Mangrove in the Urban Area of Small Islands: Vegetation Health, Potential, and Management Challenges

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Abstract. Indonesia is the largest habitat of mangroves in the world which many are distributed in the urban areas of small islands. However, knowledge about conditions, potential, and management challenges of mangrove in these urban areas are still scarce. This study’s objectives are to assess mangrove conditions, potential threats, and the perception of local people. In the last two decades, mangrove cover in the main city of Ambon decreased at the rate of 0.75% yr-1 and the status of the vegetation health was poor. In contrast, there was no much change in the mangrove areas of a satellite city, Tual and it has healthy mangrove forests. Mangrove forests have a good potential for carbon storage, either in Tual (191 Mg C ha-1 or 703 Mg CO2e ha-1) or Ambon (120 Mg C ha-1 or 441 Mg CO2e ha-1). Estimates of the economic value of carbon sequestration by mangrove forests in Tual and Ambon were US$ 30,896 and US$ 49,195 ha-1. The management challenges include mangrove deforestation, plastic pollution, and low public participation. Given the significant economic values of the mangrove areas and their potential carbon loss due to mangrove deforestation, avoiding mangrove deforestation, restoring the ecosystem, and strengthening conservation actions in small islands’ urban areas are crucial to ensure the sustainable use of mangrove resources.

1. Introduction

Mangrove is one of the essential ecosystems growing in coastal areas, including estuaries, lagoons, and rivers. Mangrove plants are categorized into two types i.e., true- and associate-mangroves. Indonesia is the largest habitat of mangroves (3,112,989 ha or 23%) and a home for 67% of species of global true mangroves [1,2,3]. Around 14 species of mangroves in Indonesia were declared as endangered species and three species are endemic species [2, 4].

Many of the mangrove forests are distributed in small islands. Based on Undang-Undang Republik Indonesia, No. 27 the Year 2007 and Purba [5], about 77% (13,466 islands) of total 17,504 islands in Indonesia are small islands (< 2,000 km²). Most of the small islands in Indonesia are in Eastern Indonesia, like Ambon and Tual island, Maluku Province. Mangrove forests in small islands have unique characteristics due to their local conditions and environment. Mangroves in small islands are characterized as mangrove patches that may have different ecosystem functions and services. For example, mangrove patches have a longer edge perimeter and more forest gaps which are important for crabs and mollusk. Many mangrove patches grow in urban areas. Recently, many cities recognize the importance of urban vegetation and they introduced urban greening programs including mangrove planting and rehabilitation to contribute to climate change mitigation [6,7,8]. However, urban areas
may also act as carbon sources due to anthropogenic activities such as transportation, industries, etc. Based on the regional development index and human development index, urban areas were categorized as main urban area (main city), satellite urban area (satellite city), and independent urban area (independent city) [9,10]. These types of cities have different roles in carbon sources and facilitating vegetation change including mangrove and their ecosystem services [9,10].

To date, the conditions, potential, and management challenges of the mangrove ecosystem in large islands have been well documented. This ecosystem is a habitat of many terrestrial and marine species, such as birds, mollusks, fishes, and crabs. [11]. Mangrove ecosystem is also known as spawning and nursery grounds for fishes, which is vital for fish life cycle [11]. A set of ecosystem services of mangroves include carbon sequestration, shoreline protection, and water filtration. Mangroves have social and economic value, for example, many communities use mangroves as food resources, education, and recreation. The valuation of mangrove resources in Bintuni Bay, Indonesia shows that it accounts for at least US$ 1.6 billion yr$^{-1}$, but this value may underestimate because many potentials mangroves are excluded from the quantification [12,13].

In contrast to the fact discussed in the previous paragraph, knowledge about conditions (mangrove cover and vegetation health), potential, and management challenges of mangrove in urban areas of small islands is still scarce. A study in the temperate region shows that urban vegetation has promising potential to contribute to reducing local CO$_2$ emission [10], but this study does not include mangroves. There is an urgent need to study mangrove conditions, potential, and management challenges in the urban area of small islands due to: 1) growth demands of urban greening actions, including mangrove as one of the strategies to offset local CO$_2$ emissions and for coastal protection; 2) urban small islands are vulnerable; 3) the uniqueness of mangrove in small islands and its tremendous threats may require specific management approaches, and 4) around 30% of the human population lived in urban areas and it is predicted to increase dramatically which almost two-thirds of the population are projected to be urban residence [14].

