Balancing Nutrient Flows in an Urbanizing Landscape: Case Study of Yuen Long's Nutrient Metabolism

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Abstract

Due to rapid urbanization, nutrient-related issues, such as environmental pollution and waste of resources, are now significant in many cities. Urban metabolism is a multidisciplinary concept that focuses on figuring out the energy and various material flows in urban systems. To understand the holistic nutrient metabolism in the context of dynamic and complex town-scale urban systems, energy flow accounting in the discipline of urban metabolism and spatial nutrient flow mapping were applied as major research methods. This research shows the large accounted output nutrient waste and critically discusses the government measurement of decreasing the nutrient pollution from 1986 to 2020 in the case study area, Yuen Long Town, with management strategies proposal, expecting the nutrient can be reused with less output in the urban system after the design input.

Keywords

Nutrient balance; Urban metabolism; Urban rural nutrient recycling

1. Introduction

1.1. Statement of the nutrient-related issues

The rapid urbanization with domestic waste, agriculture, aquaculture, and industry development caused increasingly serious issues of nutrient flow(Færge, Magid and Penning de Vries, 2001; Chen et al., 2004; Tian et al., 2014; Pleissner, 2016). Yuen Long town is located in the built-up area along the Shan Pui River in Hong Kong, where nutrients are easily accumulated and output to the Deep Bay(Wong, 1996; Cha, Young and Wong, 1997; Kong et al., 2019). From 1986 to 2020, although new sewage treatment plants(YLSTW) and inflatable dikes were settled in the Shan Pui River Basin to control nutrient pollution, the problem of river water pollution has not been eradicated(EPD, 2017; Kong et al., 2019).

Shan Pui river basin was highly channelized for flood discharge since 1950, always receiving a great amount of runoff with waste when flooding, so its water quality keeps unsolved. It also has a long history of street markets that have thrown away many leftovers of poor quality products, and similarly all other food businesses such as convenience stores and restaurants. In addition, Yuen Long still retains a relatively large area of traditional farmland(FHB and FACD, 2015), however, it also leads to large fertilizer and feed usage, and it causes field runoff carrying large nutrients or eutrophication of fish ponds. There were still many villages remaining in the south after the Yuen Long New Town project was completed and reached 169921 of population in 2021(Census and Statistics Department, 2021). However, YLSTW does not have sufficient sewage capacity to collect do-

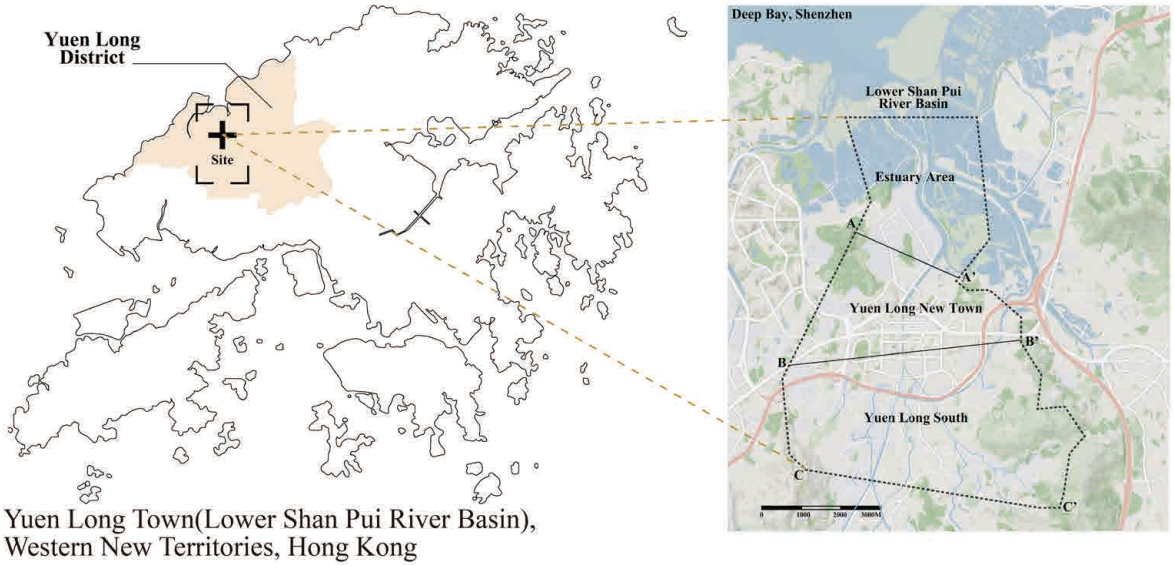


Figure 1. Location of Yuen Long town, Hong Kong(drawn by the author)

mestic wastewater from the villages, which has always been a problem.

1.2. Significance of urban metabolism accounting

In recent years, there has been a growing emphasis on employing quantified input and output measurements in water balance analyses(Færge, Magid and Penning de Vries, 2001; Leitzinger, 2001; Forkes, 2007). This emphasis is particularly relevant for conducting thorough examinations of urban nutrient dynamics and is important for urban metabolism research. Nutrient data from the urban perspective often appear fragmented and isolated. For example, nitrogen content is evaluated for water quality assessment, while nitrogen efficiency is studied in relation to agricultural products. However, urban metabolism accounting offers a method to systematically present diverse data and the interconnectedness of internal systems through energy flow.

Moreover, the complexity of the built environment system has led to increased research on urban conditions across different disciplines such as economy, social-cultural dynamics, and ecology(Aigwi et al., 2019; Stanganelli et al., 2020).. Without a synthesis of these fields of study, it becomes difficult to make correct strategic decisions.

