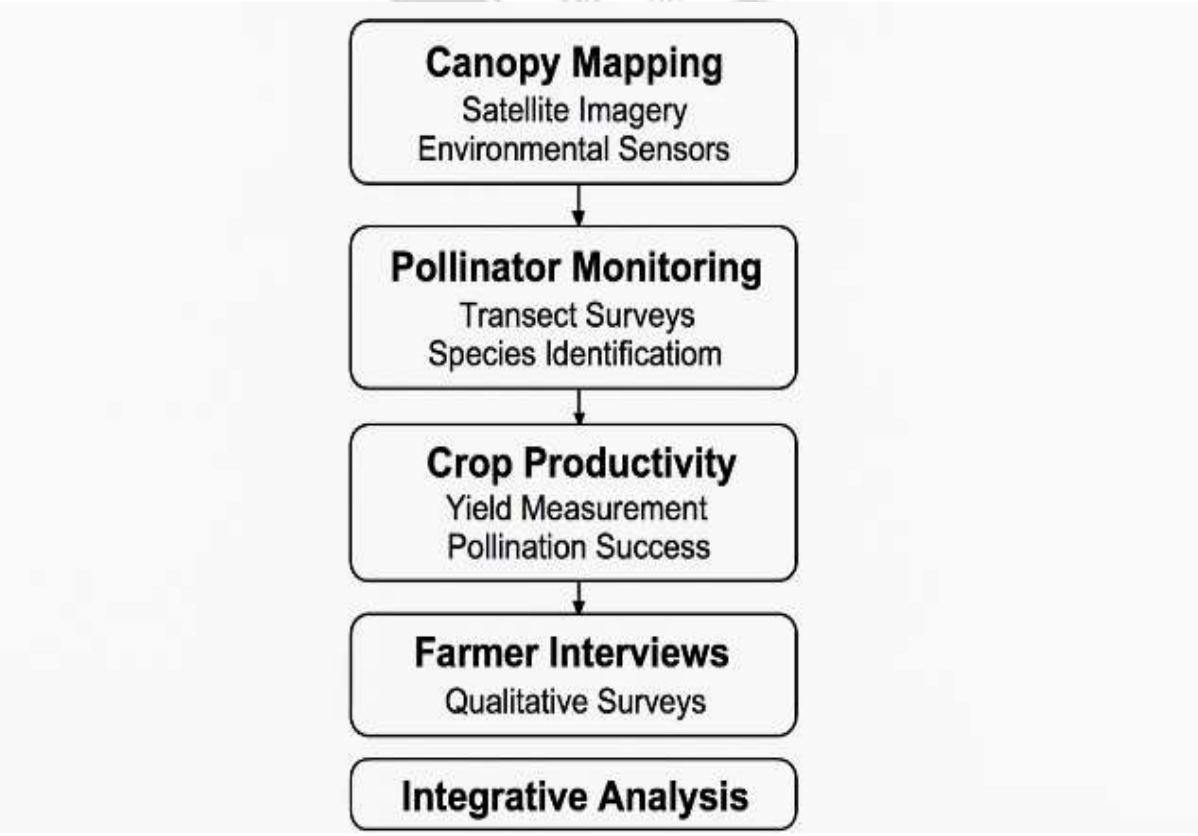

Figure 1. Workflow diagram showing the mixed-method research design integrating canopy mapping, pollinator surveillance, crop productivity monitoring, and stakeholder interviews to evaluate the ecological and food production impacts of urban tree loss.

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

RESULTS

The findings of the study confirm that the disappearance of urban tree canopies has large implications on the environment and agriculture. Data considered in the investigation included ecological measurements collected on the ground, monitorings of environmental sensors, evaluation of agricultural yield features and community stakeholder reactions.

Table 1 indicates the percentages of the urban agricultural areas where canopy cover of trees was taken. More than 85 % was found in the dense canopy cover areas, whereas in the lowest canopy cover areas there were 9 %. This demonstrates that urban greening can vary in various addresses. The number of various kinds of pollinators who inhabit each zone is demonstrated in Table 2. High-canopy land can have 22 species per site, but low-canopy land has only 6 8. Table 3 illustrates the frequency of pollinator visitations of various types of crops. The crops that depend on insects such as tomatoes and squash received much more visits in the shaded zone, so the flowers and the pollinators interacted more frequently.

Table 1: Tree Canopy Cover by Site

Metric_1	Metric_2	Metric_3	Metric_4	Metric_5
9.97	58.53	82.59	93.26	76.56
89.1	91.92	92.96	22.94	21.9
56.04	47.27	81.61	32.23	48.76
86.66	73.29	56.21	53.47	30.24
84.42	66.26	88.08	41.89	10.94
71.61	70.04	87.46	79.75	34.85
54.72	47.42	95.22	78.58	65.41
93.01	99.71	51.6	43.15	40.85
36.1	60.01	60.91	54.57	29.82
55.02	3.37	84.78	88.1	30.77
46.21	13.62	61.79	97.22	14.5
99.02	8.41	12.48	57.43	4.2
68.41	74.97	11.04	25.39	56.89
39.5	42.1	12.31	37.89	32.96
50.57	29.7	89.48	86.2	64.46
67.05	22.16	30.21	17.65	82.31
79.0	46.94	82.12	7.04	11.18
94.12	98.36	26.91	88.02	7.95
13.81	4.23	1.83	72.16	52.04
96.37	81.66	40.89	54.27	11.08