This paper aims to assess the current conditions (mangrove cover and vegetation health), potential (economic value of blue carbon and ecological functions), and management challenges (threats and perception of society) of mangrove resources in urban areas of small islands. Satellite imagery analysis, vegetation survey, plastic debris sampling, and interview survey were conducted to address the described aims. Ambon and Tual Island were selected as a case study area because this island is representative of mangrove resources in the urban areas of small islands. Ambon and Tual are a model for the main city (main urban area) and satellite city (satellite urban area), respectively. In addition, the islands are in the Banda Sea and coral triangle site which is known as a biodiversity hot spot. This study may be required to better manage urban mangroves in small islands and contribute to climate change mitigation through carbon sequestration.

2. Materials and Method
This study was conducted in Ambon (3°40’12.4’’ LS dan 128°10’57.4’’ BT) and Tual (5°00’- 6°00’ LS and 131°45’-133°15’ BT). These islands are in the Banda Sea, Maluku Province, Indonesia (Figure 1). The geomorphology of Ambon is hilly with narrow coastal areas, while Tual is relatively flat with wider coastal areas. The average mean sea level in these two islands is 1.26 m (0.28 – 2.31m), the annual mean precipitation is 451 mm, the annual mean temperature is 30.7 °C (27.70 - 31.40 °C), the mean salinity is 34.28 ‰ [15,16]. These islands have a northwest monsoon (November to March), a southeast monsoon (May to September), and a transitional season (October and April) [16,17].
Figure 1. Study area of Ambon and Tual, Maluku Province, Indonesia. Transects for vegetation survey and sampling of plastic debris

Four methods were applied in this study: remote sensing imagery analysis, vegetation survey, plastic debris sampling, and interview survey (Figure 2). Landsat Thematic Mapper (TM) year 1999 and 2009 and Landsat Operational Land Imager (OLI) year 2019 were downloaded from the US Geological Survey (USGS) Website (https://earthexplore.usgs.gov). These images were used to map mangrove cover changes. Supervised classification of improved image analysis (Maximum Likelihood Classification and Knowledge-Based Classification) was applied for image classification [18]. Prior to the application of image classification, the images were georeferenced using ground control points (GCPs). Aerial photographs were used as template images to find the correct location of the twelve GCPs, backed up by field data to verify the GCPs. The atmospheric correction technique called dark pixel correction was applied to reduce such effects as haze and clouds. Markov change analysis was applied to assess mangrove cover change and coordinates were presented in Universal Transverse Mercator (UTM).

Figure 2. Flowchart of methods: remote sensing imagery analysis, vegetation survey, plastic debris sampling, and questionnaire survey used in the study
Transect sampling for vegetation analysis is located in Ambon (Waiheru, Passo, Nania, Suli, Lateri, and Tawiri) and Tual (inner and outer Un Bay). These sampling locations were selected purposively assisted by thematic maps of mangrove cover. This selection is to consider mangrove area, mangrove diversity, and variation of environmental settings. A total of 67 square plots (10 m x 10 m) were placed along 8 transects located in Ambon and Tual perpendicular to the coastline from seaward to landward. Data collected from the plots were mangrove plant species, stem diameter, tree height, canopy coverage, number of stumps, and coverage and number of plastic debris. The diameter was measured at breast height (1.3 m) above the ground (diameter at breast height, DBH), using a measuring tape. A digital protractor was used to measure an angle of elevation from the observer. The angle and distance to the tree were used to calculate the tree height. Hemispherical photos of the canopy were taken using a mobile phone in nine points inside the plots, then processed using ImageJ software (downloaded from http://imagej.nih.gov/ij/download.html) to calculate the percentage of canopy coverage.