1.3. Importance of urban nutrient study at town scale - Research Gap

Current studies of nutrient balance tend to focus on individual cities(Færge, Magid and Penning de Vries, 2001; Leitzinger, 2001; Forkes, 2007). On a smaller scale, nutrient balance research finds its application in the field of agriculture studies(Hajdu et al., 2004; Esilaba et al., 2005; Krishna, 2010). Most of these investigations use flow charts that present data solely for input and output, with the exception of some agriculture-related studies (Table 1). This discrepancy might be attributed to the limited availability of comprehensive and detailed official data provided by local governments. However, there are few studies on town-scale systems where internal systems are identifiable and more specific.

Because the nutrient cycling problem is an urgent one, Færge, Magid and Penning de Vries (2001) stated in their research that there is no need to wait for a new (metabolism) accounting result of other cities, and the obtained figures could be simply adjusted by considering economic inequalities and the population number. Hongkong, for example, comprises the Kowloon Peninsula and many other islands without a specific large river system to collect its branches. The region's unique features include special agriculture and aquaculture practices due to the constraints of limited flatland areas. These characteristics lead to complex nutrient outflow into the aquatic environment and very different nutrient content in locally produced food, which is different from most global counterparts. Even districts within Hongkong experience distinct nutrient flows. Therefore, identifying nutrient flows at the town scale can still be valuable for many specific regions.

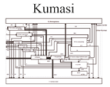
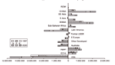
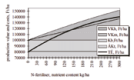
	Author(s)	Study Area	Aspects	Energy Flow
Large Scale (City/Nation)	Færge, Magid and Penning de Vries, 2001	Bangkok, Thailand	Organic waste	Bangkok
	Forkes, 2007	Toronto, Canada	Food metabolism	Toronto
	Leitzinger, 2001	Kumasi, Ghana	Composting	 Kumasi
	Grote, Craswell and Vlek, 2005	International	International trade; Ecology; Policy	 International
Smaller Scale	Hajdu et al., 2004	Farm level, Hungary	Economy, Ecology	 Hungary
	Esilaba et al., 2005	Smallholder farming, Uganda	Soil nutrient depletion	Uganda
	Krishna, 2010	Agroecosystem, South India	Genetic-related nutrient dynamic; Productivity	

Table 1. Review of the scales and aspects in the field of nutrient balance research

2.Research Aims

This study aimed to estimate the input and output of urban nutrient metabolism, clarify the nutrient flow in different types of internal systems and come up with a design strategy to approach a nutrient balance.

3.Research Questions

3.1. What are the existing values in the study area and which values are poor?

3.2. What is the quantified nutrient metabolism in the holistic system of Yuen Long town?

3.3. What is the spatial nutrient flow in the field of the built environment in Yuen Long town?

4.Methodology

4.1. A field study in the case study area and its existing values at the meso scale

This study examines a rapidly urbanizing society characterized by complex and diverse housing types and other land uses. This complexity has led to the oversight of many nutrition-related activities at the town level, and most residents cannot afford nutrient balance interventions and future upkeep without appropriate management and financial support.

Following a preliminary field analysis, the study area can be classified into three parts (from north to south): the estuary area, Yuen Long New Town, and Yuen Long South. The composition of various land uses and their occupancy ratios can be assessed using Google Earth. To determine the current site value, we categorize them according to multiple dimensions (ecological, economic, social, technological). Then, we draw the actual polygonal areas on the zoomed-in map. This representation can effectively capture the general characteristics of the three segments in the study area at a meso scale.

4.2. Energy(Nutrient) flow accounting

4.2.1. Theoretical framework for urban nutrient metabolism and data resource

The accounting methods used for different nutrient forms listed in the theoretical framework (Figure 2) are described in this section. As shown in Figure 2, the main nutrient inflow of Yuen Long results from the burning of fossil fuel to produce power, the use of fertilizers and feeds, and the food supply (imported food and locally produced food). The output is mainly landfill (food waste), two sewage treatment products (sludge and effluent), and nitrogen emission.

Due to the lack of atmospheric data, the flow from fossil fuel and N2 input toward atmospheric nutrient output is not included here. In addition, in terms of internal systems, parts of the local food production are not only supplied to the locals in Yuen Long but also to all parts of Hong Kong because they are major sources of Hong Kong's local food supply. Moreover, the water body receives both sewage treatment effluents and runoff, along with soil leachate.

Our accounting uses the latest data from 2008 to 2022 (mostly 2019-2022) to generate the annual nutrient input and output estimates (t yr-**1**) for Yuen Long town, focusing on nitrogen(N). The core data set for nutrient flow accounting includes the public data of the Hong Kong government, mainly supplied by the Environment and Ecology Bureau (EEB), Planning Department(PLAND), Agriculture, Fisheries and Conservation Department(FACD), Environmental Protection Department(EPD), and also other sources such as FAOSTAT(Food and Agriculture Organization) and the USDA Census of Agriculture (Livestock, Vegetables).