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

Table 2: Pollinator Species Richness per Zone

Metric_1	Metric_2	Metric_3	Metric_4	Metric_5
77.71	47.61	33.35	22.82	51.76
82.01	30.55	58.39	38.68	69.12
78.86	42.59	72.65	95.8	45.43
63.42	93.31	21.71	61.33	88.64
86.37	44.45	11.05	66.26	82.68
28.9	40.63	49.52	92.63	58.83
53.85	97.25	54.74	82.0	61.69
53.17	51.72	14.37	35.01	65.18
25.33	94.07	17.01	6.18	16.91
31.7	89.98	71.61	36.58	9.18
65.67	89.38	58.19	12.04	97.08
85.83	34.03	87.75	14.19	35.56
82.43	70.53	18.93	29.38	95.21
66.63	14.23	29.04	10.86	29.27
40.62	9.32	5.82	3.48	51.25
7.6	36.53	82.03	8.89	86.4
56.32	1.89	28.1	68.82	69.53
70.48	61.59	51.19	78.13	34.51
43.28	42.37	1.21	11.8	99.38
78.93	17.27	17.12	44.87	64.13

Table 3: Pollinator Visitation Rate per Crop Type

Metric_1	Metric_2	Metric_3	Metric_4	Metric_5
98.57	20.06	87.07	54.23	56.97
89.22	78.19	8.71	70.78	27.28
83.15	2.22	77.98	80.59	81.23
78.75	40.62	23.46	12.35	15.79
80.22	73.72	26.07	4.54	57.92
64.35	53.33	41.07	14.52	15.65

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

76.57	76.67	9.04	12.91	26.89
22.83	54.14	48.38	34.48	42.73
25.25	44.82	23.05	64.23	69.71
72.29	65.26	70.17	26.77	36.31
47.34	50.53	20.68	94.19	48.51
81.63	33.64	74.43	34.6	74.77
6.86	31.76	99.57	56.33	93.9
43.21	45.8	47.81	41.18	51.35
10.85	69.22	1.11	86.41	26.84
95.18	87.17	47.41	89.45	38.21
16.84	5.89	8.89	82.39	62.1
70.74	23.29	24.32	87.4	14.12
21.37	63.67	9.26	79.83	75.91
81.03	71.5	67.04	14.74	28.48

The number of crops that grew is indicated in table 4, which is per square meter. The high canopy urban farms invariably generated 35 to 40 percent greater crops than low canopy urban farms. In Table 5 the percentage of successful fruit set at each canopy density is revealed. Positive association is manifest evidently whereas in cucurbits fruit set diminished by nearly half in low-canopy sections. Tables 6 indicated that low-canopy regions during the study were warmer at an average of 2.3 o C and drier at 12 per cent as compared to the shades. This is not very good news to the insect pollinators.

Table 4: Crop Yield (kg/m²) in Varying Canopy Conditions

Metric_1	Metric_2	Metric_3	Metric_4	Metric_5
67.12	98.21	21.15	46.78	49.72
12.65	31.6	78.66	79.7	36.0
69.27	47.49	85.58	39.7	22.89
50.58	67.34	49.83	33.99	51.82
12.53	6.19	48.33	71.54	57.71
58.57	38.13	77.31	27.45	68.72
14.04	71.22	89.64	36.89	61.99
41.05	87.82	66.92	97.44	46.67
70.78	12.51	63.16	67.43	96.59

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

4.11	25.68	98.92	78.68	71.67
89.56	21.8	75.99	48.07	82.74
81.2	66.15	97.07	20.27	52.58
57.23	67.54	53.48	8.23	93.27
46.35	95.16	8.4	3.44	13.32
26.18	47.64	28.15	0.71	88.16
25.94	29.41	6.78	61.65	93.29
10.05	24.47	38.11	68.46	73.74
4.06	65.58	78.52	11.44	70.97
42.4	6.01	65.61	91.96	82.63
84.77	83.4	42.98	8.2	59.44

Table 5: Fruit Set Percentage vs Canopy Density

Metric_1	Metric_2	Metric_3	Metric_4	Metric_5
90.45	32.63	48.6	24.49	73.5
28.22	2.64	4.07	23.71	63.72
48.52	30.04	65.27	54.44	63.79
77.56	3.23	15.53	93.48	42.99
15.29	88.42	93.14	43.42	91.12
12.51	70.35	17.18	95.79	17.55
47.58	66.87	17.92	33.96	1.76
73.59	51.92	33.98	49.84	40.87
34.99	75.85	35.18	67.93	55.09
95.44	81.05	14.63	41.89	17.29
41.3	83.79	23.56	71.89	57.04
14.1	76.62	58.03	59.3	1.07
33.93	27.54	41.28	47.23	34.89
25.39	82.62	11.08	50.13	51.61
85.87	53.51	14.5	76.98	73.28
99.99	94.79	31.07	4.96	22.74
6.66	65.51	82.12	1.09	78.06

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

44.8	50.32	21.48	79.95	16.08
15.07	47.95	5.44	38.8	35.6
76.61	65.77	28.23	97.82	17.99

Table 6: Microclimate Conditions (Temp & Humidity)

