Chapter

Effects of Climate Change on City Life: Case Study in the City of Ambon, Indonesia East Region

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Abstract

It is no stranger that the diminishing amount of forest land to become non-forested in the world has changed the microclimate in almost all urban and rural areas. Thus it globally has triggered climate change. The influence of forests or vegetated areas on climate, especially the microclimate and mesoclimate, is important. The disrupted microclimate will cause anomalies in elements of the microclimate such as rainfall, air temperature, relative humidity, solar radiation, wind, etc. Microclimate changes will affect the presence of forests in the region because plants have a large dependence on climate and weather conditions. The impact of climate change that is beginning to be seen and felt today has caused discomfort for urban and rural communities. The aim of this present paper is to investigate the comfort level of the population and the availability of green open space (GOS) in Ambon City, Maluku Province, Indonesia. The city of Ambon turned out to provide less comfort for residents who live there. Extreme rainfall has triggered the occurrence of flooding and has been detrimental to city residents, especially during the rainy season. On the contrary, very hot weather in the dry season has made city residents uncomfortable. This situation was triggered by the expansion of settlement construction in protected forest areas as a result of humanitarian riots that occurred in years 1999–2002, limited GOS, and the effects of climate change.

Keywords: extreme rainfall, flooding, microclimate, green open spaces, NDVI, GIS

1. Introduction

It is no stranger that forest areas and other vegetation areas are balancing components of various cycles in nature, including for circulation of climate and local-scale weather. Utomo argues that climate is a generalization of various weather conditions in a large area in a long time. Climates always change according to space and time. Based on certain timescale, climate change will form a particular pattern or cycle, daily, seasonal, annual, and several yearly cycles [1]. In addition to changes in patterned cycles, human activity causes climate patterns to change sustainably, both on a global and local scale. Forests regulate the temperature of the earth and weather patterns which are carried out by storing large amounts of carbon and water. This function as regulator also has a huge influence on the local climate. The role of forests as a regulator of the microclimate in the surrounding environment is very important [2]. Of course the different conditions of the forest in an area have different capabilities in regulating the microclimate in the forest environment, for example, air temperature, air humidity, reception of sunlight, and deficit of water vapor pressure. In general, the microclimate that arises is caused by the existence of various differences from the weather and climate conditions which are quite large, especially the physical properties of the atmosphere. Air temperature near the surface of the ground is strongly influenced by the amount of solar radiation absorbed by the surface of the soil itself. Some of the radiation received by the soil surface during the day is used to heat and propagate to deeper parts, and some of it is irradiated in the form of heat waves that heat the air and evaporate water. Short energy solar radiation that propagates into the soil is converted into heat energy in the soil which will affect the temperature of the soil.

The influence of forests on climate is very important with increasing forest area and forest stand density. At first the forest compiler vegetation was only affected by microclimate, but later it was gradually influenced by the macroclimate and mesoclimate. Climate elements that affect the growth of vegetation include rainfall, temperature, wind, sunlight, humidity, and evapotranspiration. In other words there is a close relationship between climate patterns and the distribution of forest stands. Therefore some climate classifications are based on the world of vegetation. Vegetation has been seen as something sensitive and complex to climate influences, such as solar radiation, heating of soil and air, soil and air humidity, and so on. Seeing the close relationship between forests and climate, the increasing number of forest areas that have been converted into non-forest areas resulting in degradation and deforestation in almost all parts of the world has triggered climate change. The impact of this climate change has caused human misery both in urban and rural areas. This paper intends to describe a city whose population is uncomfortable due to the many natural disasters that occur because of the illegal settlements of protected forest areas in the center of Ambon Island. Besides that, it is also due to the limited GOS in the city. This happened because of conflicts in the nuances of the tribe, religion, and race (TRR) that occurred in years 1999–2002.

2. Methodology

This research uses survey and descriptive methods. The study was conducted in Ambon City, Maluku Province, Indonesia. Ambon City or Ambonese is a big city and also the capital of Maluku Province with a land area of 359.45 km^2 and a sea area of 17.55 km^2 with a coastline length of 98 Km. At present, "Ambon Manise" has become a more advanced city and is regarded as an international city in Eastern Indonesia. The administrative area of Ambon City is 377 km^2 or 2/5 of the area of Ambon Island. Geographically, Ambon City is located 3° 34‘ 8.40 "–3° 47' 42.00" south latitude and 128° 1′ 33.60 "–128° 18' 3.60" east longitude. Geographically, this city on Ambon Island is surrounded by the sea**.** This causes Ambon City to have two seasons, namely, tropical climate and seasonal climate. The location of Ambon City is bordered by the Banda Sea on the south, the Central Maluku Regency on the east (Lease Islands), the land of Hila-Leihitu and Kaitetu-Leihitu on the west, and Salahutu District, Central Maluku, on the north. At present, Ambon City is divided into five sub-districts, Nusaniwe, Sirimau, Teluk Ambon, Teluk Baguala, and Leitimur Selatan, which are divided into 50 villages. The area of the study covers three administrative villages, namely, Honipopu Village, Ahusen Village, and Uritetu Village, with an area of 1,115,900 m^2 or 111.6 ha. This location is the entire GOS area of the Ambon City.

To find out rainfall patterns and climate information in Ambon City, it was conducted by collecting various climate data, i.e., humidity, precipitation, wind, temperature, etc., and the history of natural disasters in Ambon City. Based on everyday experience, if we are in a vegetated area, it will feel cooler and more comfortable. This is especially felt during the daytime during the dry season. This is closely related to air humidity and air temperature conditions around us. In this regard, to analyze the distribution of humidity, air temperature, and its relation to a fairly extensive urban vegetation distribution, spatial analysis on the geographical information system (GIS) can be used. Besides that, the normalized difference vegetation index (NDVI) approach is also used to monitor vegetated areas. NDVI quantifies vegetation by measuring the difference between near-infrared (NIR) (which vegetation strongly reflects) and red light (which vegetation absorbs) [3]. Remote sensing and GIS technology have advanced rapidly in recent decades and now play an important role in environmental fields, i.e., climate science, biodiversity conservation, forestry, urban–rural planning, land and water management, etc. Thus spatial data is becoming increasingly accessible and used by various governments and research institutions, private businesses, consulting companies, and others.