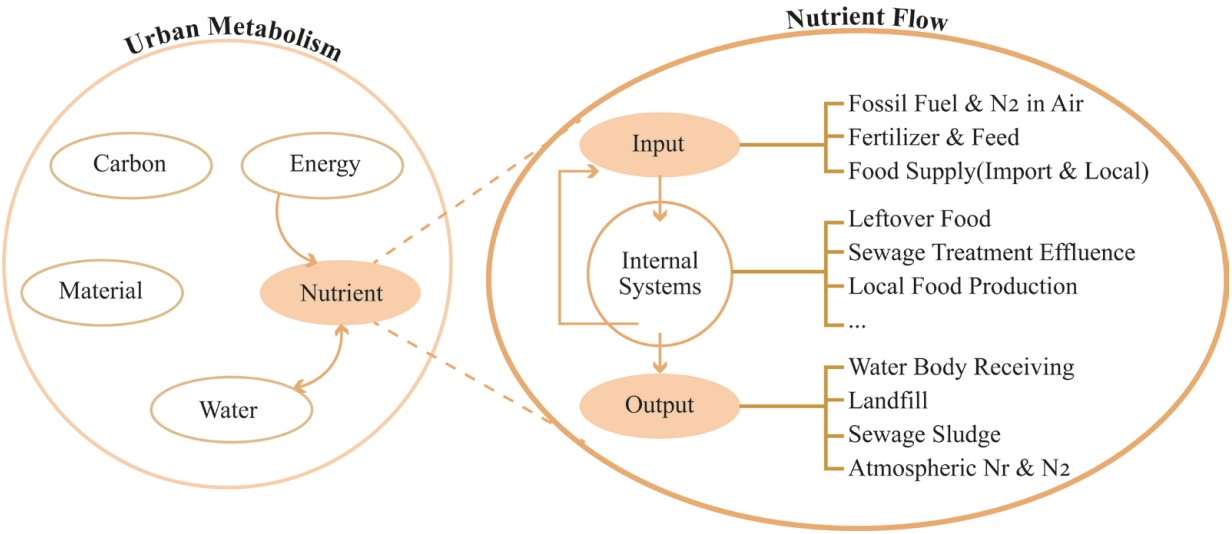


Figure 2. Theoretical framework of nutrient flow in the field of urban metabolism(developed by the author)

4.2.2. Nutrient content in the entire food supply as input

According to the database from FAOSTAT(Food and Agriculture Organization, 2022), the average protein supply from 2016 to 2018 in Hong Kong was 131.00 g capita^{-1} day^{-1}. To convert this number to the same unit of measurement(tyr^{1}), using 169921 as the population in 2021 as mentioned above(Census and Statistics Department, 2021) and a conversion factor (protein into N) of 0.162, the content of N is estimated to be 8126 t yr^{1}.

4.2.3. Nutrients in feed and fertilizer as input

The area of farmland, excluding fish ponds, in this study is determined based on the land utilization map provided by Planning Department. It is estimated to be about 300.6 ha. Note that this number may be inaccurate as the data are not intended for exact calculations(Planning Department, 2019). In 2016, the fertilizer (typically nitrogen, potassium, and phosphorus) consumption for farmland in Hong Kong was 2704.00 kg per hectare(Food and Agriculture Organization, 2020). Unfortunately, the organic matter content of Hong Kong's farmland is low, and the demand for fertilizers is high. Since the NPK ratio data in Hongkong are unavailable, this study assumes that Hong Kong generally uses urea, one of the common fertilizers, which contains 46% N(Nadarajan and Sukumaran, 2021), according to the AFCD(AFCD, no date), as the estimated maximum. This results in a fertilizer use of 373.90 t yr^{1}.

Because the relevant data for agricultural production in specific towns are not available, we estimate the corresponding food-related local production based on the ratio of the farm area of Yuen Long(300.6 ha) to the total agricultural land (733ha, including vegetable, flower, orchard, field land) in Hong Kong. Local farming produced 41 tons of vegetables, 330 pigs and 10800 poultry per day in 2022(AFCD, 2023). Growing one broiler require 4kg of feed, according to the government of Manitoba (2016), with as much as 23% protein(Fowler, 2022). In addition, for pigs, the feed need is about 295 kg/head median(Carlton Ernst, 2017), with a protein content mean of 23%. Hence, the combined weight of pig and poultry feed N is 783.7 t yr^{1}.

Most of the inland fishponds are located in the northwestern New Territories, including Yuen Long Town. As for aquaculture feed, intensive fish ponds need 2-3 kg of feed (wheat and pellet) for each kilogram of production (FAO, 1984). The freshwater fish production rate in 2020 was 2.21 t ha^{-1}(AFCD Annual Reports, 2021). This production figure is likely lower than the estimated local fish production when Google Earth is used to measure the area of ponds (about 277 ha) because of non-intensive production methods and some abandoned ponds. Therefore, the maximum need for aquaculture feed is 1836.51 t yr^{1}, which contains an average of 16% nitrogen(Chapman & Miles, 2010), and the corresponding nitrogen quantity could reach 293.84 t yr^{1}.

4.2.4. Nutrients in local food production

According to the result in 4.2.3, for a nitrogen content of 0.49% (mass) of fresh vegetables(Ford et al., 2023), 8.55 kg per head for live pigs and 0.07 kg per head for live poultry(USDA, 2023), the corresponding mass of nitrogen in Yuen Long can be estimated: 29.33 t yr^{-1} (vegetables), 422.24 t yr^{-1} (pigs), and 113.14 t yr^{-1} (poultry).

As stated in 5.2.3, aquaculture production in Yuen Long is estimated to be 612.17 t yr^{-1}, based on the per-unit protein data of finfish from USDA(2019) (there is no open data from the Hong Kong government), the estimated maximum nitrogen content in local aquaculture production is 21.92 t yr^{-1}. Hence, the total for the main local food production is 586.63 t yr^{-1}.