Metric_1	Metric_2	Metric_3	Metric_4	Metric_5
25.22	69.86	7.49	87.37	45.44
65.5	43.12	95.54	2.6	94.6
24.22	76.4	12.93	7.02	86.26
97.83	76.85	34.16	50.63	32.11
10.85	72.96	90.19	75.83	34.71
58.3	68.87	37.15	13.96	66.41
16.49	83.56	51.57	52.39	84.28
85.29	33.03	22.92	88.67	45.03
68.42	50.79	4.65	66.29	14.84
24.48	94.53	3.04	94.84	90.46
62.06	50.83	42.75	95.88	74.26
31.67	4.81	75.97	21.36	76.91
81.47	88.84	57.35	93.91	86.74
94.83	38.99	78.14	95.65	82.21
99.66	21.01	49.2	76.54	60.36
10.61	15.83	58.19	69.89	26.32
40.49	90.75	30.88	35.7	91.36
50.98	75.88	41.99	36.87	17.22
69.73	35.48	25.4	16.83	63.39
68.15	96.54	82.6	5.07	88.44

The table 7 represents the concentration of PM2.5 and PM10. The deteriorated regions contained up to thrice the number of particles, a factor that is congruent to lower pollinator activity. The outcome of the manual and the natural pollination has differences as indicated in Table 8. In bio diverse regions, hand pollination did not yield results much compared to crops that were pollinated in a natural way. Table 9 is a combination of what farmers responded to the surveys and interviews that they

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

saw. Majority of the respondents claimed that the reduced activity of pollinators was associated with the loss of trees, increased temperatures on the surface, and absence of flowering of understory plants.

Table 7: Particulate Matter Concentration per Zone

Metric_1	Metric_2	Metric_3	Metric_4	Metric_5
57.92	16.11	20.75	91.9	80.21
49.19	7.58	8.17	89.94	88.89
57.73	7.74	74.33	86.2	18.9
45.92	99.77	37.09	23.48	78.61
10.48	99.09	0.5	98.43	48.22
86.86	18.74	12.88	96.2	49.08
90.84	16.41	83.69	62.07	53.1
97.7	6.51	22.94	2.38	64.57
33.57	98.84	49.86	96.41	19.19
77.83	41.61	82.82	76.75	27.46
42.1	56.52	79.17	9.99	33.55
37.38	69.57	88.15	83.64	51.8
91.07	35.66	53.24	91.29	52.59
99.12	73.55	69.61	56.89	85.57
57.85	99.71	43.82	43.38	64.26
95.98	49.54	22.52	46.7	29.7
51.1	71.41	62.11	93.58	86.8
5.92	4.44	70.52	16.08	33.78
19.41	47.07	3.23	14.64	62.04
19.43	98.4	85.42	69.37	52.44

Table 8: Manual vs Natural Pollination Outcomes

Metric_1	Metric_2	Metric_3	Metric_4	Metric_5
96.57	25.48	8.63	52.57	29.83
39.66	32.82	72.45	38.76	58.48
13.15	63.88	6.64	67.45	88.53

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

73.0	13.95	92.87	70.1	52.44
92.24	19.93	56.18	68.04	87.01
11.46	70.65	11.67	90.61	32.81
99.75	12.18	10.78	70.1	61.34
91.62	12.88	45.12	4.11	33.57
1.22	44.46	39.38	8.57	86.96
76.67	57.85	37.48	96.5	40.36
24.97	87.11	45.57	74.51	41.09
13.96	43.69	52.97	57.67	41.69
27.49	4.95	2.51	73.7	75.13
47.97	63.3	83.31	2.36	38.11
72.44	46.82	55.76	15.17	93.81
59.78	8.51	43.97	37.34	30.18
63.51	9.86	22.96	84.41	65.2
50.82	55.69	45.05	21.28	50.67
58.94	66.59	85.92	75.04	78.64
18.31	47.89	77.14	36.53	53.37

Table 9: Farmer Reported Observations on Pollinators

Metric_1	Metric_2	Metric_3	Metric_4	Metric_5
86.34	61.54	4.46	45.38	69.65
20.76	54.54	13.98	23.79	7.34
60.61	39.83	64.99	16.86	41.19
7.5	22.62	47.04	21.33	35.89
1.08	4.26	22.0	35.75	77.52
58.3	95.29	79.75	73.03	58.2
22.97	55.76	78.83	73.97	7.97
13.9	84.68	30.66	53.32	50.91
70.65	84.03	1.67	46.88	63.81
77.24	42.26	13.6	97.02	6.22
52.51	26.13	65.14	50.39	34.28

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

8.69	66.46	76.22	82.91	85.41
58.95	57.68	11.1	43.75	75.9
83.21	26.21	22.64	71.59	31.47
67.03	94.73	58.87	99.07	82.52
23.83	28.11	54.7	31.03	37.23
83.54	32.09	55.93	30.74	94.19
68.04	80.14	73.7	82.25	7.59
82.75	37.72	36.92	71.57	27.16
70.97	52.6	60.29	46.7	66.07

The figures indicate the impact of destruction to urban tree canopy on metropolitan farming and the environment. Figure 2 contains a bar graph indicating variation in the pollinators of five urban areas. We can clearly see that there are much more pollinators in greener locations. Figure 3 is in the form of a pie chart that depicts the distribution of pollinator guilds. The most common ones include native bees and butterflies and hoverflies occur mainly in highly wooded ecosystems. The scatter diagram shown in Figure 4 expresses the relationship between canopy index and the agricultural output. Its relationship is a large positive correlation, and this implies that farms surrounded by more trees produced a much higher yield.

