The Influence of Greenness on Non-Communicable Diseases (NCDs) Prevalence in Semi-Urban and Rural Areas: A Case Study of Chiang Mai Province, Thailand

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Abstract

Green areas contribute to the creation of favorable surroundings that have significant effects on people's health. This study examines the distribution of greenness and its influence on NCDs in the subdistricts of San Pa Pao, which represents the semi-urban area, and Thep Sadet, which represents the rural area, Chiang Mai province, Thailand. The greenness data obtained from Landsat 8 satellite images and the NCD data of the residents came from Ban Pa Kang Subdistrict Health Promotion Hospital and the Chiang Mai Provincial Public Health Office, which was separated into three groups: healthy, at-risk, and patient. To determine the mean Normalized Difference Vegetation Index (NDVI) surrounding residences, a buffer was constructed from the residents' position in distance 300 meters. The mean NDVI differences between the health groups were analyzed using one-way ANOVA. The results from the analysis found that in San Pa Pao and Thep Sadet subdistrict, the mean of NDVI surrounding residence of the patient group is significantly lower than the at-risk and healthy groups with the statistically significant level at 0.05. However, the influence of greenness on NCDs is complex, the physical and lifestyle characteristics have played an important role in the influence of greenness on NCDs illness, which requires further study to precisely explanation.

Keywords: Greenness, Non-Communicable Diseases (NCDs), Normalized Difference Vegetation Index

1. Introduction

Greenness has been widely recognized for their profound benefits on mental health and overall well-being. As environments can significantly enhance caring and well-being of mental health, particularly for psychiatric patients, a connection with nature supports the recovery process [1]. The presence of greenness in urban environments, furthermore, significantly influences the prevalence and management of Non-Communicable Diseases (NCDs) [2].

Research indicates that greenness is associated with a reduced prevalence of overweight/obesity, diabetes, and hypertension, with odds ratios (OR) of 0.86, 0.83, and 0.77, respectively, suggesting a strong inverse relationship between greenness and these conditions [2]. In addition, greenness contributes to improved air quality by reducing pollutants such as carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, and particulate matter, thereby lowering the risk of cardiovascular and respiratory diseases by up to 25% among urban populations. Mortality from circulatory diseases was lower among populations living in green areas [3]. Additionally, the proportion of greenness significantly impacted diabetes rates at the .05 level [4], consistent with studies by [5] in the Netherlands and [6] in Leicestershire, UK. Furthermore, a detailed assessment of non-cancer risks related to pollution found that the presence of greenness significantly reduces such risks [7]. Risk factors for NCDs decrease with increased greenness and infrastructure that supports walking and cycling, access to aesthetics, and social interaction areas [8]. Housing with a higher proportion of greenness was negatively correlated with NCD prevalence, indicating that residents in greener areas had a reduced risk of developing NCDs.

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Green vacant lots in Philadelphia, Pennsylvania, reduced stress and increased physical activity among urban residents [9]. Similarly, [10] stated that greater access to greenness reduces mental health issues such as depression and anxiety. The relationship between physical environments and health has shown positive outcomes. However, the distribution and accessibility of greenness are crucial, as uneven distribution can diminish public health benefits [11]. The application of geospatial information can help monitor the distribution of greenness and people's access to greenness, which can enhance community health.

There are various methods for analyzing greenness, with the Normalized Difference Vegetation Index (NDVI) being widely recognized approaches [12][13][14] and [15]. NDVI measures the proportion of vegetation covering a surface, with values ranging from -1 to 1. The calculation of greenness proportions around residential areas was studied by [12] regarding greenness exposure and mortality among women in 11 U.S. states (California, Connecticut, Florida, Maryland, Massachusetts, Michigan, New Jersey, New York, Ohio, Pennsylvania, and Texas). The study measured the average NDVI within a 250-meter radius around participants' homes, considering the direct access range to nearby greenness. The results showed that women living in areas with higher average NDVI within 250 meters had a 12% lower mortality rate from NCDs than those living in areas with lower NDVI. Additionally, [13] studied the distance from green spaces and physical activity among Swedes, finding that those living more than 1 kilometer away from green spaces were less likely to use them for exercise than those living within 300 meters. They also found that those living more than 1 kilometer from greenness had higher obesity rates (BMI ≥ 30) than those living within 300 meters.

The World Health Organization's report states that the percentage of fatalities from NCDs is higher than that from communicable diseases and that this percentage is rising both domestically and internationally. In Thailand, NCDs are responsible for 74% of all fatalities, followed by communicable diseases at 16% and accidents at 10% [16]. The two study areas were selected due to their differing contexts. San Pa Pao Subdistrict is a suburban community located only 10 kilometers from Chiang Mai City. As a result, it is influenced by urban growth and consumerism. According to statistics from Ban Pa Kang Subdistrict Health Promotion Hospital (2018) and the Chiang Mai Provincial Public Health Office (2018), the NCDs mortality of San Pa Pao subdistrict accounted for 63.3 percent of all deaths (30 persons) in 2018. Meanwhile, the NDCs morbidity was 997 people in 2018, up from 601 in 2014 an increase of 65.9 percent. Cardiovascular disease (725) was the most common diagnosis, followed by diabetes (239), chronic respiratory disease (25) and cancer (8) (Table 1). In contrast, Thep Sadet Subdistrict, which is geographically rural, highland area with a lifestyle based on forests and natural systems, reported NCD-related mortality accounting for 58.3 percent of all NCD deaths (12 individuals) in 2018 (Pang Hai Subdistrict Health Promotion Hospital, 2018). In that the same year, there were 352 cases of NCD morbidity, up from 326 in 2014, accounting for 8% of the total. Cardiovascular disease was the most common diagnosis (253 cases), followed by diabetes (79), chronic respiratory disease (18), and cancer (2) (Chiang Mai Provincial Public Health Office, 2018). The increasing number of NCD patients in the study areas--particularly in San Pa Pao subdistrict, which is transitional into an urban environment with declining greenness may be associated with changes in the physical environment. This study therefore aims to analyze greenness in both semi-urban and rural areas using the NDVI derived from remote sensing data, and to analyze the influence of greenness on NCD prevalence.