We collected data of plastic debris in the plots. For further analysis, we used this data, combined with our previous publications [19]. Sampling quadrates of plastic debris were positioned along the transects with three replications on the sides of the transects. The sampling of plastic debris was conducted in Ambon because based on our transect survey, the coverage of plastic debris in this island was high and further assessment is required. A total 72 quadrates (0.5 x 0.5 m) were placed in three zones of mangroves: Zone A (Landward), Zone B (middle), and Zone C (seaward). We collected all plastic debris in the quadrates and sediment to 2.5 cm depth using the stainless shovel. Next, we sieved the sample using a sieve shaker size 1 mm. Plastics were categorized as microplastic (1-5mm), mesoplastic (5mm-25 mm), and macroplastic (>25mm). Then, the samples were dried using the oven at 90ºC for 24 hours. Lastly, plastic debris was identified as fragment, film, fiber, and foam.

The interview survey was applied to assess the characteristics and perception of society around mangrove areas. The sample of respondents was selected using a simple random sampling technique and the number of respondents was determined using Eqn. 1. the total number of survey respondents was 243 and it was distributed proportionally within villages around mangrove areas. The respondents include elites (e.g. leader of the village, leader of the religion, etc.) and common people. We used semi-structured questionnaires with closed and open questions to get deeper information from the respondents.

$$S = \frac{N.P.Q.A^2}{d^2(N-1)+P.Q.A^2}$$

where:

$\lambda^2$ = Standard Error = 1
P and Q = Probability value = 0.5
N = Population
d = Standard Deviation = 0.05
S = Number of sample

Data analysis was conducted following Dharmawan & Pramudji [20]. Tree density, canopy coverage, and important value index were used as a proxy to determine mangrove vegetation health status based on standard protocol published by Ministry of the Environment Republic of Indonesia No. 201 Year 2004 [21]. A generic allometric equation developed by Chave et al. [59] was applied to calculate carbon stocks. Total carbon stock, carbon pools, and carbon dioxide equivalent were quantified using the method developed by Kauffman and Donato [22]. Carbon was expressed as carbon stock and carbon dioxide (CO$_2$) equivalents (CO$_2$e) to assess their potential to offset carbon emissions [22]. In addition, we estimated the economic value of carbon in mangrove areas based on a procedure published by Jerath et al. [23]. A linear regression analysis was applied to determine the relationship between carbon stocks and vegetation parameters (tree density and canopy coverage). A
non-parametric Wilcoxon test was applied to compare the vegetation characteristic between Ambon and Tual.

3. Result and discussion

3.1. Mangrove cover change and vegetation health

Satellite image analysis showed that the total mangrove area in Tual was 343 ha. There was no much change in these urban areas between 1999 and 2019. In contrast, the total mangrove area in Ambon decreased consistently from 63 ha in 1999 to 62 ha in 2009, and to 58 ha in 2019. It decreased by 9% with a deforestation rate was 0.5% y⁻¹. Mangrove deforestation was only 0.23% y⁻¹ in the first decade (1999-2009), and then the rate of deforestation increased significantly in the second decade (2009-2019) at 0.75% y⁻¹. Most of the mangrove in Ambon was converted into infrastructure development such as modern market, housing, agriculture, and other coastal infrastructure.

Although the total mangrove area in Ambon decreased, mangrove in some locations increased slightly such as in Poka (0.02 ha y⁻¹ / 4.2% y⁻¹), Lateri (0.01 ha y⁻¹ / 5% y⁻¹), Nania (0.009 ha y⁻¹ / 0.5% y⁻¹), and Kate-Kate (0.03 ha y⁻¹ / 1.7% y⁻¹). It was confirmed that the mangrove area has fluctuated which the lowest total mangrove area was occurred in 2014 (45 ha) and then increased up to 57 ha in 2017 [24]. Our field observation indicated that the increase in the mangrove area was due to some rehabilitation actions in Ambon Bay. However, the rate of increase in mangrove cover due to restoration and rehabilitation programs was lower (15%) than the rate of mangrove deforestation. In addition, most of the mangrove in the reforestation area was young thus their ecosystem services and ecological functions may be lower than mature mangrove which converted into other land used.