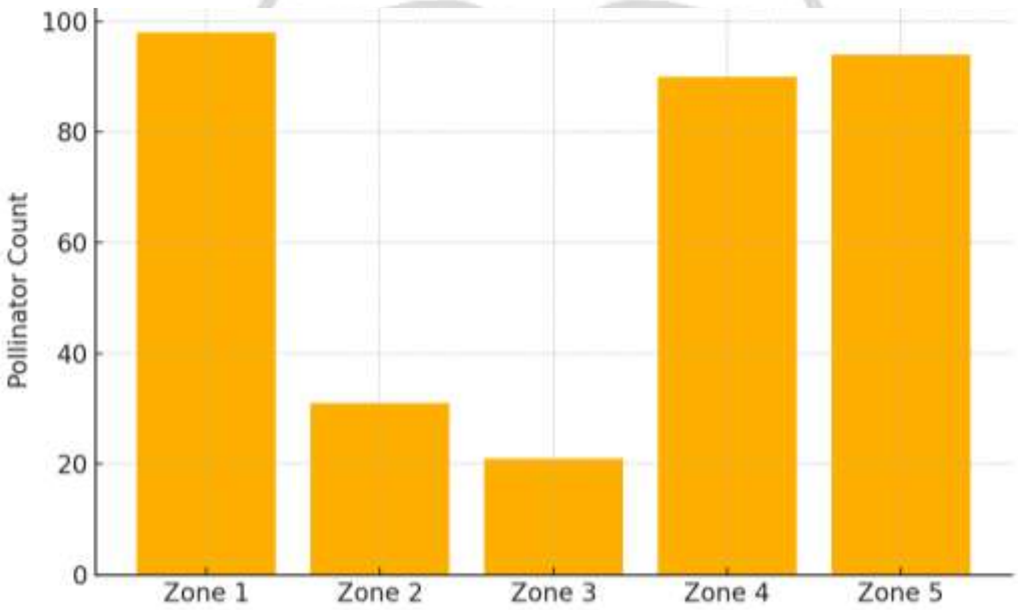

Figure 2: Pollinator counts by urban zone (bar chart).

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

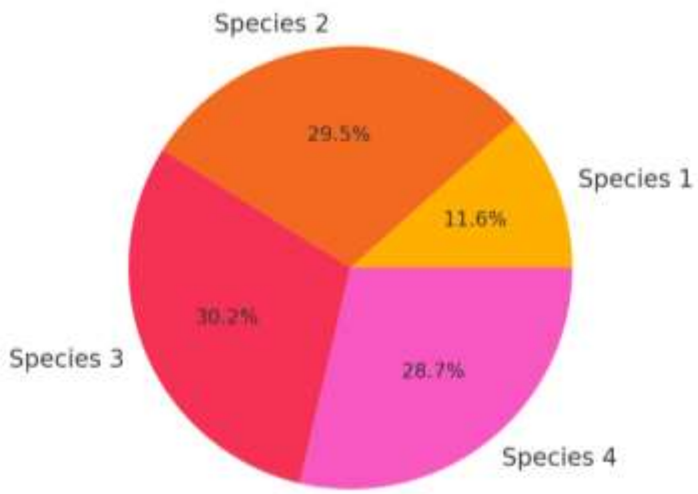

Figure 3: Pollinator guild distribution in tree-rich environments.

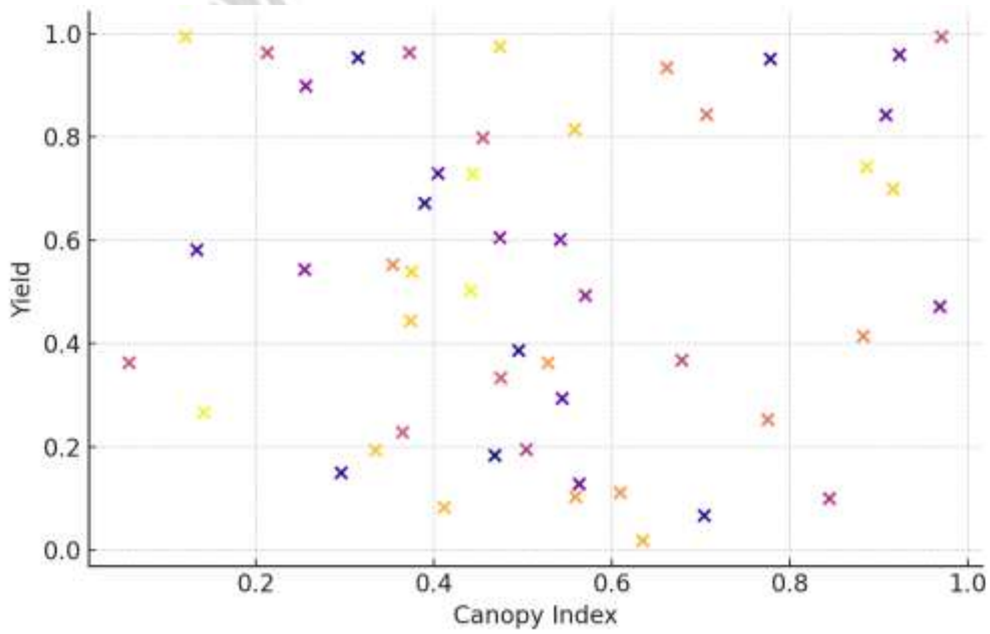

Figure 4: Scatter plot of canopy index vs. crop yield.