The distribution of vegetation in Ambon City is obtained by the NDVI value approach. The vegetation index value is calculated as the measured reflection ratio of the red (R) and near-infrared (NIR) bands on the electromagnetic wave spectrum. Both of these bands were chosen as vegetation index parameters because the measurement results were most affected by the absorption of leaf chlorophyll or green vegetation. In general the NDVI formula is written with the following equation:

$$NDVI = (NIR - R)/(NIR + R) \quad (1)$$

where NIR is near-infrared and R is infrared. NDVI is classified into four classes of greenness level as presented in **Table 1**.

Through the NDVI distribution map, a ground check was then carried out. Locations selected, for example, are determined considering places that have high, medium, and low NDVI values and are not vegetated. In this case, nine sample points are set to take observational data in the field which include the distribution of vegetation (grass and trees), air temperature, air humidity, solar radiation, and noise that are evenly distributed in urban areas. The location mapping activity was carried out directly on the green lane along the road and the city park area in the corner of Ambon City spatial planning, and the distribution of the stand inventory lane was adjusted to the potential of plant species to facilitate recording and measurement. Vegetation mapping in open green areas in the spatial layout is done by GIS using ArcGIS 10.1 software. The collection of vegetation (grass and trees) plot points is carried out using global positioning system (GPS). Landsat ETM-8 imagery is processed using ENVI 4.7 and MAPINFO 10.5 software for merging image data bands. To find out the value of DI in this study, use the formula of DI [5] as follows:

$$DI = Ta - \mathbf{0.55}\ (\mathbf{1} - \mathbf{0.01}\ RH)\ (Ta - \mathbf{14.5}) \quad (2)$$

where **DI** is the value of discomfort index, **Ta** is the air temperature, and **RH** is the relative humidity (%). DI is classified into six discomfort classes as presented in **Table 2**.

Based on the discomfort value in **Table 2**, three discomfort distribution maps are made, each of which includes six discomfort classes for Ambon city at 09:00–12:00 pm and 16:00 pm. Ground check is carried out in nine sampling locations by observing the discomfort distribution map created. The interview activities were carried out to 150 respondents or 150 head of families aged between 30 and 60 years at the sampling location. The aim is to see representation in capturing

No.	Vegetation index class	Greeness level
1	0.40–1	High
2	0.25–< 0.40	Medium
3	0.03–< 0.25	Low
4	−1–< 0.03	Non-vegetated

Source: Marwoto and Ginting [4].

Table 1.
Vegetation index class (NDVI).

No.	Discomfort index	Discomfort condition	Remarks
1.	DI < 21	Comfort	100% comfortable
2.	22 ≤ DI ≤ 24	Less than 50% of the population feel discomfortable	50% uncomfortable
3.	25 ≤ DI ≤ 27	More than 50% of the population feel discomfortable	60% uncomfortable
4.	27 ≤ DI ≤ 29	Most of the population feel discomfortable	70% uncomfortable
5.	30 ≤ DI ≤ 32	High-level discomfort	80% uncomfortable
6.	DI ≥ 32	Need health services	100% uncomfortable

Table 2.
Classification of discomfort index *value [4].*

information and data on population comfort levels related to the existence of GOS in Ambon City. The next step is to overlay the NDVI distribution map with the three discomfort distribution maps. Thus three new maps were obtained, i.e., the NDVI distribution index map and discomfort in Ambon City at 09:00–12:00 pm and 16:00 pm.

3. Results and discussion

3.1 Rainfall and extreme distribution of rainfall and flooding in Ambon City

The climate in Ambon City is classified as a tropical climate with significant rainfall with precipitation even during the driest month. The climate here is classified as Af based on the Köppen-Geiger system. The average rainfall is 3392 mm, and the average temperature in Ambon City reaches 26.5°C. The lowest average precipitation in November is 103 mm, while the highest is 622 mm in June (**Figure 1**).

In connection with the highest precipitation, the months June, July, and August are the months of caution for the city government and residents of Ambon City because it is the time of natural disasters (floods and landslides). The average air temperature is 27.5°C in January which is the hottest month and 25.0°C in July which is the coldest month of the year (**Figure 2**).

Between the driest and wettest months, the difference in precipitation is 519 mm. The variation in annual temperature is around 2.5°C. The Ambon City climate is presented in **Table 3.**

During the last 7 years, there have been at least four floods, i.e., in year 2012, 2013, 2016, and 2017. Floods occurred in August 2012 in inundated five subdistricts: Nusaniwe, Sirimau, Ambon Bay, Baguala, and Leitimur [7]. In the village