4.2.5. Nutrient content in landfilled food waste as output

Hong Kong discarded 3600 t of food waste into landfill every day in 2011, according to the Hong Kong Environment and Ecology Bureau (EEB, no date), while the food waste in Yuen Long is estimated based on the population: about 31569.74(t yr^{-1}). Because the food waste in Hong Kong contains 58–99 (mg g^{-1}) protein(Pleissner, Kwan and Lin, 2014), the maximum content of nitrogen can be converted to about 3125.4 t yr^{-1}.

4.2.6. Nutrient load in aquatic environments as output

Nutrients in sewage output are among the main reasons for polluting water. It is reported that the total nitrogen(TN) load to Deep Bay was 2002.03 t yr^{-1} before the planned upgrading treatment projects in 2025-2030(EPD, 2017), including both the effluence from the YLSTW (1.862 t day^{-1}) and the domestic waste of villages without sewers (3.623 t day^{-1}).

4.2.7. Nutrients in sewage sludge as output

Hong Kong generated approximately 30000 m3 of sludge per day in 2008(EPD, 2008). Sludge is the by-product of the sewage treatment processes of industrial and domestic sewage. The sludge quantity from YLSTW is 1.58% of Hong Kong's total, i.e., 341.75 t per day, assuming a density of 0.72 t/m^3. Although there are significant differences in the chemical properties of Hong Kong sludge due to a lack of exact data, this study estimated that sewage sludge comprises 3% nitrogen and 2% phosphorus(Ahmed, Fawy and Abdel-Hady, 2010). Therefore, it can be inferred that the sewage sludge in Yuen Long contains about 3742.16 (t yr^{-1}) of nitrogen and 2494.78 (t yr^{-1}) of phosphorus.

4.3. Mapping spatial nutrient flow

Based on the field study and site partition, specific nutrient-related locations are identified. These spots are colour-coded to correspond with nutrient flows. These examples can illustrate the actual physical movement of nutrients along streets and roads. Furthermore, the relationships and nutrient flow directions between different food providers and receivers (e.g., food wholesalers, street markets, supermarket, factories with nutrient waste, ancient temples, types of restaurants, sewage treatment, and farmlands) are shown as lines with corresponding colours.

Hence, detailed internal nutrient flow activities can be visualized. In addition, according to HK Audit Commission(AUD, 2010) in the mapping, the sewer pipelines can visually represent the physical direction of internal wastewater inflow to the sewage treatment with the effluence of the treatment as output.

5. Research Findings and Discussion

5.1. Land use and current value

Clearly, the estuary area in the north of Yuen Long is dominated by fishponds (many of which are abandoned as meadows or reef beds) and industrial land. Yuen Long New Town is an urban built environment but still has villages with ancient temples. Yuen Long South, however, is sub-urban, dominated by villages, farmland, and industrial areas - see Figure 3.

Figure 4 shows the existing values somewhat correlate with the type of land use, and the characteristics of the three segments within the study area are distinct. The estuary area has large areas of fish ponds which provide ecological value. However, they do not benefit the environment too much due to the pollution (which includes nutrients) today. There is an industrial estate, which is linked to technological value, whose land utilization rate has been declining during this decade(info.gov.hk, 2017). However, the vacant land on this estate has been

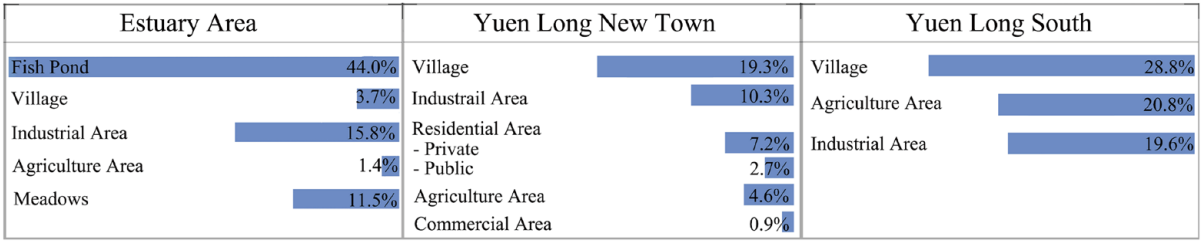


Figure 3. Land use occupation ratio of the three parts(drawn by the author)

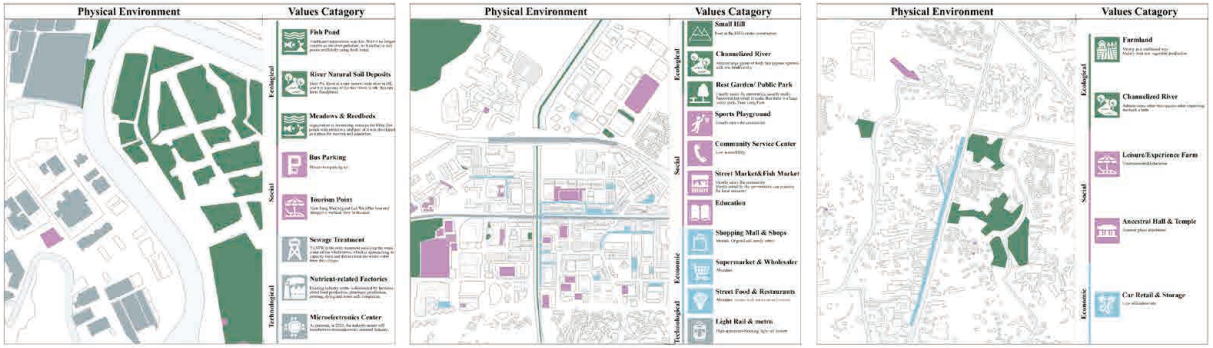


Figure 4. Value of the three parts in four dimensions at meso scale(drawn by the author)