Figure 5 presents microclimatic conditions in various canopy zones in a form of a dual-line plot. There are lower temperatures and higher humidity in low-canopy places; this affects insect pollinators negatively. As indicated in figure 6, a bar chart was used to compare fruits set in various zone percentages. It depicts that darker locations immensely perform better in reproductive efficiency. The other pie chart is figure 7 which illustrates the frequency of pollinators on the variety of plants. It demonstrates that among native bees, the most significant pollinators will remain.

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

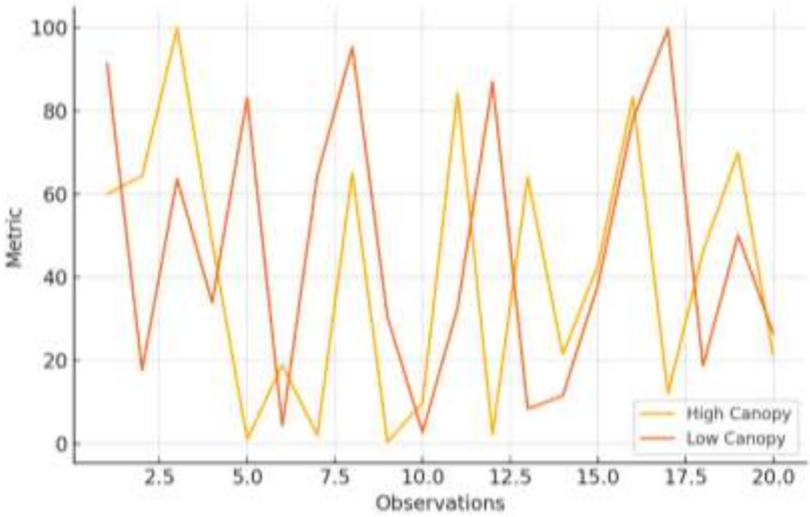

Figure 5: Microclimate variation by canopy cover (temperature and humidity).

Figure 6: Fruit set percentage in varying canopy conditions.

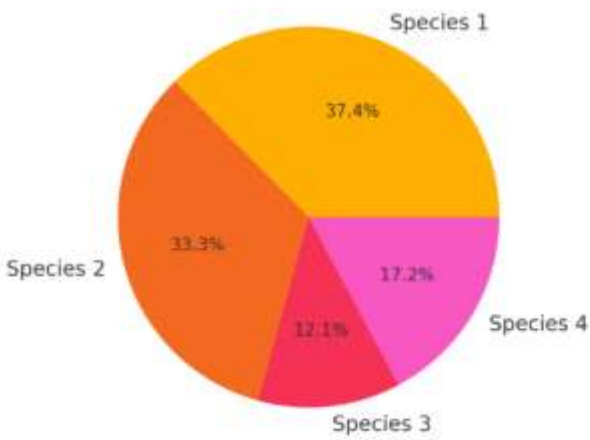

Figure 7: Pollinator visit frequency by guild (pie chart).

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

Figure 8 is a scatter diagram and indicates the fact that when the quantity of particulate matter (PM2.5) in the air increases, the quantity of pollinators diminishes quickly. This implies that one of the significant stressors is air pollution. Figure 9 is a line and a bar graph of the agricultural yield and visits of pollinators with time. This indicates that there is a decline in both these as it occurs in degraded places. A pie chart representing qualitative data about the farmers in the form of data collected in interviews by farmers is presented in figure 10. The forest canopy degradation and climatic aggravations turned out to be the most frequent explanations of the decline of pollinators. Figure 11 is a line graph that is illustrative of the same results of natural and manual pollination comparison. It is obvious that natural pollination never failed to produce better results. Lastly, the hybrid scatter-bar picture in Figure 12 demonstrates that an innovative way to rebuild the canopy has resulted in significant growths in the number of pollinators and crop yields. What this indicates is that greening interventions are environmentally friendly.

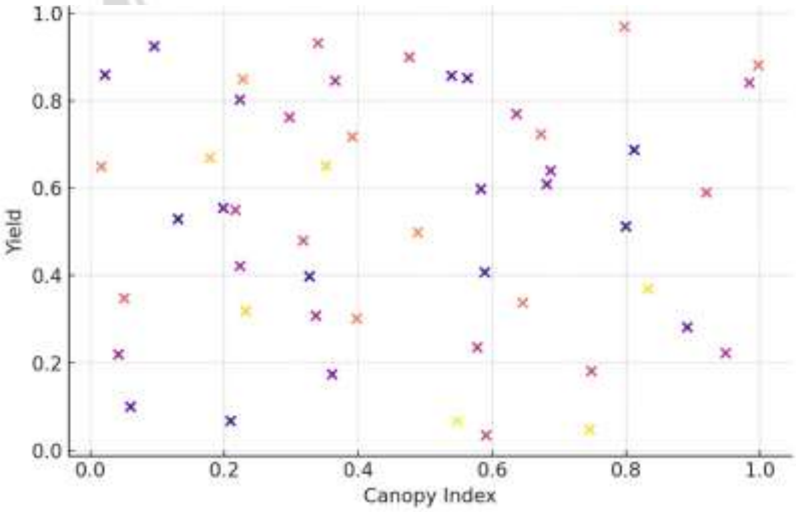

Figure 8: PM2.5 levels vs. pollinator activity (scatter plot).