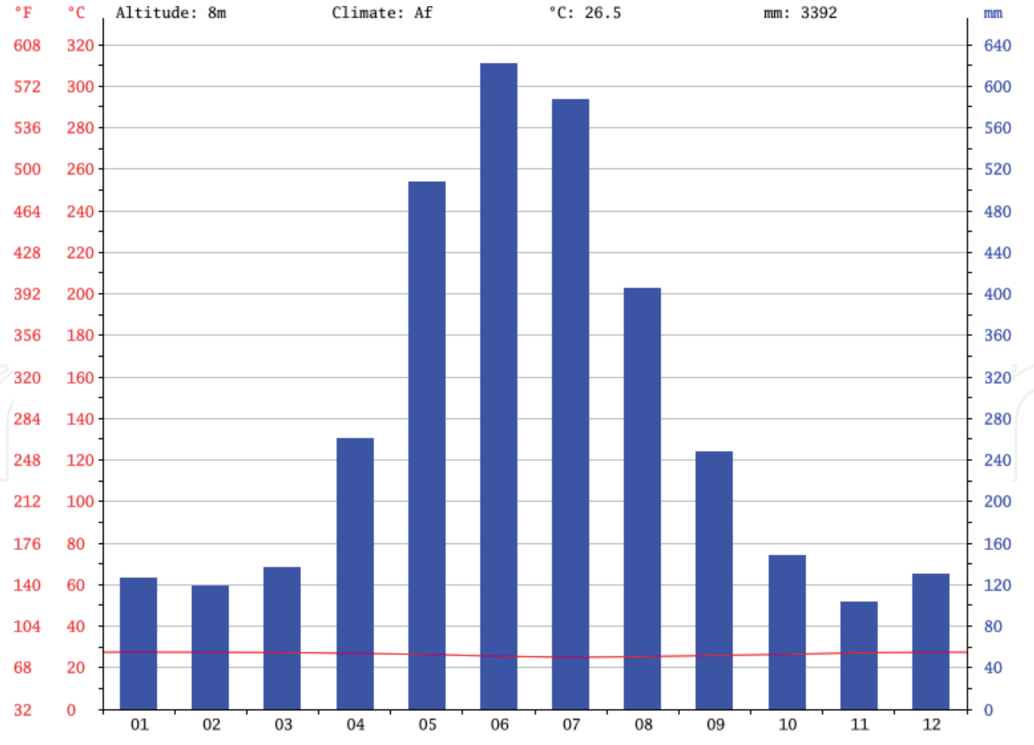

Figure 1.
Ambon City climate. Source: Climate-Data [6].

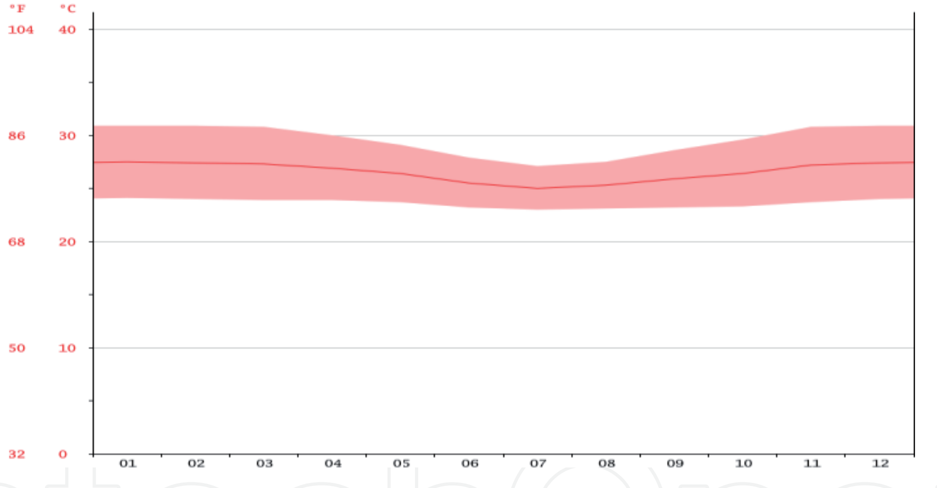

Figure 2.
Air temperature of Ambon City. Source: Climate-Data [6].

of Galala, floods soaked dozens of homes with 50 cm of water. In addition, the 3-m-high river water barrier and sea waves beside the Galala Bridge were damaged and collapsed [8]. Floods in year 2013 also occurred due to heavy rain for 2 days, July 29–30, 2013 [9]. These massive floods and landslides have caused 14 fatalities and forced thousands of residents to leave their homes and left huge infrastructure and environmental damage. The natural floods and landslides occurred again on July 16–17 and July 29–August 1, 2016. This disaster has caused damage to infrastructure and public facilities so that it covers the street body and shoulders at 10 points [10]. Moreover, floods also occur in the following year, 2017. A little description of the rainfall situation that triggers the occurrence of flooding is as follows: the rainfall in the Maluku Province exceeds the normal limit in the period of June 1–14, 2017. The amount of rainfall then continues to increase because it is the peak month of rain. Based on the Council of Meteorology, Climatology, and Geophysics measurements recorded 842 mm while normal rainfall in June ranges

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average temperature (°C)	27.5	27.4	27.3	26.9	26.4	25.5	25	25.3	25.9	26.4	27.2	27.4
Minimum temperature (°C)	24.1	24	23.9	23.9	23.7	23.2	23	23.1	23.2	23.3	23.7	24
Maximum temperature (°C)	30.9	30.9	30.8	30	29.1	27.9	27.1	27.5	28.6	29.6	30.8	30.9
Average temperature (°F)	81.5	81.3	81.1	80.4	79.5	77.9	77.0	77.5	78.6	79.5	81.0	81.3
Minimum temperature (°F)	75.4	75.2	75.0	75.0	74.7	73.8	73.4	73.6	73.8	73.9	74.7	75.2
Maximum temperature (°F)	87.6	87.6	87.4	86.0	84.4	82.2	80.8	81.5	83.5	85.3	87.4	87.6
Precipitation/rainfall (mm)	126	118	136	261	508	622	587	405	248	148	103	130

Source: Climate-Data [6].

Table 3.
Weather by month/weather averages of Ambon City.

from 690 mm. This increase actually happened in the previous month (May 2017) where it was recorded at the Pattimura Ambon Meteorological Station, which was 753.3 mm, significantly exceeding normal rainfall of 400–500 mm. In addition the wind speed reaches 10–40 km/hour where the wind blows from east to southeast. This high rainfall is generally due to closed circulation around the Makassar Strait, attracting most of the saturated mass from the southern Pacific region through a large portion, Maluku region. As a result, there is a change in air mass in the central and northern Maluku regions. Meanwhile, the air humidity of the upper layers of the Maluku region shows a relatively wet condition (80–100%), which indicates the addition of water vapor supply. This is what drives the occurrence of high rainfall which will result in floods and landslides [11]. As a result of the overflowing of a number of rivers in the city of Ambon, dozens of houses and some roads in the city were submerged.