Table 1: Comparison of NCD Morbidity and Mortality in Semi-Urban and Rural Subdistricts of Chiang Mai Province, 2014–2018

Subdistrict	NCDs Mortality		All Mortality		Morbidity								Total Morbidity	
					Cardiovascular		Diabetes		Chronic respiration		Cancer			
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
San Pa Pao	19	63.3	30	100	725	72.7	239	24.0	25	2.5	8	0.8	997	100
Thep Sadet	7	58.3	12	100	253	71.9	79	22.4	18	5.1	2	0.6	352	100

Note: *The mortality data for San Pa Pao Subdistrict is from Ban Pa Kang Subdistrict Health Promotion Hospital (2018), and for Thep Sadet Subdistrict, from Ban Pang Hai Subdistrict Health Promotion Hospital (2018). Meanwhile, the morbidity data for both subdistricts is from the Chiang Mai Provincial Public Health Office (2018).*

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2. Methodology

2.1 Study Areas

The study area was Chiang Mai Province, Thailand, focusing on two target areas (Figure 1 shows the study area):

1. San Pa Pao Subdistrict, San Sai District: A semi-urban area sensitive to land use changes due to its proximity to Chiang Mai City, located just 10 kilometers away. The area covers 6.46 square kilometers of flat terrain, with most of the population engaged in wage labor, followed by trading and agriculture.
2. Thep Sadet Subdistrict, Doi Saket District: A rural area situated 50 kilometers from Chiang Mai City, covering 115 square kilometers in a mountainous region. The population primarily engages in agriculture, followed by trading.

These two distinct areas were selected to test the hypothesis that areas with higher greenness exposure would have lower NCD morbidity compared to areas with extensive urban development. Additionally, it was hypothesized that within each area, residents living closer to greenness would exhibit lower NCD morbidity than those living farther away.

2.2 Data Collection

The key parameters are health states and greenness surrounding residence. Figure 2 presents the workflow of the research. The health categories are separated into three groups as following: NCDs patient, at-risk group, and healthy group. Landsat 8 OLT/TIRS and Pléiades satellites are used to calculate NDVI values for presenting greenness levels surrounding residence in the study areas. A set of health data points from both areas was utilized to analyze the effects of vegetation areas on health groups using one-way ANOVA.

2.2.1 Housing Location Data

The location of houses and the distribution of samples were studied using GPS tools, with spatial data imported into a Geographic Information System (GIS) to calculate the proportion of greenness. The samples included 506 residents in San Pa Pao subdistrict and 260 residents from Thep Sadet subdistrict. Community health data were obtained from San Pa Kang Subdistrict Health Promoting Hospital (SHPH) in San Pa Pao subdistrict and Ban Pang Hai SHPH located in Thep Sadet subdistrict for categorizing the samples. Based on established criteria from [17][18] and [19], the samples were categorized into three groups:

Group 1: Patients with non-communicable diseases (NCDs): Individuals diagnosed with conditions such as diabetes, cardiovascular diseases, cancer, and chronic respiratory diseases.

Group 2: At-risk groups for NCDs: This group was divided further divided into two subgroups:

- Behavioral risk factors: Individuals who are not currently diagnosed with NCDs but exhibit risk behaviors such as smoking or alcohol consumption.
- Biological risk factors: Individuals with risk indicators, including a body mass index (BMI) above standard levels, high blood pressure, or elevated blood sugar levels. A person exhibiting any of these risk factors were classified as at-risk.

Group 3: Healthy group: Individuals who did not have NCDs and did not exhibit risk factors for NCDs. This was determined based on five factors: normal BMI, normal blood pressure levels, normal blood sugar levels, non-smoking behavior, and non-alcohol-consumption.

According to health categories mentioned above, the sample distribution in San Pa Pao was as follows: 143 patients, 172 at-risk individuals, and 191 healthy individuals. The residential location data classified by health status collected by GPS and analyzed spatial distribution with GIS revealed that patients and at-risk groups in San Pa Pao Subdistrict was concentrated in areas transitioning from agricultural zones to large housing estates such as Ban San Ton Pao, Ban Payaknoi and Ban Bohin as shown in Figure 3(a). In Thep Sadet, there were 80 patients, 101 at-risk individuals, and 79 healthy individuals. The patients and at-risk groups were distributed around tourist attractions, such as Ban Pang Hai and Ban Mae Thon Luang, which featured by both resorts, houses, restaurants and coffee shops, frequented by both from locals and outsiders doing business, as shown in Figure 3(b).

However, analyzing data from the three health groups alongside vegetation intensity data around their residences requires selecting locations of each sample group residences with non-overlapping radius to avoid redundancy in assessing the influence of surrounding vegetation intensity on non-communicable diseases conditions (see more details in 2.3).