earmarked for the construction of a Microelectronics Centre in line with re-industrialization and estate transformation goals. It appears that all commercial areas and street markets are located in the new town area, whereas leisure parks in urban areas are mostly fragmented and small in size - similar to other areas in Hong Kong. Overall, the area meets the basic requirements of residents and tourists. However, there is room for improvement in terms of ecological dimensions. Finally, smaller valuable areas exist in the southern part, mainly the ancestral hall in villages, farmland and car storage, and maintenance land within the village. Some of these were converted from abandoned farmland. Without high-tech industry, the value of an industrial area cannot be very high in Yuen Long South.

As for the water body, the river has been fully channelized, and plants grown by the government appeared in the town's new region. Scattered patches of vegetation persist intermittently along the south stretches of the Shan Pui River, according to the field study. Since the water level of the channel can suddenly rise during a flood, the plant species on the banks may not be able to adapt. Hence, test planting of the species selection is necessary if the intention is to help decrease pollution by nutrients.

5.2. Nutrient flow and waste

Overall, the accounted main nitrogen output of Yuen Long town is close to the figure for input when fossil fuel usage and atmospheric N are not considered - Figure 5.

The output of the sewage treatment process is high and accounts for over 46.8% of the total output. The government planned to upgrade YLSTW in 2025-2030, and EPD assumed more than half of the aquatic Nitrogen load caused by sewer will be reduced (by 1055.58 t/yr) when the upgrade is finalized. However, the nitrogen output in sewage sludge will rise significantly (by 5880.54 t/yr) at the same time when more villages connect to the treatment facility. Therefore, the nutrient balance problem may not be solved by improving the treatment process. In Hong Kong, attempts were made to reuse nutrients from sludge for agricultural use. This initiative arises from the constraints on landfill space, and incineration can not help much because nitrogen by-products are still released into the atmosphere, which requires alternative disposal methods. Besides, the sludge from Yuen Long is different from other sewage plants in Hong Kong. This is because of the inclusion of leather industrial waste in the Yuen Long sludge, which results in its chromium concentration exceeding the allowed limits, so it cannot be used for agricultural purposes(Wong et al., 2001). However, with the science and technology changes in Yuen Long Industrial Estate, the problematic chromium pollution may decrease. Moreover, if the sewage from industrial areas can be gathered in a separate treatment facility, and effluence can be reused as grey water, the problem can be (partially) mitigated.

Nitrogen in food waste from landfills accounts for 33% of the total nitrogen output and also leads to nitrogen deposition after incineration. Apart from the incineration plant, the Hong

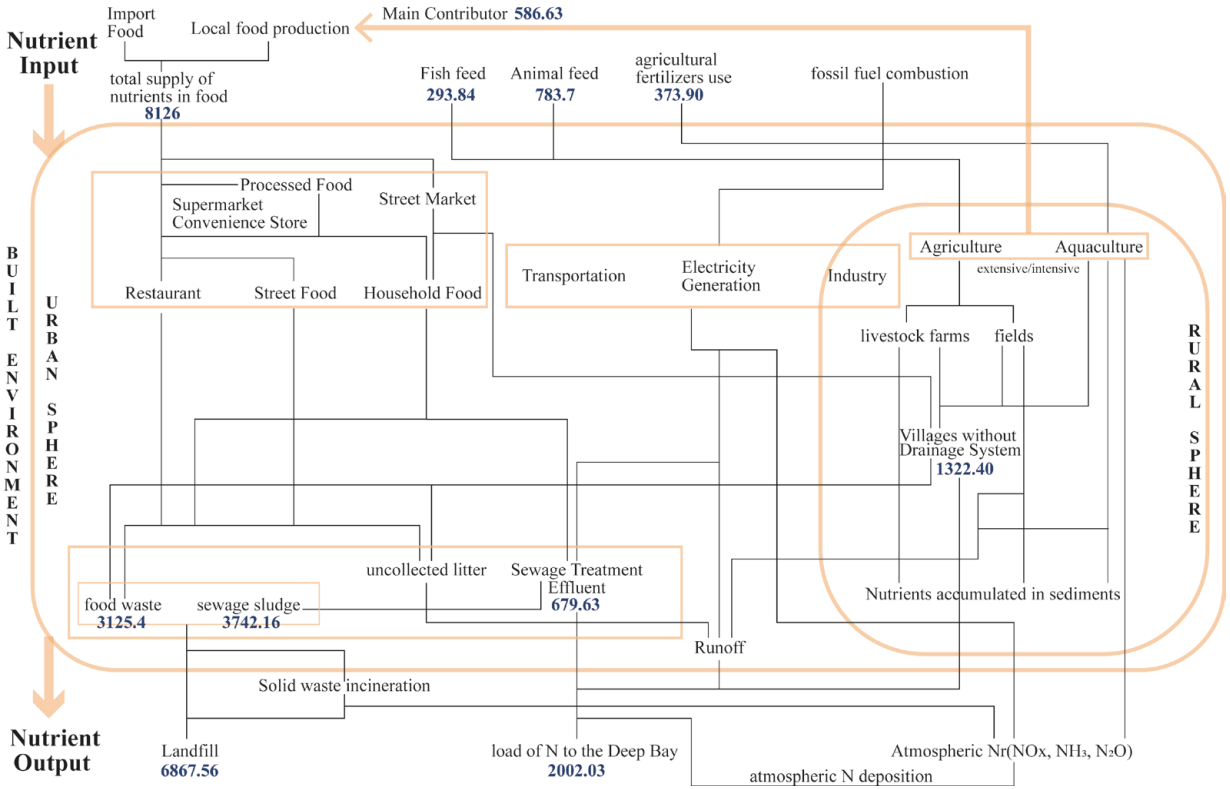


Figure 5. Holistic nutrient(N: t yr^{-1}) flow in Yuen Long town system(drawn by the author)