The amount of damage caused by floods is triggered by extreme rainfall, and there are also violations of the stipulated city spatial plan. As is known, Ambon City had been hit by social unrest motivated by the TRR between years 1999 and 2002. Residents of Ambon City felt the bad effects of riots that occurred more than a decade ago. One prominent factor is the construction of settlements that violate many spatial rules that have been set by the Ambon City government such as land clearing for settlements, agriculture and other activities in protected forests, etc. After the year of TRR conflict, many new settlements were built very heavily on cliffs, riverbanks, and valleys that were very risky for natural disasters. The most severe is the expansion of settlements in protected forest areas of Gunung Sirimau. This condition is exacerbated by the behavior of people who carelessly dispose of and accumulate garbage in places and areas that are not supposed to. This has an impact on natural disasters that are increasingly common in Ambon City and Islands. Ambon Island as a whole has a high disaster risk index.

In connection with the more frequent occurrence of floods, the Maluku Regional Development Planning Agency (BAPPEDA) has made the map of flood risk of Ambon City. The map was made from data on capacity and vulnerability of Ambon City to disaster and also disaster map of Ambon City (**Figure 3**). In this figure, it can be seen that almost half of Ambon City has a medium and high level of flood risk (yellow and red area).

Nara has analyzed rainfall trends toward extreme data on watersheds on Ambon Island for 32 years (1984–2015). In this study, the Mann-Kendall method and extreme value theory (EVT) were used to discuss extreme events that occurred and were modeled with the generalized extreme value (GEV) distribution, and the result was a trend of changes in rainfall in Ambon city. The annual maximum daily rainfall occurs in year 1984 which is 430.70 mm, and the minimum is 0 mm in year 1999, 2001, and 2003. Average rainfall varies between years 1984 and 2015, which is 25.63 to 131.408 mm, while the average value is 181.07 mm [13]. The distribution of average monthly rainfall in the study area tends to increase rainfall for 32 years but is not too significant because the rainfall data series is put together. Statistically, a significant trend was found for 8 months with an upward trend (positive) and 4 months experiencing a downward trend (negative). In other words, in a year there is an upward trend (positive) for 8 months, and the trend decreases for 4 months significantly (α = 0.05), and there is an increase in rainfall for the period of 1984–2015. Based on the results of the tests conducted, it has provided an analysis that rainfall data follows the form of GEV distribution with an average (μ) = 38,629, standard deviation (σ) = 36.64, and shape (ξ) = 0.436. This proves that rainfall in the watershed in Ambon Island has extreme distribution and has a maximum value distribution function for observing a period that is appropriate for the return period [13].

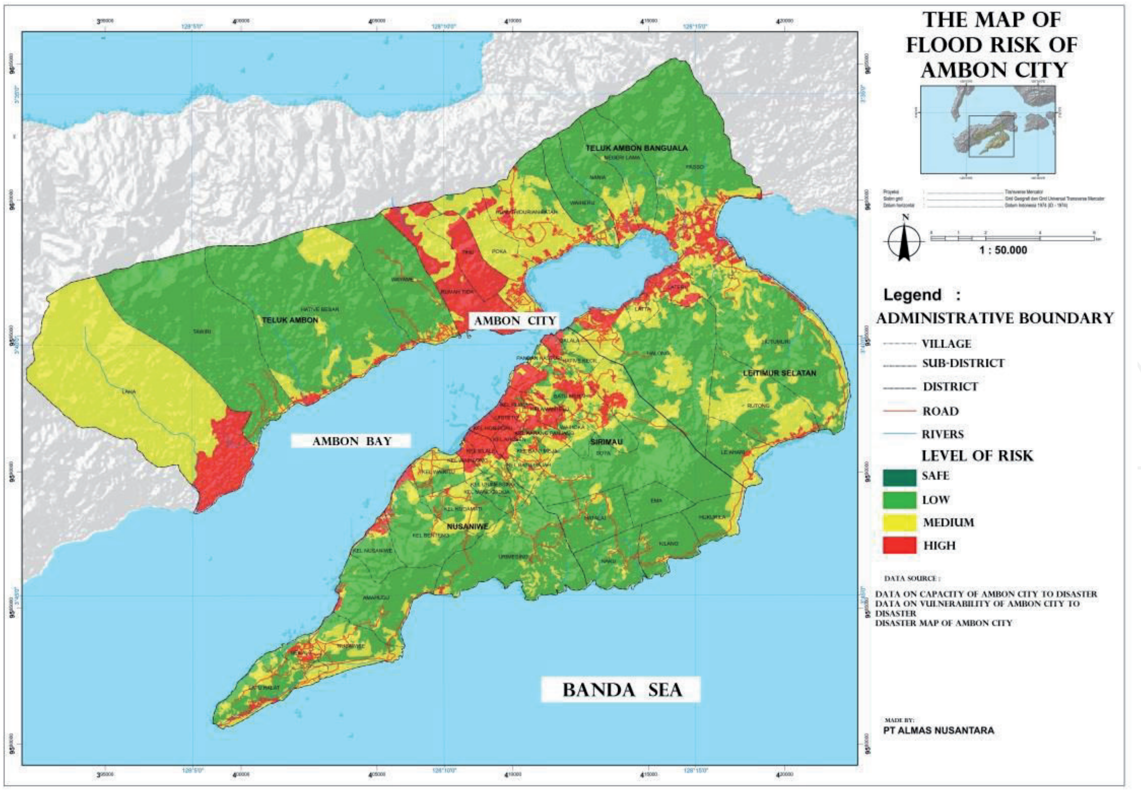

Figure 3.
The map of flood risk of Ambon City. Source: BAPPEDA Maluku [12].