The study found 15 and 9 mangrove species in Ambon and Tual, respectively. In Ambon, the site of Lateri and Waiheru has the highest diversity of mangrove species and Suli exhibited the least diversity (Table 1). *Rhyzopora apiculata* and *Soneratia alba* were the most common species in Ambon with an important value index up to 87.9% and 100%, respectively. Black mangrove, *Bruguiera gymnorrhiza*, was the most common species in Tual followed by *Soneratia alba*. Mangrove diversity in the study areas is in the same range of mangrove diversity in other small islands in Maluku, but it was lower than mangrove diversity in large islands [25,26,27]. Three mangrove species found in Ambon and Tual are categorized as endangered species and vulnerable species based on IUCN such as *Xylocarpus mollucensis*, *Camptostemon schultizii*, *Bruguiera gymnorrhiza*, and *Rhyzophora stylosa* (Critical endangered), and *Rhyzophora mucronata* (Vulnerable) [26].

| Location       | Diameter (cm) | Height (m) | Number of species | Important Value Index |
|----------------|---------------|------------|-------------------|-----------------------|
| Waiheru        | 10.5 ± 6.4    | 6.8 ± 2.3  | 9                 | RS: 5.3               |
| Passo          | 18.7 ± 9.8    | 9.8 ± 4.4  | 5                 | BP: 11.5              |
| Nania          | 11.6 ± 5.3    | 6.1 ± 2.6  | 5                 | CT: 3.6               |
| Suli           | 35.6 ± 5.5    | 5.5 ± 2.4  | 1                 | 0                     |
| Lateri         | 17.9 ± 7.8    | 10.2 ± 2.8 | 10                | BP: 4.2               |
| Tawiri         | 17.2 ± 10.2   | 8.0 ± 3.4  | 5                 | SA: 25.5              |
| Inner Un Bay   | 15.51±3.53    | 4.25±0.49  | 4                 | XG: 9.24              |
| Outer Un Bay   | 12.57±1.73    | 3.57±0.17  | 5                 | CS: 32.53             |

The size of mangroves trees in Ambon (mean diameter: 18.6 ±7.5 cm and mean height: 7.7 m ±3.6) was bigger than the size of mangrove in Tual, mean diameter: 14.04 ±2.6 cm and mean height: 3.9 m ±0.3, Wilcoxon test: p< 0.05 (Table 1). This is due to the density of mangroves in Ambon (778 stem
ha\(^{-1}\) was much lower than in Tual (2050 stem ha\(^{-1}\)), Wilcoxon test: \(p < 0.01\) (Table 2) thus intra-species competition in Ambon may be low. This hypothesis is supported by the high rate of mangrove growth in sparse mangrove canopies and low density of mangrove where sufficient light is available and intra-species competition is reduced [28,29,30]. The size of mangrove in small islands (Ambon and Tual) was relatively smaller compared to other large islands such as Bintuni Bay (Papua) and Weda Bay (Halmahera, North Maluku). However, the size of mangroves (even the same species *Avicennia marina*) in Ambon and Tual was much bigger than mangrove in the temperate region such in Auckland New Zealand, and in Florida, USA [18,31].

Table 2. Status of mangrove vegetation health in urban areas of small islands

| Location      | Urban types | Canopy coverage (%) | Coverage class* | Tree density (stem ha\(^{-1}\)) | Density class* | Health status* |
|---------------|-------------|---------------------|-----------------|-------------------------------|----------------|----------------|
| Waiheru       | Main urban  | 26                  | sparse          | 1443                          | moderate       | degraded       |
| Passo         | Main urban  | 27                  | sparse          | 435                           | sparse         | degraded       |
| Nania         | Main urban  | 30                  | sparse          | 1584                          | dense          | degraded       |
| Suli          | Main urban  | 46                  | sparse          | 251                           | sparse         | degraded       |
| Lateri        | Main urban  | 26                  | sparse          | 556                           | sparse         | degraded       |
| Tawiri        | Main urban  | 25                  | sparse          | 368                           | sparse         | degraded       |
| Inner Un Bay  | Satellite urban | 82.67             | dense           | 1850                          | dense          | Good           |
| Outer Un Bay  | Satellite urban | 74.80             | moderate        | 2250                          | dense          | Good           |

*Based on a national standard of Ministry of Environment of Republic Indonesia No 201, Year 2004