Kong government is operating the new O Park, which uses anaerobic digestion technology that produces much less atmospheric nitrogen(Malet et al., 2023), and it generates biogas, and compost as reuse. However, the required transport distance with respect to emissions can be problematic. While reusing leftovers as animal feed before disposal can decrease overall waste output, it is important to consider that energy is expended and losses occur during feed production.

Even assuming that all feed in Yuen Long Town is provided by food waste, there will still remain 2017.86 t yr^{-1} nitrogen in food waste. Considering the situation above, the anaerobic digestion plant and reuse as feed are promising directions. For example, if the leftovers from street markets and chain convenience stores can be managed and gathered in compost bins and transported to a nearby anaerobic digestion plant of medium size (not as large as O Park with 200t/day), the nitrogen output may be reduced due to lower energy use. At the same time, the nitrogenic fertilizer and feed inputs are small, and nutrient

resources can be saved.

Based on the discussion above, it may also pay off to reduce resource waste if the nutrient input can be reduced following the proposed improvements in the aquatic environment, as outlined earlier. Taking a nutrient recycling method as an example, the traditional way of aquaculture in Hong Kong is Gei Wai. This approach also requires less commercial feed because the fish and shrimps can consume the food seasonally supplied by estuary flooding. However, its production efficiency dropped quickly in the 1990s because of the pollution in Deep Bay(Cha, Young and Wong, 1997). This study proposes that, after the nitrogen load has been reduced, some abandoned meadows may be used to test the Gei Wai production. This may be helpful for decision-makers to decide whether to reintroduce it or not. Further research is urgently needed on social acceptance and the future energy flow aspects of these management strategies.

5.3. Mapping nutrient flow

Based on the research findings in 5.1. and 5.2., spatial nutrient mapping (Figure 6) can be generated fairly easily. As mentioned in 4.3., this map can be useful to decision-makers because it shows real-life locations, distances, and relations. For instance, it can be seen that although larger brownfield areas in the southern region could accommodate biogas plants or composting facilities, their distance is not conducive to efficient food waste collection from the new town area. However, these spaces are suitable for composting agricultural materials generated from nearby plants. This also supports the need (see 5.2) to sort and collect food waste systematically for anaerobic digestion or composting from nearby street markets in a new town, which should result in higher stakeholder acceptance. Furthermore, it can be seen that the industrial estate sewer water is collected in one pipe before it flows to YLSTW, means that the mentioned way(see 5.2) to separate industrial wastewater that could be feasible.

5.4. Constrains and data quality

When measuring land use occupation through Google Earth, the figures may not be very accurate, but it appears high to obtain valuable research insights. Deviations in nutrient accounting may be large for several reasons. Firstly, even though fossil fuel burning and emission are not considered here, it is still noticeable that a large amount of nitrogen emission might contribute to the nutrient content received by water bodies through atmospheric deposition(Sundarambal et al., 2010). This fact causes the figure estimate based on the nitrogen content in the water body to be likely larger than the true number. Secondly, the nutrient load in the aquatic environment data from EPD(2017) does not include the runoff carrying nutrients during heavy stormwater, which reduces the output. Thirdly, even though not all the data align with the same year, this study has made efforts to minimize substantial deviations during the data collection process.