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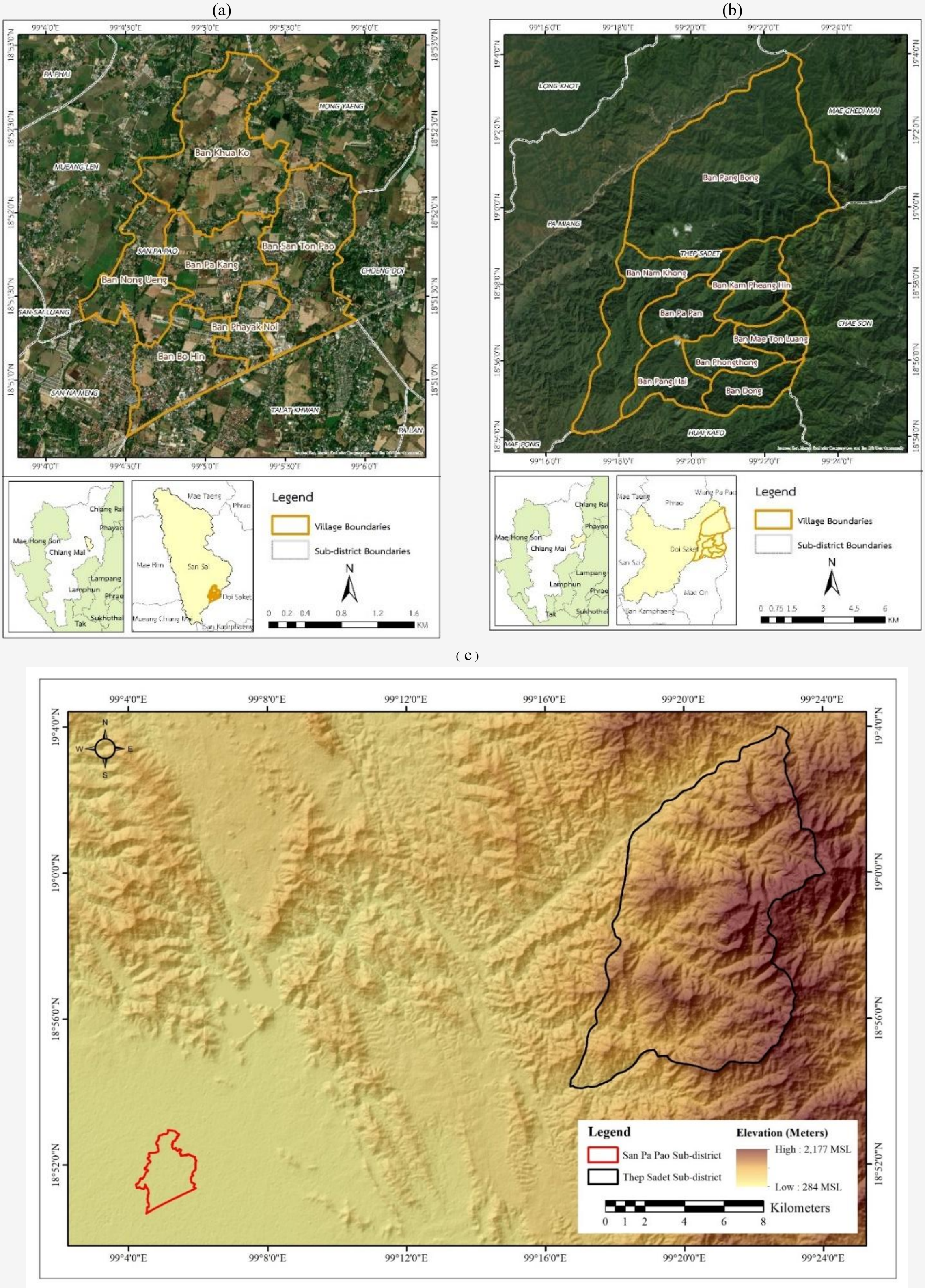

Figure 1: Study Area Boundaries of (a) San Pa Pao Subdistrict, San Sai District; (b) Thep Sadet Subdistrict, Doi Saket District, Chiang Mai Province; and (c) elevation comparison of the study areas