3.2 Comfortability of city residents in Ambon City

The ideal climate for humans is clean air with temperatures of approximately 27–28°C and air humidity between 40 and 75% [14]. However, this condition often changes in a certain period of time which is quite drastic. This is caused by a significant change in land use, due to changes in the designation function, for example, from forested land to non-forest. Not only humans, in fact flora and fauna also often feel unfavorable effects due to changes in microclimate conditions, especially air temperature and air humidity [14]. If based on Laurie's opinion in 1986, the population of Ambon City is far from ideal climate conditions. Based on our direct measurement, results in 2017 are as follows: air temperature at 09:00, 12:00 pm, and 16:00 pm, respectively, is 26.73–29.97°C, 30.60–35.00°C, and 27.70–33.43°C; air humidity, respectively, is 85.67–97.00%, 35.00–64.33%, and 57.67%; and solar radiation, respectively, is 95–617 lux, 150–1299 lux, and 126–1252 lux. This situation will worsen if the wind speed on a certain day is very low. It is not surprising that the use of fans and air conditioners in government and private offices, shopping centers, and settlements has increased from year to year. Actually, this can be slightly overcome by the existence of urban green space (UGS)-GOS which is filled with a variety of vegetation. Unfortunately the existence of UGS-GOS is still very limited. UGS, green open space, city parks, vegetation areas, and others are useful in maintaining the natural balance of the city structure. Green spaces should not be considered as inefficient land or reserve land for urban development or simply a beauty program because they play a major role in balance, continuity, sustainability, comfort, health, and improvement of the quality of the city environment [15].

In general the development of urban areas will increase over time. The availability of facilities and infrastructure in urban areas to meet the living needs of the population (boards, food, clothing, vehicles, entertainment, etc.) has encouraged the increasing number of villagers to move toward urban areas or urbanization.

Of course cities that have exceeded their carrying capacity will have many negative impacts on the environment. Not infrequently if in a large city, there are certain areas that are not maintained, slum, dirty, and become a source of criminalization. Having created a peaceful atmosphere from the existence of a patterned conflict of TRR in years 1999–2002 has triggered massive urbanization which will negatively impact the comfort of living in Ambon City. Therefore, it is not surprising that the negative effects associated with urbanization are increasing concerns that attract the attention of people around the world. Urbanization has a negative impact on the environment mainly due to modification of the chemical and physical properties of the atmosphere, pollution production, and ground cover. All the accumulated negative impacts are known as urban heat island (UHI). The UHI is understood to be a rise in the temperature of man-made regions, producing a clear “warm island” among the “cool seas” represented by lower temperatures than the nearby natural landscape. Hot islands on the spatial scale can actually be formed in urban and rural areas. Hot islands in cities are preferred because their surfaces tend to release large amounts of heat. Nevertheless, the negative impact of UHI not only affects the population in the urban environment but also humans and their ecosystems that are far from the city. UHI is indirectly related to climate change because of its contribution to the greenhouse effect. This situation will ultimately lead to global warming, the impact of which is beginning to be felt today by almost the majority of the population living in developed and developing countries [16]. The interaction between climate change and heat island effect occurs in two ways, namely, (1) the warming climate will increase higher temperatures in hot island areas, and (2) cooling strategies to reduce hot islands can help communities adapt to the effects of climate change. In addition, it can also reduce greenhouse gas emissions that cause climate change. Climate change generally causes higher temperatures and longer heat waves, more often and more severely. Therefore in urban areas that have suffered due to heat, the island will bear the brunt of this tougher heat event [17]. Furthermore, the climate change that occurs will contribute to the increase in the cost of “hot islands” for urban areas [18].

To find out how much the population feels comfortable living in Ambon city, an index is used which indicates the existence of a comfortable or uncomfortable situation by taking into account the humidity and air temperature. This index is known as the temperature humidity index (THI). Based on the editors of the *Encyclopaedia Britannica*, THI is a combination of water humidity and water that is a measure of the degree of discomfort experienced by individuals in warm weather; it was originally called the discomfort index. The THI formula is as follows:

$$THI = Tdb - [0.55 - (0.55 \times RH/100)] \times (Tdb - 58) \quad (3)$$

where Tdb (°F) is the temperature of water measured by a thermometer freely exposed to the air but shielded from radiation and moisture. It is a temperature thermometer, and it is the true thermodynamic temperature, and RH (%) is the relative humidity [19]. Besides that, there is also another THI, namely, discomfort index (DI). DI is intended to determine the inconvenience of the microclimate conditions in a place quantitatively. Basic calculation of DI also uses air humidity and air temperature data [5].

3.3 NDVI distribution and discomfort index in Ambon City

NDVI value is a value from the processing of vegetation indices from infrared satellite channels and red canals that show the level of leaf chlorophyll concentration which correlates with vegetation density based on spectral values in each pixel.

NDVI always ranges from −1 to +1, but there isn't a distinct boundary for each type of land cover. If we have negative values, it's highly likely that it's water. On the other hand, if we have a NDVI value close to +1, there's a high possibility that it's dense green leaves. In case NDVI is close to zero, there are no green leaves, and it could even be an urbanized area [20]. In other words, the distribution of NDVI shows the distribution of the amount of vegetation on a land. High NDVI values generally indicate a land cover with a lot of vegetation that will provide an atmosphere of coolness in the local environment. The vegetation index in this study is used to determine the percentage of green cover that can be assumed as a GOS from the LANDSAT-8 image so that it is expected to reflect the actual conditions in the study area. Based on the results of the analysis conducted, it shows that the higher the NDVI value, the higher the percentage value of green cover. This confirms that there is a close relationship between the value of the vegetation index and the percentage of green cover in the study area. The distribution of NDVI values in Ambon City is presented in **Figure 4**.