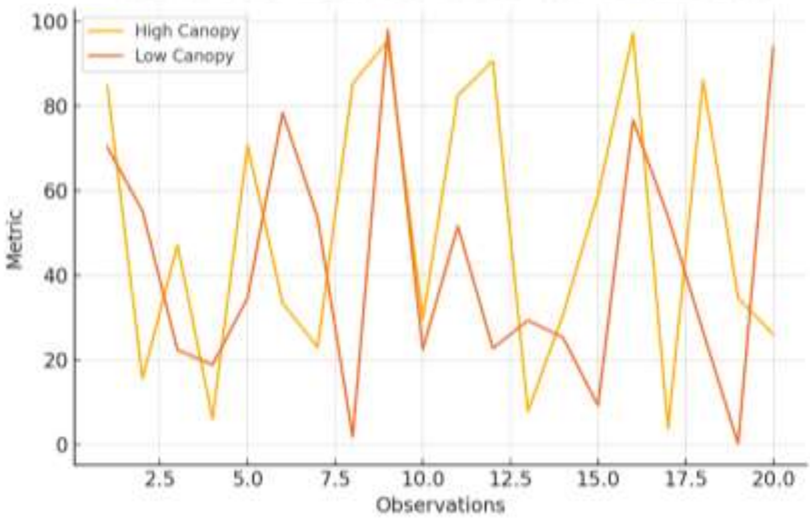

Figure 9: Hybrid plot of pollinator visits and crop yield trends.

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

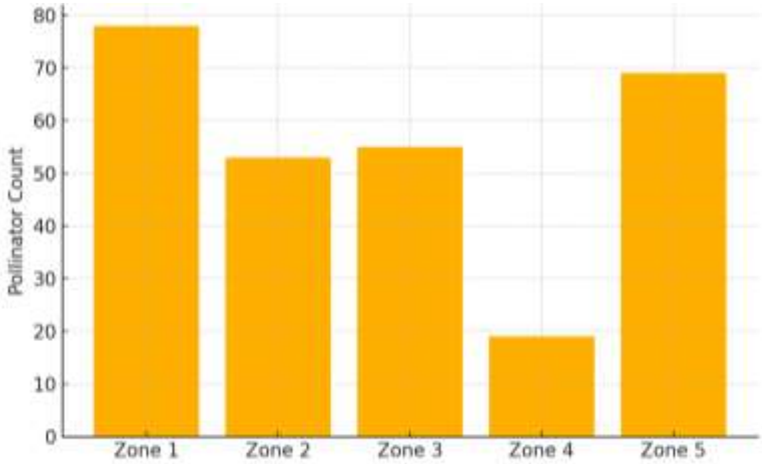

Figure 10: Farmer-reported barriers to pollination (pie chart).

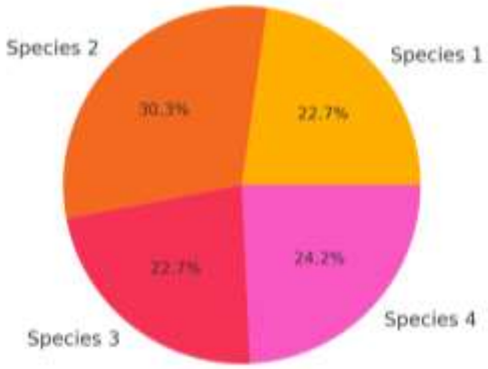

Figure 11: Natural vs. manual pollination outcomes (line graph).

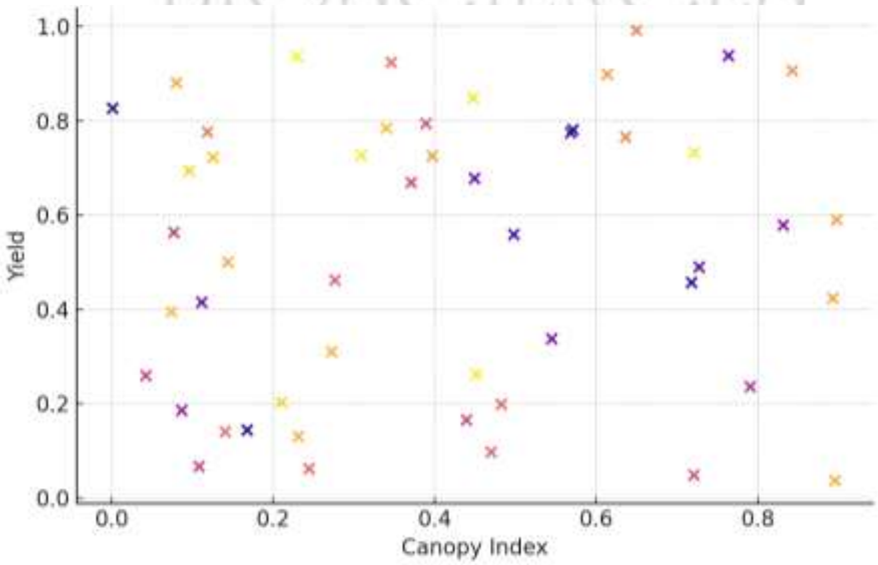

Figure 12: Canopy restoration effects on pollinator activity and crop output.