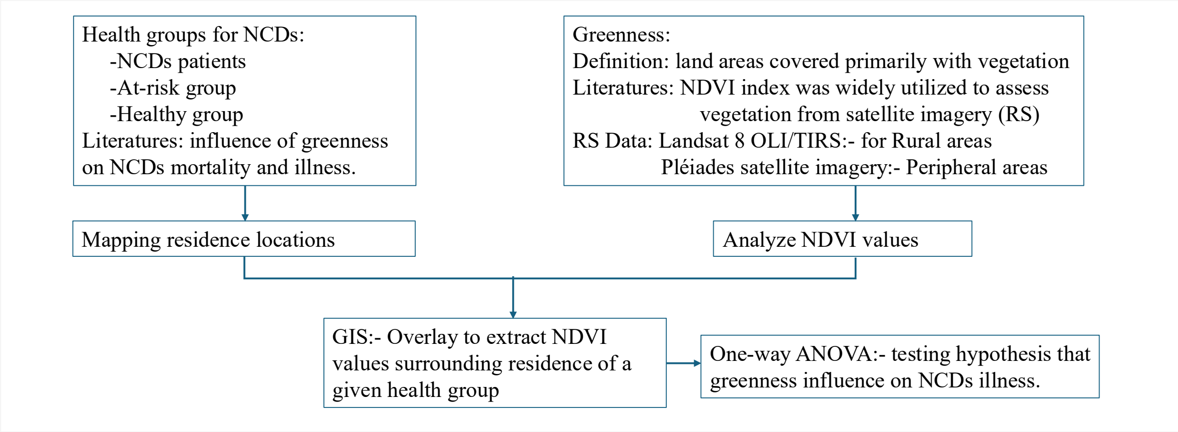

Figure 2: Workflow of research

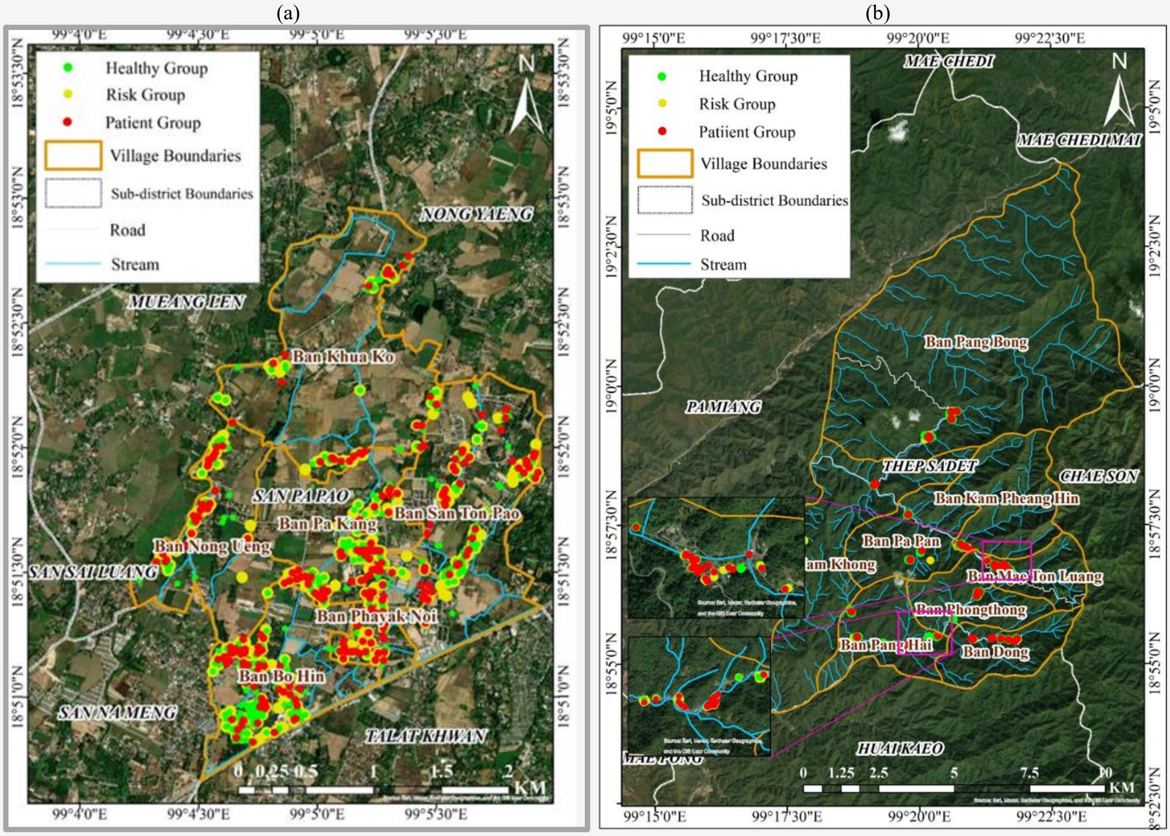

Figure 3: Locations of Health Groups in (a) San Pa Pao Subdistrict and (b) Thep Sadet Subdistrict

2.2.2 Greenness Data

Greenness refers to land areas covered primarily with vegetation, while NDVI method was widely utilized to assess urban greenness from satellite imagery [20][21] and [22]. In this study, data was obtained from two sources of satellite data. One is Landsat 8 OLI/TIRS satellite imagery dated April 19, 2019, with a spatial resolution of 30 meters. The data were accessed via the LAADS DAAC platform at https://ladsweb.modaps.eosdis.nasa.gov/. The analysis utilized spectral bands 4 and 5 as it corresponds to the red reflectance and the near-infrared reflectance with wavelengths 0.63-0.68 and 0.845-0.885 micrometers respectively. Another satellite imagery is Pléiades with a 2-meter resolution dated April 12, 2018.

The satellite image correction process involved two main steps. The first step is image pre-processing**:** The adjustment of the satellite image's numerical data, and secondly, field survey, data collection to support satellite image for geometric correction, leading to the evaluation of NDVI. NDVI indicates the health of vegetation cover, calculated using relevant spectral bands. The equations for evaluating NDVI are as follows:

NDVI index utilizes the fundamental characteristic of vegetation to differentiate healthy vegetation from non-vegetation or unhealthy vegetation. This is based on the unique reflectance characteristic, as healthy plants have a high chlorophyll content, and that allows them to absorb more light in the red region of the spectrum and reflects more light in the NIR region [23]. This characteristic can be evaluated using Equation 1.

$$NDVI = \frac{(\mathrm{NIR} - RED)}{(\mathrm{NIR} + \mathrm{RED})}$$

Equation 1

Where:

NIR = the near-infrared reflectance

RED = the red reflectance in the visible spectrum.

The estimated NDVI values range between -1 and 1, with NDVI values close to 1 indicate greater green vegetation cover. NDVI values of 0 indicate bare soil and water. NDVI values close to -1 indicate no vegetation; if quality of health plants is taken into account, NDVI is in the range of; -1-0 indicate dead plants of inanimate object; 0-0.33 indicate unhealthy plant, 0.33-0.66 indicate moderately healthy plant, and 0.66-1 indicate very healthy plant [23].

NDVI was applied and widely used as an alternative estimator [24][25] and [26]. According to the study areas focus on peripheral and rural areas, in order to investigate greenness, the peripheral areas need higher resolution data than rural areas; however, there are restrictions on the budget, the high-resolution data being selected for the peripheral area and free available data being selected for the rural area. In addition, although the vegetation characteristics being the greenest in the rainy season, it is time with limitations in recording satellite imagery data because it is a cloudy period, resulting in inappropriate data for analysis. Meanwhile, the time when satellite images are best recorded is in the dry season with less clouds, but it is the time when vegetation characteristics are the least green during the year. Due to the limitations of satellite imagery data, the test of the influence of greenness on NCD in this study uses vegetation data during the time when vegetation characteristics are the least green to test the influence of greenness on NCD, which has characteristics that do not change in the short term within a year.

2.3 Data Analysis

In order to analyze greenness in semi-urban and rural areas, Geographic Information System: GIS and Global Position system: GPS were used to map the location of residence of health categories, as well as to present the distribution of greenness in the study area. This tool also can be used to extract greenness value surrounding the residence of health's groups. It should be noted that the residences of participants divided into patient, at-risk, and healthy groups may be located in proximity, resulting in overlapping areas within the buffer radius around their homes. To eliminate the influence of overlapping environmental conditions when using average NDVI data to analyze the effect of greenness on NCDs, only data from non-overlapping buffer zones around the residences of each health group were selected for analysis (see Figure 4). Therefore, in San Pa Pao Subdistrict, there were 33 patients, 34 at-risk individuals, and 37 healthy samples, respectively. Meanwhile, in Thep Sadet Subdistrict, there were 36 samples in the patient group, 39 in the at-risk group, and 40 in the healthy group, with no overlaps between the groups. Then these data lead to analyzing the influence of greenness on NCDs morbidity.