In general, high NDVI values in Ambon City are located in the northern part and a little in the south as shown in the area which is dark yellow to brown. Other regions have low NDVI values which indicate that there is very little vegetation in the area. The NDVI distribution consists of four levels of greenness, high, medium, low, and non-vegetated as presented in **Figure 4**, and then is overlapped with three discomfort distribution maps so that the three new maps are obtained, i.e., the NDVI map distribution and discomfort in Ambon City at 09:00–12:00 pm and 16:00 pm. The NDVI index distribution map illustrates clearly that the distribution of NDVI values is dominated by low NDVI followed by only a small number of medium NDVI in the northern and southern parts of the city. The non-vegetated area is also very small in the northwest, while high NDVI is not present.

The comfort level of an area is an indicator used in UGS planning in an urban area. Change in climate elements, namely, the increasing air temperature, is the most direct factor that can be felt and affect the level of human comfort [21]. Quantitatively, the comfort level of an area can be approached with various

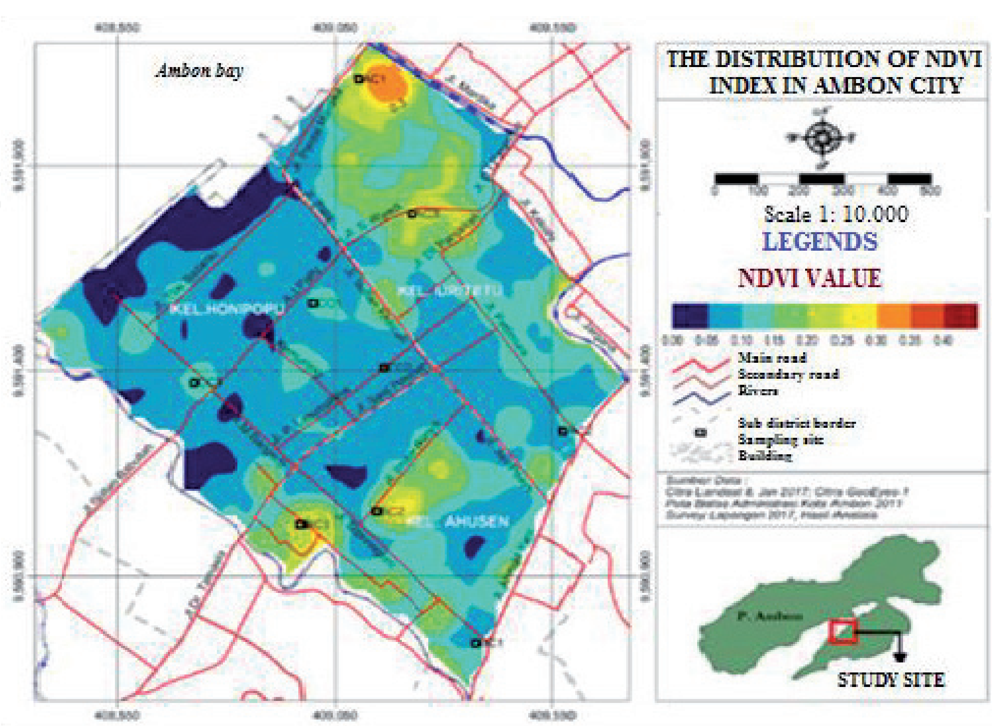

Figure 4.
The distribution of NDVI values in Ambon City.

Code of demonstration plot	Value of discomfort index at			
	09:00 pm	12:00 pm	16:00 pm	Remarks
A1	27.9	28.5	28.6	
A2	28.1	29.6	29.3	
A3	28.4	30.0	28.4	
B1	28.1	29.1	27.8	
B2	27.3	28.5	27.2	
B3	25.4	29.5	28.6	
C1	26.7	28.8	29.2	
C2	28.3	29.9	27.5	
C3	28.4	30.2	28.7	
Average	**27.6**	**29.3**	**28.4**	

Table 4.
Distribution of discomfort index value in Ambon City.

approaches. One of them is DI as implemented in this research. In addition to air temperature, comfort is influenced by other climate parameters and subjects who feel comfortable. A climate parameter that also affects human comfort is wind. The results of temperature measurements and the humidity of the green open space area of the city of Ambon in nine sampling locations showed different values based on the analysis of inconvenience index (DI) for the morning interval (at 09:00 pm); during the day (12:00 pm) and evening (16:00 pm) as presented in **Table 4**.

From **Table 4**, there are three new maps that describe the distribution of DI, which are discomfort map in Ambon City at 09:00–12:00 pm and 16:00 pm. Based on the results of interviews with 150 respondents in 9 sampling locations, 141 people fit the inconvenience as stated on the map, and 9 people stated that they did not match the distribution map of DI. Thus, this confirms that the making of the distribution map of DI is in accordance with the reality in the field regarding the discomfort felt during occupying in Ambon City. These three maps are then one-by-one overlaid with the map of the distribution of NDVI index so that the NDVI distribution index map and discomfort in Ambon City at 09:00–12:00 pm and 16:00 pm are obtained. The map is presented in **Figures 5**–7.

The majority condition of DI 70% is in the low NDVI and is followed by DI 60% in the southern part of the city (**Figure 5**). This situation shows that in the morning alone, more than 50% of the city population does not feel comfortable. In other words it may lead to physical symptoms and also influence mental health. The existence of medium NDVI is also due to too little area, so it cannot provide significant comfort for city residents.

DI conditions that rose sharply to DI 80% were in low NDVI, and those that remained were DI 70% only in the north especially near medium NDVI (**Figure 6**). This condition shows that during the day, medium NDVI plays a small role in maintaining a level of DI 70%. Although in the southern part of the city, two NDVI medium areas were found, they were found unable to maintain DI 60% in the area as shown at 09:00 pm in the morning. This condition illustrates that urban residents are increasingly uncomfortable as indicated by the increase DI 80%.