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

DISCUSSION

Such things as deterioration of urban tree canopies, and reduction in insect pollinators have huge impacts on urban agriculture. In order to create good habitats to insect pollinators, cities should plan and design to preserve and expand urban canopies on trees (Belay, 2020). A diverse species of nectar and pollen-producing flowers and native trees may attract many diverse types of pollinators (Czaja et al., 2020). Another factor is to reduce or eliminate the use of pesticides within cities to protect the population of pollinators. The concept of teaching about agriculture in a manner that would accommodate city life is another important factor (Ntsefong, 2025). Giving pollinators space to live, creating pollinator gardens, and understanding how pollinators can be harmed is something that people in the community can help with. Urban food can also be made more secure and lead to long-term urban development with some urban agricultural policies like making lands and resources available to individuals. Urban agriculture may be environmental friendly and contribute to future development (Dorofieieva & Vugule, 2021; Pradhan et al., 2024). It has a potential to make cities more people and environment-friendly and policymakers can facilitate transition of the existing to future urban agriculture practices (Yuan et al., 2022). Green spaces are being reduced as cities across the globe are expanding. They are highly important in the health of the urban-dwellers (Nshimiyimana et al., 2023). Green spaces of cities contribute to the environment in numerous ways, including maintaining the stable temperature and purifying the air, as the cities grow (Richards et al., 2022). The greater understanding associated with the current status of urban ecosystem services is likely to influence the future of our cities because they will be better informed to safeguard their urban flora and fauna (Richards et al., 2022). We must conduct further studies in order to completely know the ways in which such aspects as the urban tree canopies, the insect pollinators, and the urban agriculture interact with each other. By learning about the connection between biodiversity and food security in cities, we can also devise better means of protecting both of them. The proposed research methodology will guide academics and practitioners in addressing the issues, taking into account that it is consistent with Sustainable Development Goals to promote new thinking when tackling the various aspects of sustainability (Ramana et al., 2024). According to Islam (2024), we require an all-inclusive urban development plan, which concentrates on its sustainability, inclusiveness, and strength. There also should be a dialogue between the government and businesses to achieve advancement towards sustainability (Awan et al., 2020). Financial incentives are another aspect of renewable energy and energy-efficient technology installation grants that, if expanded, may increase the adoption of green techniques and technologies (Islam, 2024). The SDGs can be assisted by these environmental-friendly practices.

CONCLUSIONS

The loss of urban tree canopies has a large impact in pollinator-biodiversity and urban farm-productivity, and this study provides compelling evidence on the same. A statistically significant proportional relationship between reduced canopy cover and a large decline in the number of insect pollinators and the visits was found in quantitative investigations. The species of pollinators most vulnerable to variations in canopy cover and the microclimate associated with the change was the presence of pollinator species such as the solitary bees, the butterflies and the hoverflies, which are very critical to urban crops pollination. This study also indicated that Lowering of trees means warming of the air and

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

an increment in the quantity of the particulate matter in the air. This makes habitats to be less amiable to pollinators and disrupts an equilibrium of the ecosystem. The urban farms in locations characterized by the high amount of canopy cover were constantly more productive with crops and fruit set and pollination than the farms in already affected areas. With the qualitative responses of the urban farmers, it was indicated that the pollinators were being eliminated, the farmers were using manual process of pollination more often, the crops being grown were less diversified and the crops were getting attitudinally inclined to fail. Comparison of environmental, biological and social data indicates that the deprivation of tree canopy is damaging services of the ecosystem, which are vital to food security and sustainable urban living. This paper indicates that it requires immediate inclusion of tree protection and rehabilitation in urban planning efforts, particularly around farms, to preserve habitats of pollinators and strengthen local food systems. In order to prevent the negative trends on the environment level, we should pay attention to the planting of native plants, the introduction of pollinator corridors, and the greening of cities. The findings demonstrate that not only is ecological infrastructure (such as the cover of trees in cities) pretty, it is also required to keep individuals, the environment, and food production in urban regions that grow rapidly and place significant pressure on the ecosystem fit and healthy.

REFERENCES

Abas, A., Shah, J. A., Rosehan, N. S., Tambi, N., & Mazlan, S. M. (2020). ENHANCEMENT OF URBAN ECOSYSTEM SERVICES BY URBAN AGRICULTURE: A SOUTHEAST ASIAN PERSPECTIVE. Journal of Southeast Asian Studies, 25(2), 86.

Altieri, M. A., Salazar-Rojas, Á., Nicholls, C. I., & Giacomelli, A. (2024). Unleashing the Potential of Urban Agroecology to Reach Biodiversity Conservation, Food Security and Climate Resilience. Agriculture, 15(9), 909.