By testing the hypothesis that exposure to greenness affects NCD morbidity, H0 refers to the average of NDVI surrounding residence of patient group is not lower than healthy group while H1 refers to mean of NDVI surrounding residence of patient group is lower than healthy group. The NDVI values as the representative of greenness presented surrounding the sample group's residence were applied for statistic tests. It should be noted that the NDVI has seasonally changed but NCDs do not change by seasonal; therefore, information of a situation of greenness surrounding given residence, which was acquired from remote sensors, is reasonable for investigating those influences. By means of the one-way ANOVA could indicate whether the hypothesis is accepted or protested.

This study utilized average NDVI values derived from satellite imagery at a radius of 300 meters surrounding the participants' residences. These distances were selected based on recommendations from existing literature [12][13][27] and [28]. Whereas the influence of greenness on behavior in accessing greenness among suburban and rural communities was analyzed using one-way ANOVA.

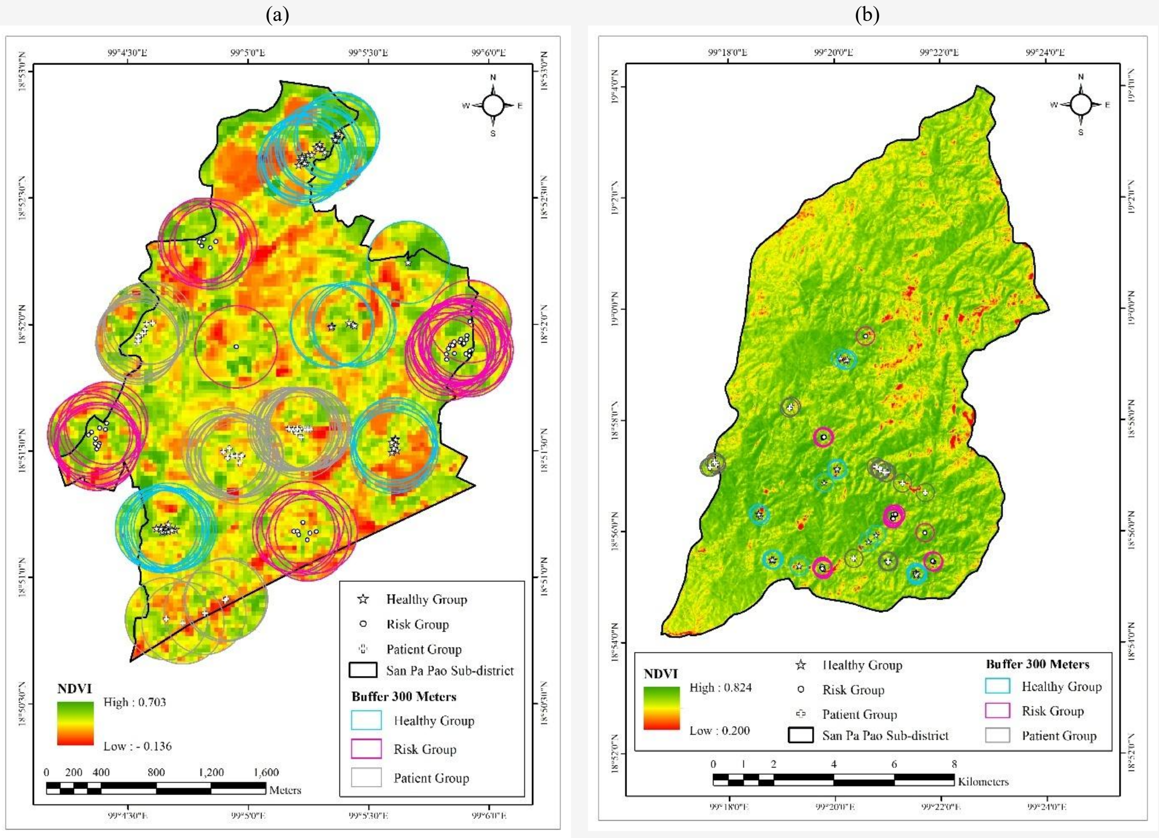

Figure 4: The Buffer Radius around the Residence of Health's Groups in a) San Pa Pao Subdistrict, San Sai District, (b) Thep Sadet Subdistrict, Doi Saket District, Chiang Mai Province

3. Results

According to the aim of the study, the result of the study presented the state of greenness surrounding residences of health's categories, and the influence of greenness on NCD illness as follows.

3.1 Distribution of Vegetation State in the Study Area

From satellite imagery analysis of NDVI, it was found that the NDVI in the San Pa Pao Subdistrict had ranging from -0.630 to 0.565 while the those in Thep Sadet Subdistrict ranged from 0.200 to 0.824. This indicates that Thep Sadet Subdistrict has generally denser vegetation cover than San Pa Pao Subdistrict, as shown in Figure 5.

3.2 Influence of Vegetation Area Surrounding Residential Areas on NCD Illness

Based on the health categories relating to NCD illness of two case studies, categorized into patient groups, at-risk groups, and healthy groups, the distribution of vegetation around the residences was analyzed using NDVI for both subdistricts. The details are as follows:

3.2.1 NDVI Values Surrounding Residential Areas by Health Group in San Pa Pao

The average Normalized Difference Vegetation Index (NDVI) within 300-meter surrounding residential areas in San Pa Pao was analyzed across three health groups Patient, At-risk, and Healthy. The results indicate that the mean NDVI surrounding the residence of the patient group was the lowest, while the values for the healthy and at-risk groups were quite similar (Table 2 and Figure 6). The patient group showing the narrowest range and the smallest standard deviation (SD = 0.13), indicating less variation in green exposure. In contrast, the healthy and at-risk groups show slightly broader ranges and higher SD (0.28 and 0.27, respectively). This suggests that individuals in the patient group were more likely to live in areas with less vegetation. The ANOVA results ($F = 19.095$, $df = 2$, $p = 0.00$) indicate that the differences in mean NDVI between groups are statistically significant at 0.05 level. Pairwise comparisons indicate that the mean NDVI surrounding the residences of patient group was significantly lower than that of the healthy and at-risk groups, with a significant level at 0.05.