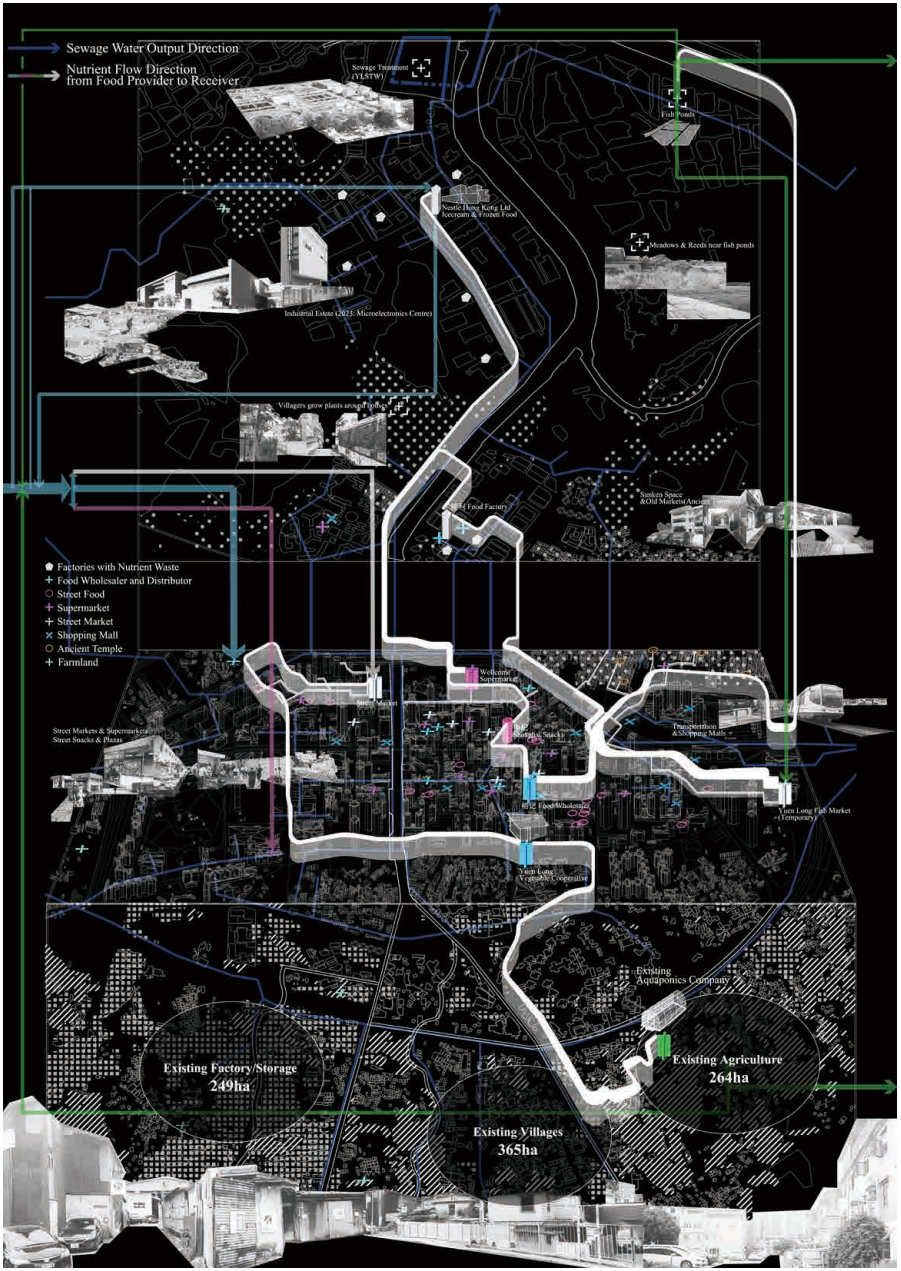


Figure 6. Mapping of spatial N flow example in Yuen Long town at macro scale(drawn by the author)

6. Conclusion

Based on the results of a field study and a nutrient flow analysis within the field of urban metabolism, this study discussed and proposed several potential management strategies. These strategies include reusing leftovers, reintroducing traditional aquaculture and separating industrial sewage outputs, and so on, which can reduce nutrient resource wastage or pollution within the Yuen Long town system through nutrient recycling. However, future design practice needs to evaluate and test multiple nutrient management schemes, considering value shifts, nutrient balance changes, and spatial factors. This evaluation should extend beyond individual measures or technologies. Otherwise, the nutrient flow results obtained from this research cannot be applied effectively.

Reference List

[1] ADCP/REP/84/21 - Inland Aquaculture Engineering (1984) APPENDIX A - Fish Pond Technologies. Available at: https://www.fao.org/3/x5744E/x5744e00.htm

[2] AFCD (no date). 施肥要訣. [online] https://www.afcd.gov.hk/english/agriculture/agr_useful/agr_useful_cul/files/fertilizer.pdf. Available at: https://www.afcd.gov.hk/ [Accessed 18 Aug. 2023].

[3] (No date) A Food Waste & Yard Waste Plan for Hong Kong - eeb.gov.hk. Available at: https://www.eeb.gov.hk/en/files/FoodWastePolicyEng.pdf

[4] Agriculture in HK (2023) Agriculture, Fisheries and Conservation Department The Government of the Hong Kong Special Administrative Region. Available at: https://www.afcd.gov.hk/english/agriculture/agr_hk/agr_hk.html

[5] Aigwi, I.E. et al. (2019) 'A performance-based framework to prioritise underutilised historical buildings for adaptive reuse interventions in New Zealand', Sustainable Cities and Society, 48, p. 101547.

[6] AUD (2010). Environmental Protection Department Drainage Services Department Provision of village sewerage Audit Commission. [online] p.8. Available at: https://www.aud.gov.hk/pdf_e/e55ch09.pdf [Accessed 2010].

[7] Carlton Ernst (2017). Swine Nutrition. [online] UNH Cooperative Extension. Available at:

https://extension.unh.edu/resource/swine-nutrition [Accessed 18 Aug. 2023].

[8] Cha, M.W., Young, L. and Wong, K.M. (1997) 'The fate of traditional extensive (gei wai) shrimp farming at the Mai Po Marshes Nature Reserve, Hong Kong', in Asia-Pacific Conference on Science and Management of Coastal Environment. Springer Netherlands, pp. 295–303.

[9] Chapman, F.A. and Miles, R. (2010) 'Interpreting a fish food package label', EDIS, 2010(2). doi:10.32473/edis-fa159-2009.

[10] Chen, X. et al. (2004) 'Integration of multisource data for water quality classification in the Pearl River estuary and its adjacent coastal waters of Hong Kong', Continental shelf research, 24(16), pp. 1827–1843.

[11] (2021) Departmental Annual Report 2020-2021. rep. Agriculture, Fisheries and Conservation Department . Available at: https://www.afcd.gov.hk/misc/download/annualreport2021/en/fisheries

[12] Environmental Protection Department(2008) Sludge treatment facilities (STF) - fts.com.hk. Available at: http://fts.com.hk/epd/infocen/default.htm

[13] EPD (2017). 5.7.2. Operation Phase [online] Epd.gov.hk. Available at: https://www.epd.gov.hk/eia/register/report/eiareport/eia_2592019/CD%20for%20EPD_HTML/HTML/EIA%20Report/S5_Water.htm#_Toc533889 [Accessed 18 Aug. 2023].