The condition in the evening at 16:00 pm remains the same as the condition at 09:00 pm in the morning (**Figure 7**). However, DI 80% still remains, especially in the western part of the city. The area of DI 60% which was originally in the south

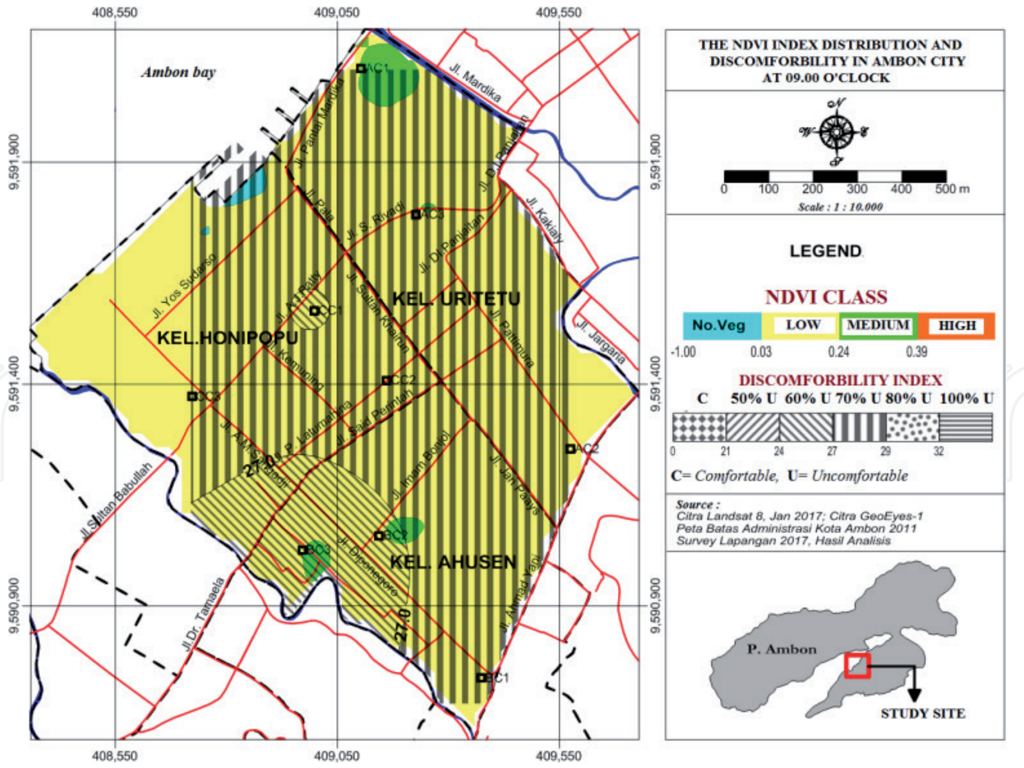

Figure 5.
The NDVI index distribution and discomfort in Ambon City at 09:00 pm.

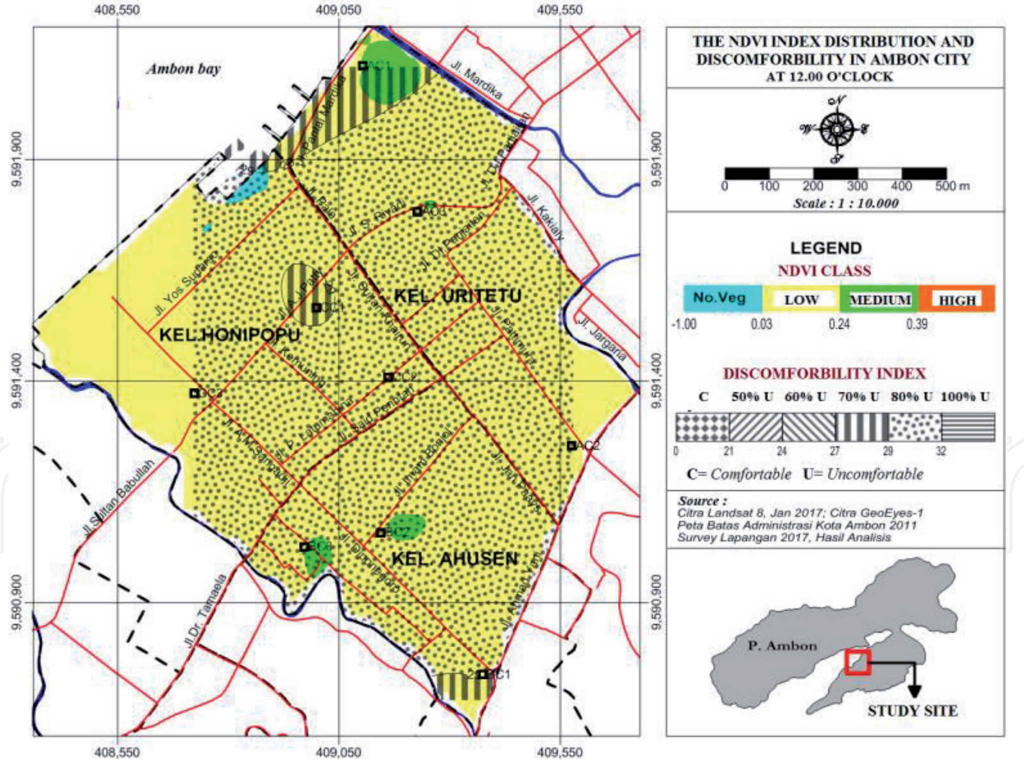

Figure 6.
The NDVI index distribution and discomfort in Ambon City at 12:00 pm.

at 09:00 pm turned out at 16:00 pm it remained at DI 80%. This shows that there is no change in discomfort at all. Through the three NDVI distribution index maps and discomfort in Ambon City (at 09:00–12:00 pm and 16:00 pm), we can find out which areas have high and low vegetation. Thus we can plan which areas need to be planted with vegetation, both grasses and trees, including how wide the building needs to be planted. Thus, in general, Ambon City residents feel uncomfortable.