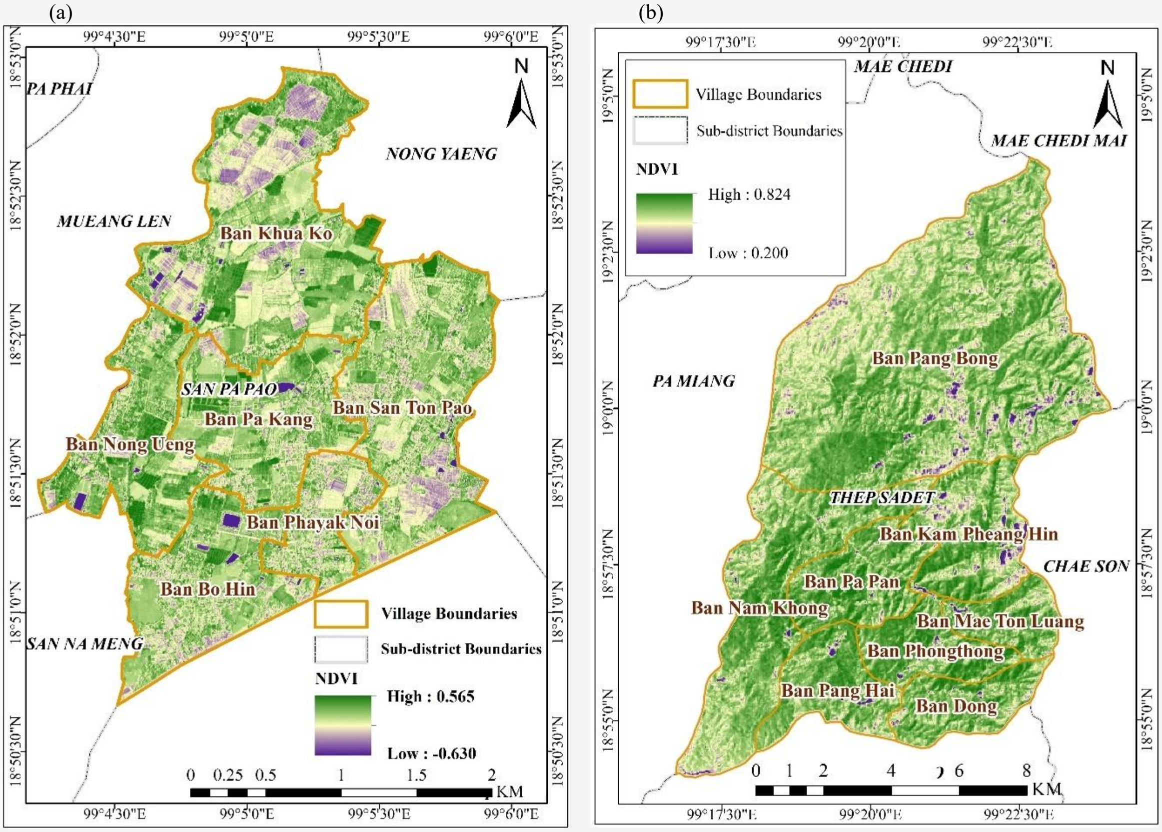

Figure 5: NDVI of the Study Areas (a) San Pa Pao Subdistrict and (b) Thep Sadet Subdistrict

Table 2: Average values of NDVI surrounding the residential area of San Pa Pao Classified by Health Group

Health Group	N	Mean	Minimum	Maximum	SD	*df*	*F*	*P*
Healthy	33	.418	.375	.477	.028	2	19.095	.000*
At-risk	37	.422	.364	.452	.027			
Patient	34	.388	.365	.412	.013			

*Remark * significantly at 0.05 level*

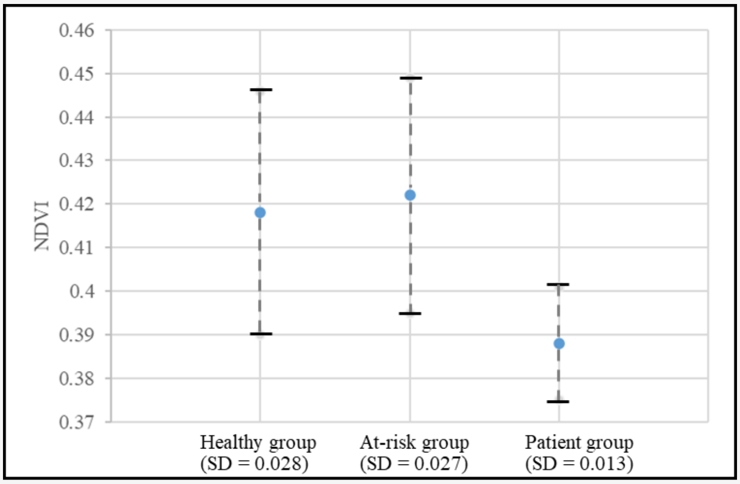

Figure 6: Distribution of Mean and Standard Deviation NDVI Values by Health Group in San Pa Pao Subdistrict

However, there was no statistically significant difference between the healthy and at-risk groups (see Table 3). This suggests that greater exposure to green environments may be associated with better health outcomes, particularly in reducing the prevalence or severity of non-communicable diseases. However, further research is necessary to investigate causal relationships and explore underlying environmental or socio-economic factors.