[14] Esilaba, A.O. et al. (2005) 'Resource flows and nutrient balances for crop and animal production in smallholder farming systems in eastern Uganda', Agriculture, ecosystems & environment, 109(3), pp. 192–201.

[15] Færge, J., Magid, J. and Penning de Vries, F.W.T. (2001) 'Urban nutrient balance for Bangkok', Ecological modelling, 139(1), pp. 63–74.

[16] (2008) FISHERIES IMPACT ASSESSMENT. rep. Environmental Protection Department. Available at: https://www.epd.gov.hk/eia/register/report/eiareport/eia_1492008/EIA%20Report/pdf/FLW_EIA_S12.pdf.

[17] Food and Agriculture Organization(2020) Fertilizer consumption (kilograms per hectare of arable land) - "fao ... Available at: https://data.apps.fao.org/catalog/dataset/fertilizer-consumption

[18] Food and Agriculture Organization(2022) Undata | record view | average protein supply (G/Cap/day) (3-year average). Available at: https://data.un.org/Data.aspx?d=FAO&f=itemCode%3A21013

[19] Food and Health Bureau and Agriculture, Fisheries and Conservation Department (2015). Business Consultation e-Platform. [online] www.gov.hk. Available at: https://www.gov.hk/en/theme/bf/consultation/ [Accessed 18 Aug. 2023].

[20] Fooddata Central Search Results (2019) Fish, salmon, Atlantic, farmed, cooked, dry heat. Available at: https://fdc.nal.usda.gov/fdc-app.html#/food-details/175168/nutrients

[21] Fooddata Central Search Results (2023) FoodData Central. Available at: https://fdc.nal.usda.gov/fdc-app.html#/food-search

[22] Ford, S. et al. (2023) 'Amino Acid Analyses of Plant Foods Used in the Dietary Management of Inherited Amino Acid Disorders', Nutrients, 15(10). Available at: https://doi.org/10.3390/nu15102387.

[23] Fowler, J. (2022). Nutrition for the Backyard Flock. [online] Available at: https://secure.caes.uga.edu/extension/publications/files/pdf/C%20954_5.PDF [Accessed 18 Aug. 2023].

[24] Hajdu, D. et al. (2004) István Sz cs (Chairman). real-j.mtak.hu. Available at: http://real-j.mtak.hu/21292/1/Studies%2Bin%2BAgricultural%2BEconomics%2BNo.%2B101.pdf#page=89 (Accessed: 4 May 2023).

[25] Kong, H. et al. (no date) Responses of macrobenthic communities to pollution control and fisheries management measures in Hong Kong. Available at: https://scholars.hkbu.edu.hk/ws/portalfiles/portal/55044032/OA-0644.pdf.

[26] Krishna, K.R. (2010) Agroecosystems of South India: Nutrient Dynamics, Ecology and Productivity. Universal-Publishers.

[27] Land Utilization (2019) Planning Department - Land Utilization in Hong Kong. Available at: https://www.pland.gov.hk/pland_en/info_serv/open_data/landu/index.html

[28] Malet, N. et al. (2023) 'Does anaerobic digestion really help to reduce greenhouse gas emissions? A nuanced case study based on 30 cogeneration plants in France', Journal of cleaner production, 384, p. 135578.

[29] Nadarajan, S. and Sukumaran, S. (2021) 'Chapter 12 - Chemistry and toxicology behind chemical fertilizers', in F.B. Lewu et al. (eds) Controlled Release Fertilizers for Sustainable Agriculture. Academic Press, pp. 195–229.

[30] Pleissner, D., Kwan, T.H. and Lin, C.S.K. (2014) 'Fungal hydrolysis in submerged fermentation for food waste treatment and fermentation feedstock preparation', Bioresource technology, 158, pp. 48–54.

[31] Province of Manitoba - Agriculture. (2016). Agriculture | Province of Manitoba. [online] Available at: https://www.gov.mb.ca/agriculture/livestock/production/poultry/basic-feeding-programs-for-small-chicken-flocks.html [Accessed 18 Aug. 2023].

[32] Stanganelli, M. et al. (2020) 'An integrated strategic-performative planning methodology towards enhancing the sustainable decisional regeneration of fragile territories', Sustainable Cities and Society, 53, p. 101920.

[33] Sundarambal, P. et al. (2010) 'Impact of biomass burning on ocean water quality in Southeast Asia through atmospheric deposition: field observations', Atmospheric Chemistry and Physics, 10(23), pp. 11323–11336.

[34] Tian, L. et al. (2014) 'Assessment of Total Suspended Sediment Distribution under Varying Tidal Conditions in Deep Bay: Initial Results from HJ-1A/1B Satellite CCD Images', Remote Sensing, 6(10), pp. 9911–9929.

[35] Wong, W.L. (1996) The physical and chemical characteristics of the sediment and water in Mai Po Gei wai. B. Sc. thesis, City University of Hong Kong.

[36] www.census2021.gov.hk. (2021). 2021 Population Census. [online] Available at: https://www.census2021.gov.hk/ [Accessed 18 Aug. 2023].

[37] www.info.gov.hk. (2017). 立法會十九題：再工業化及工業邨. [online] Available at: https://www.info.gov.hk/gia/general/201705/17/P2017051700491.htm [Accessed 20 Aug. 2023].