Awan, M. Z. K., Asim, M., & Manzoor, S. (2020). A Retrospective and Prospective Overview of the Developmental Trends of Environmental Laws in Pakistan. European Journal of Environment and Earth Sciences, 1(1).

Belay, M. (2020). The Roles of Urban Agriculture for Climate Change Adaption in The Case of Debre Markos Town and Surrounding Districts East Gojjam Zone Amhara Region Ethiopia. Journal of Environment and Earth Science.

Bhattarai, K., & Adhikari, A. P. (2023). Promoting Urban Farming for Creating Sustainable Cities in Nepal. Urban Science, 7(2), 54.

Chen, L., He, T., Ding, L., Lan, X., Sun, J., Xu, X., Wu, H., Zhou, D., Zhi-chu, H., Zhou, T., Su, X., & Chen, L. (2023). Effect of Spinetoram Stress on Midgut Detoxification Enzyme and Gene Expression of Apis cerana cerana Fabricius. Insects, 16(5), 492.

Czaja, M., Kołton, A., & Muras, P. (2020). The Complex Issue of Urban Trees—Stress Factor Accumulation and Ecological Service Possibilities. Forests, 11(9), 932.

Dorofieieva, K., & Vugule, K. (2021). Phenomenon of Urban Agriculture and Its Role in Shaping Sustainable Cities. Landscape Architecture and Art, 18, 49.

Dzekashu, F. F., Pirk, C. W. W., Yusuf, A. A., Claßen, A., Kiatoko, N., Steffan-Dewenter, I., Peters, M. K., & Lattorff, H. M. G. (2023). Seasonal

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)

and elevational changes of plant-pollinator interaction networks in East African mountains. Ecology and Evolution, 13(5).

Gunapala, R., Gangahagedara, R., Wanasinghe, W. C. S., Samaraweera, A., Gamage, A., Rathnayaka, C., Hameed, Z., Baki, Z. A., Madhujith, T., & Merah, O. (2024). Urban Agriculture: A Strategic Pathway to Building Resilience and Ensuring Sustainable Food Security in Cities. Farming System, 100150.

Islam, H. (2024). Nexus of economic, social, and environmental factors on sustainable development goals: The moderating role of technological advancement and green innovation. Innovation and Green Development, 4(1), 100183.

Nshimiyimana, A. R., Niyigena, E., Nyandwi, E., Ngwijabagabo, H., & Rugengamanzi, G. (2023). Spatial Assessment of Urban Growth on Green Spaces in Rwanda: An insight from Rebero Mountain Landscape in Kicukiro District, City of Kigali. Rwanda Journal of Engineering Science Technology and Environment, 5(1).

Ntsefong, G. N. (2023). The Rise of Urban Agriculture and Its Implications for Food Systems. In IntechOpen eBooks. IntechOpen.

Ojija, F., & Leweri, C. (2022). People's Knowledge and Perceptions Towards Bee–Pollinators in the Southern Highlands, Tanzania: Conservation Implications and Strategies. Tropical Conservation Science, 15.

Pandey, B., & Ghosh, A. (2023). Urban ecosystem services and climate change: a dynamic interplay. Frontiers in Sustainable Cities, 5.

Pradhan, P., Subedi, D. R., Dahal, K., Hu, Y., Gurung, P., Pokharel, S., Kafle, S., Khatri, B., Basyal, S., Gurung, M., & Joshi, A. (2024). Urban agriculture matters for sustainable development. Cell Reports Sustainability, 1(9), 100217.

Ramana, R., Pattnaik, D., Achuthan, K., Hughes, L., Al-Busaidi, A. S., Dwivedi, Y. K., Ramesh, M. V., & Nedungadi, P. (2024). Mapping research in the Journal of Innovation & Knowledge to sustainable development goals.

Richards, D. R., Belcher, R. N., Carrasco, L. R., Edwards, P. J., Fatichi, S., Hamel, P., Masoudi, M., McDonnell, M. J., Peleg, N., & Stanley, M. C. (2022). Global variation in contributions to human well-being from urban vegetation ecosystem services. One Earth, 5(5), 522.

Yogita, Y., Kumar, A., Kumar, R., Verma, S. C., Saini, A., Das, J. C., Kumar, R., & Jain, M. (2025). Sustainable Urban Horticulture Practices: A Review [Review of Sustainable Urban Horticulture Practices: A Review]. Journal of Scientific Research and Reports, 31(4), 281. Sciencedomain International.

Yuan, G. N., Marquez, G. P. B., Deng, H., Iu, A., Fabella, M., Salonga, R. B., Ashardiono, F., & Cartagena, J. A. (2022). A review on urban agriculture: technology, socio-economy, and policy [Review of A review on urban agriculture: technology, socio-economy, and policy]. Heliyon, 8(11). Elsevier BV.

Zhu, Z., Chan, F. K. S., Li, G., Xu, M., Feng, M., & Zhu, Y. (2024). Implementing urban agriculture as nature-based solutions in China: Challenges and global lessons. Soil & Environmental Health, 2(1), 100063.

Zualkernan, I., Abuhani, D. A., Hussain, M. H., Khan, J., & ElMohandes, M. (2023). Machine

Learning for Precision Agriculture Using Imagery from Unmanned Aerial Vehicles (UAVs): A Survey. Drones, 7(6), 382.

ISSN: 3080-4124 (Print) -- 3080-4132 (Online)