3.2.2 NDVI around Residential Areas in Each Health Group in Thep Sadet

The average value of NDVI surrounding the residential area within 300 m buffer distances for *Thep Sadet* was analyzed across three health groups Patient, At-risk, and Healthy. It has been found that the mean NDVI surrounding the residences of the healthy group (0.692), followed by the at-risk group (0.688), and the lowest among the patient group (0.680). The SD is relatively low for all groups (ranging from 0.012 to 0.016), suggesting limited variability in greenness exposure within each group (Table 4 and Figure 7). A one-way ANOVA test revealed a statistically significant difference in mean NDVI values across the health groups (F = 7.460, df = 2, p = 0.001). The pairwise comparisons between average NDVI and health groups indicated that the NDVI around the healthy group was significantly higher than that of the patient group (mean difference = 0.012, *p* = 0.001). Similarly, the at-risk group also has significantly higher NDVI values compared to the patient group (mean difference = 0.008, *p* = 0.048). However, there was no statistically significant difference between the healthy and at-risk groups (p = 0.414) (Table 5). These findings suggest that individuals in the patient group are likely to live in areas with a noticeably lower vegetation density compared to the other two groups. The results indicate that the mean of NDVI surrounding the residences of the three groups in Thep Sadet subdistrict is presented as similar as the case of San Pa Pao subdistrict. This could be remarked as the factors of physical geography and lifestyles. Thep Sadet consists of plains interspersed with rolling hills and high mountains, with an average elevation of 1,050 meters above mean sea level and a peak of 1,950 meters at Doi Langka Luang [29].

Table 3: Average values of NDVI surrounding the residential area Comparison Test Categorized by Health Groups in San Pa Pao Subdistrict

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Healthy	At-risk	-.004	.005	.736	-.018	.009
	Patient	.029*	.005	.000	.014	.044
At-risk	Healthy	.004	.005	.736	-.009	.018
	Patient	.033*	.005	.000	.019	.048
Patient	Healthy	-.029*	.005	.000	-.044	-.014
	At-risk	-.033*	.005	.000	-.048	-.019

* The mean difference is significant at the 0.05 level.

Table 4: Average values of NDVI surrounding the residential area of Thep Sadet Classified by Health Group

Health Group	N	Mean	Minimum	Maximum	*SD*	*df*	*F*	*P*
Healthy	40	.692	.673	.736	.012	2	7.460	.001
At-risk	39	.688	.660	.707	.016			
Patient	36	.680	.659	.709	.013			

*Remark * significantly at 0.05 level*

Table 5: Average values of NDVI surrounding the residential area Comparison Test Categorized by Health Groups in Thep Sadet Subdistrict

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
healthy	at-risk	.004	.003	.414	-.003	.012
	patient	.012*	.003	.001	.004	.020
at-risk	healthy	-.004	.003	.414	-.012	.003
	patient	.008*	.003	.048	.000	.016
patient	healthy	-.012*	.003	.001	-.020	-.004
	at-risk	-.008*	.003	.048	-.016	-.000

** The mean difference is significant at the 0.05 level.*

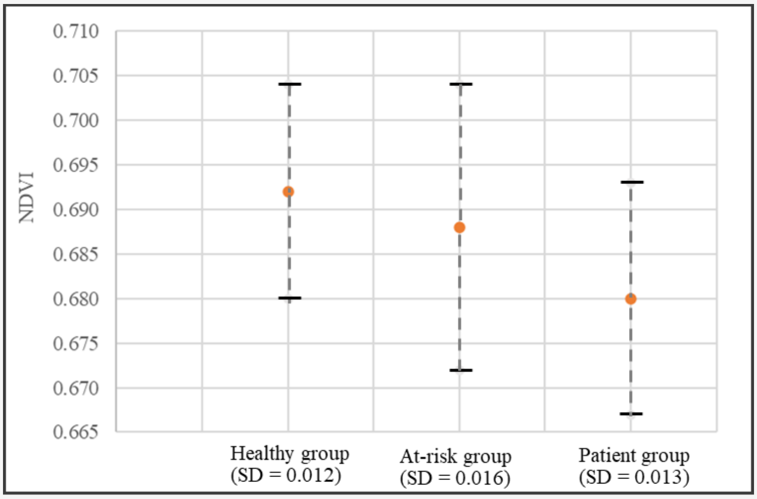

Figure 7: Distribution of NDVI Values by Health Group in Thep Sadet Subdistrict

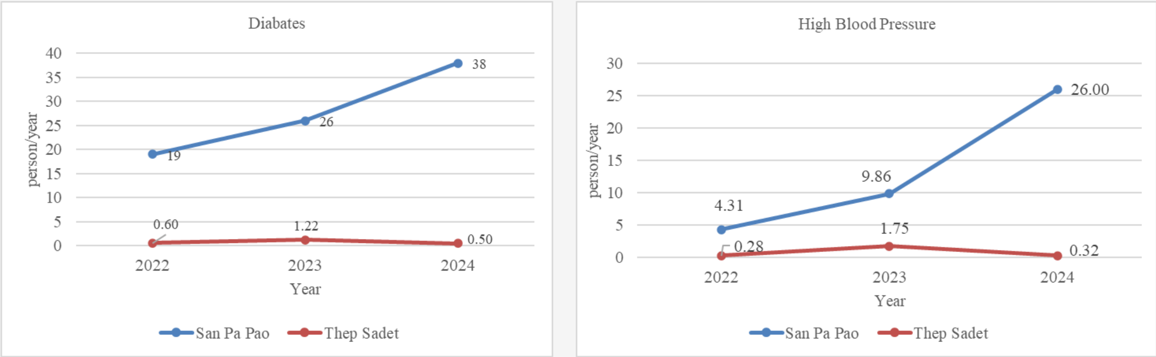

Figure 8: Incident Rate of Diabetes and High Blood Pressure of San Pa Pao and Thep Sadet Subdistricts Annual Incidence rate (cases/1000 population/year)

In contrast, San Pa Pao subdistrict is a lowland area with an elevation ranging from 300 to 350 meters above sea level [30]. Additionally, the lifestyle in Thep Sadet is directly related to the horticulture, whereas San Pa Pao has been undergone to urbanization, leading to a shift toward urban lifestyles. Even though there is difference in physical geography and lifestyles, the mean NDVI still presented on NCDs prevalence in Thep Sadet as the mean NDVI surrounding residences of the patient group which demonstrated statistically significant with the healthy and at-risk groups. However, it should be noted that the level of significant value (0.048) between patient and at-risk groups in the case of Thep Sadet almost exceeds the acceptant level at 95%. This is as well as the case of San Pa Pao subdistrict likely moderated by other factors beyond greenness alone.