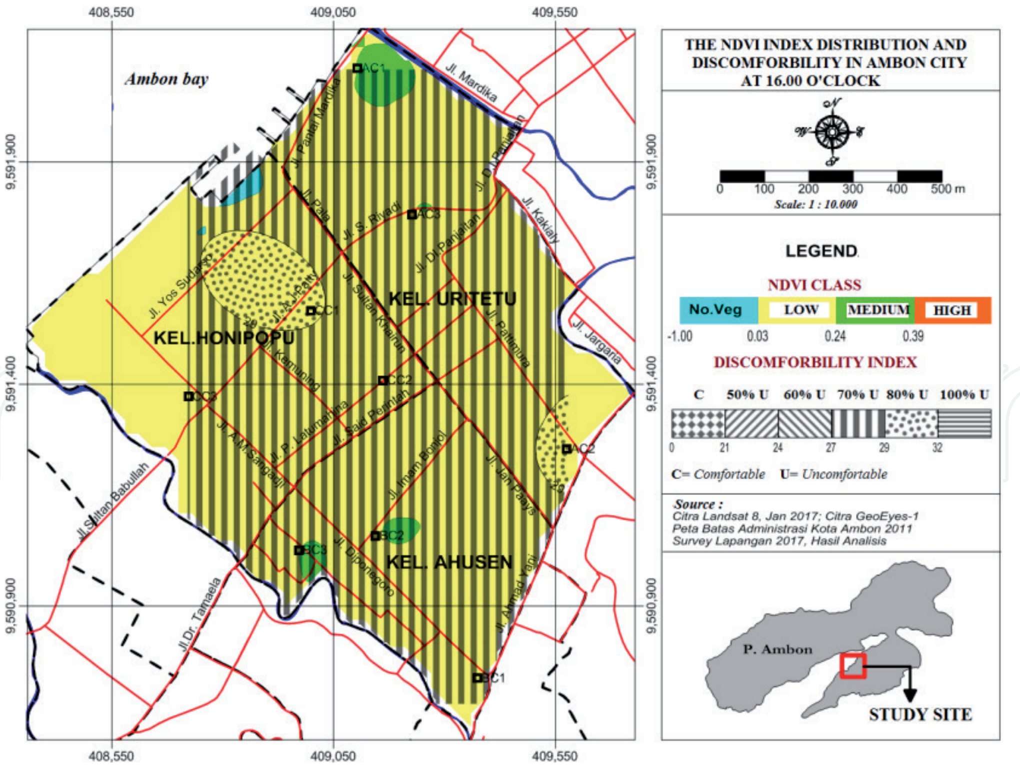

Figure 7.
The NDVI index distribution and discomfort in Ambon City at 16:00 pm.

Real effort is needed to carry out adaptations and mitigations in both the urban center and the environment. Based on the experience of daily living in European countries and Indonesia, the inconvenience is certainly felt more by developed countries than developing countries. Of course because of the people who have enjoyed abundant prosperity so that there is a small disturbance, there will be more complaints than people from developing countries.

Spatial analysis in GIS applications has supported in urban spatial planning. Good planning in the procurement of GOS in Ambon City can provide better comfort in the future. The more limited land for GOS due to development in urban areas has urged the application of the concept of green infrastructure, especially in every implementation of development. It is realized that the government of Ambon City has not had much in the development of green infrastructure such as green roofs, green facades, green walls, etc. This is certainly very different from urban planning in developed countries such as Switzerland, the United States, France, Canada, etc. that have intensively carried out the construction of green roofs, green facades, and green walls. Furthermore, green roofs are constructed for multiple reasons, for example, for architectural features or to achieve particular environmental benefits (improved diversity species, storm water capture and retention, insulation of a building against heat gain or loss, etc.). In addition to the green roof, the green facade and green wall are also known. A green facade is created by growing climbing plants up and across the facade of a building, either plants grown in garden beds at its base or by container planting installed at different levels across the building. A green wall is made up of plants grown in supported vertical systems that are generally attached to internal or external walls, although in some cases it can be freestanding. Green walls differ from green facades in that they incorporate multiple containerized plantings to vegetation cover rather than being reliant on fewer numbers of plants that climb and spread to provide cover. They are also known as vertical gardens or living walls or bio-walls [22]. Hopefully, the government of Ambon City in the future will be able to provide wider GOS and begin to apply the concept of green infrastructure in every implementation of development.

4. Conclusion

Ambon City has really been affected by climate change. Extreme rainfall that occurs in the rainy season has triggered big flooding and has been detrimental to city residents. The impact of the flood caused a huge loss of city residents. This is due to the expansion of settlements in the protected forest area of Gunung Sirimau, the construction of houses on steep slopes, as well as the impact of littering, etc. Conversely, very hot weather in the dry season makes the city residents uncomfortable. In Ambon City it was considered less comfortable as felt by residents because of the limitations of GOS. In this case, a solution needs to be sought, among others, by providing a wider area of GOS and starting to apply the concept of green infrastructure in each development implementation in Ambon City. In addition, the adequacy of GOS in Ambon City can be known by spatial analysis in GIS. With the support of NDVI distribution maps, DI maps for observations at 09:00–12:00 pm and 16:00 pm, and overlays of thematic maps, areas that are high in DI and areas that are still lacking in vegetation can be seen including how big the area is. This research is important because it can be used as preliminary study to see the development of GOS associated with DI in Ambon City. Similar research on a regular basis or time series will be able to know the development of GOS and DI in the future.

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Conflict of interest

We (Gun Mardiatmoko and Jan Willem Hatulesila) as the authors of the paper entitled “Effects of Climate Change on City Life: Case Study in the City of Ambon, Indonesia East Region” hereby declare that there is no conflict of interest in making this paper.

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