Furthermore, Figure 8 shows incident rate of diabetes and high blood pressure data from Chiang Mai Public Health Office and indicates that San Pa Pao experienced a notable increase in both diabetes and high blood pressure cases from 2022 to 2024, while Thep Sadet maintained relatively low and stable rates. This trend may be associated with urbanization and lifestyle changes, such as reduced physical activity and dietary shifts, which are known risk factors for these conditions. In contrast, Thep Sadet shows minimal fluctuations in both health metrics, with overall lower prevalence rates. The relatively stable and low numbers in Thep Sadet could be attributed to its rural setting, where lifestyles may involve more physical activity and traditional diets, potentially mitigating the risk factors associated with diabetes and high blood pressure. Further research is necessary to identify the specific factors contributing to these trends in each subdistrict, including potential differences in healthcare access, socioeconomic status, and environmental influences.

4. Discussion

The results showed that the mean NDVI values surrounding residential areas significantly influenced the prevalence of non-communicable diseases (NCDs). Specifically, there were statistically significant differences between the patient group and both the healthy and at-risk groups, while no significant difference was observed between the healthy and at-risk groups. When comparing the two study areas, San Pa Pao characterized by semi-urban lifestyles demonstrated a stronger statistical significance ($p = 0.000$) in NDVI differences between the patient and at-risk groups than Thep Sadet, a more rural and agriculture-based area ($p = 0.048$). This suggests a complex influence of environmental factors on the health status of communities. Additionally, lifestyle appears to play a crucial role in moderating the influence of environmental conditions, with greener environments having a distinct effect on patient groups, while lifestyle factors may have a greater impact on the at-risk population.

The study's results are consistent with previous research indicating the influence of greenness in reducing the prevalence of NCDs in urban environments with greenness [8]. For example, neighborhoods in Los Angeles with more connected, aggregated, coherent, and complex-shaped greenspace morphologies were associated with a lower prevalence of NCDs. Similarly, the relationship between greenness and the prevalence of chronic NCDs has been explored in developing countries, particularly in Southeast Asia [31]. Greenness has also been shown to improve and restore mental health by reducing depression and anxiety through nature therapy [1] and [10], and alleviate stress [9]. Physical activity facilitated by greenness helps reduce the risk of being overweight, obesity, diabetes, and hypertension [2], as well as heart disease, respiratory illness, pollution-related cancers [5] and [7], diabetes [4] and [6], and infectious diseases such as dysentery, tuberculosis, and malaria [32]. The creation and maintenance of greenness is crucial for promoting overall health and well-being, particularly by ensuring equitable access to greenness for all communities [33]. Proximity to green spaces affects exercise behavior [13], and research suggests that greenness should be designed within 250-300 meters of residential areas [12] and [13]. Several studies indicate that urban areas often experience higher levels of air pollution, which can contribute to increased morbidity and mortality from NCDs [34][35][36][37] and [38]. The relationship between environmental factors and NCDs is complex and multifaceted. In contrast, rural areas typically exhibit lower air pollution levels and more physically active lifestyles, often centered around labor-intensive agricultural work, which can reduce certain NCD risk factors [34][39]. These associations are influenced by mediating factors such as air pollution and physical inactivity.

However, the relationship between greenness and the prevalence of NCDs may be influenced by other environmental factors, such as air pollution. For example, a study from rural districts in Anhui Province, China, reported a negative correlation between green space and hypertension (HTN), a major preventable cause of cardiovascular disease. However, the detrimental effects of green space on HTN may diminish when air pollution levels increase [35]. Similarly, greenness might positively impact the morbidity, prognosis, and mortality of chronic obstructive pulmonary disease (COPD), primarily due to reductions in particulate matter (PM) concentration [36]. Furthermore, reducing PM1 pollution while increasing greenness levels could be an effective strategy for alleviating the burden of cardiovascular diseases, particularly in resource-limited regions [37]. These findings highlight the critical role of green space accessibility in shaping community health outcomes, particularly in semi-urban contexts. Strategic urban planning that integrates accessible greenness may serve as an effective tool in mitigating the burden of non-communicable diseases.

5. Conclusion

This study examined exposure to greenness and its influence on the prevalence of non-communicable diseases (NCDs) in San Pa Pao Subdistrict (a semi-urban area) and Thep Sadet Subdistrict (a rural area) in Chiang Mai province. According to NDVI range, Thep Sadet Subdistrict has generally denser vegetation cover than San Pa Pao Subdistrict, suggesting that Thep Sadet may represent healthier ecosystems. While, San Pa Pao, with lower NDVI values and a more urban lifestyle, requires green space development. Regarding NCDs situations, the dense vegetation region should be presented positively, whereas the sparse vegetation area may be shown negatively.

The average NDVI within 300 meters of residential areas was compared across three health groups: patient, at-risk, and healthy. In San Pa Pao, ANOVA results ($F = 19.095$, $df = 2$, $p = 0.00$) revealed statistically significant differences in mean NDVI among these groups.

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Pairwise comparisons indicated that the patient group's mean NDVI was significantly lower than that of the healthy and at-risk groups, whereas the healthy and at-risk groups did not differ significantly. In Thep Sadet, the patient group also presented a statistically significant difference in mean NDVI compared to the other health groups. The NDVI around the healthy group was significantly higher than that of the patient group. These significantly indicate the influence of greenness around residences on the prevalence of NCDs, and this should be a major concern for our society. The study implies that greater exposure to greenness is associated with reduced prevalence or severity of NCDs. Therefore, urban planners should consider increasing green spaces in residential areas to promote better health outcomes.

6. Limitations

Acquiring physical data to investigate the influence of greenness on NCDs has required time and effort. The study focuses on applying remote sensing data to define greenness around residence so that the impact of greenness on NCDs could be primarily investigated. However, it still has limitations that various factors--air pollution levels, socioeconomic status, or individual lifestyle factors may also influence NCDs conditions and could have affected the observed relationships. Future studies should integrate multi-source environmental and behavioral data to better understand the mechanisms underlying the relationship between greenness and NCDs. This would help inform more targeted health and environmental interventions.

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