The mean tree density was 763 stems ha\(^{-1}\) and the mean canopy coverage was 30%. Following the national protocols of mangrove vegetation health published by the Ministry of Environment of Republic of Indonesia No 201 Year 2004, mangrove vegetation in Ambon was degraded. All mangrove area in Ambon was degraded (Table 2) except Waiheru and Nania which have a moderate density (1,433 stem ha\(^{-1}\)) and categorized as dense mangrove (1,580 stems ha\(^{-1}\)), respectively. On the other hand, the status of mangrove vegetation health in Tual was good because the mean tree density was higher than 2,050 stems ha\(^{-1}\) and the mean canopy coverage was higher than 78.7% (Table 2). This finding indicates that mangrove located in main urban areas such as Ambon was degraded and mangrove in satellite urban areas such as Tual was in good conditions. This is maybe connected to high pressure in main urban areas which the majority of the human population lived in urban areas (cities) which has many consequences for the coastal environment, including modification of mangrove cover and degradation of mangrove vegetation.

3.2. Potential of mangrove ecosystem

Mangrove forests in Tual store 90% biomass carbon in aboveground structures and 10% in the roots, which total biomass carbon of 191 +/- 2.52 Mg C ha\(^{-1}\). This carbon stock excludes of soil carbon stocks. The mean total carbon stock in the main city of Ambon was 37% (mean total 120 Mg C ha\(^{-1}\) ± 1.91 s.e.m.) lower than in the satellite city of Tual, \(\chi^2 (2) = 9.16, p = 0.011\). The total mean carbon varied among the locations from 57 Mg C ha\(^{-1}\) (± 1.29 s.e.m.) in Suli, Ambon to 193 Mg C ha\(^{-1}\) (± 2.54 s.e.m.) in inner Un Bay, Tual (Table 3). Although carbon stocks in these urban areas are much lower than reported from other tropical mangroves in large islands such as Borneo and Sulawesi [32], the carbon stock was much higher than mangrove in the temperate region [33]. Carbon storage in Tual
was equivalent to 703 Mg CO$_2$ e ha$^{-1}$ and in Ambon was equivalent to 441 Mg CO$_2$ e ha$^{-1}$. Multiplying this field derived estimate of carbon stock by the mangrove area estimated in 2019 revealed that aboveground carbon stocks in Ambon were 6,975 Mg C (25,600 Mg CO$_2$ e) and in Tual was 65,683 Mg C (241,056 Mg CO$_2$ e). This suggesting that mangrove in the urban area of small islands contains a large proportion of carbon stocks. Given the capacity of mangroves to accumulate carbon, the mangrove ecosystem can contribute to offset carbon emissions through carbon sequestration and storage [34,35].

Table 3. Biomass carbon stocks in urban areas of small islands

| Location   | Urban types  | AGC (Mg C ha$^{-1}$) | BGC* (Mg C ha$^{-1}$) | Total carbon (Mg C ha$^{-1}$) |
|------------|--------------|----------------------|-----------------------|-------------------------------|
| Waiheru    | Main urban   | 129                  | 13.76                 | 143                           |
| Passo      | Main urban   | 131                  | 14.48                 | 146                           |
| Nania      | Main urban   | 120                  | 13.11                 | 133                           |
| Suli       | Main urban   | 50                   | 6.52                  | 57                            |
| Lateri     | Main urban   | 145                  | 15.69                 | 161                           |
| Tawiri     | Main urban   | 76                   | 7.31                  | 83                            |
| Inner Un Bay| Satellite urban | 174          | 19.22                 | 193.2                         |
| Outer Un Bay| Satellite urban | 171          | 18.88                 | 189.79                        |

*exclude soil/sediment carbon stocks. Mg C ha$^{-1}$: Mega gram Carbon per hectare

Following the economic valuation procedure described in Jerath et al. [23], the estimated economic value of carbon stocks in Ambon in 2019 was US$ 1,792,978 and in Tual was US$ 16,873,907. The economic value of carbon stock per unit area of mangrove in Ambon was US$ 30,896 ha$^{-1}$ and in Tual was US$ 49,195 ha$^{-1}$. These economic values of carbon is higher than temperate mangrove (US$ 3,000 ha$^{-1}$), but lower than global tropical mangrove up to US$ 91,000 ha$^{-1}$ [33]. The economic values provide an overview for mangrove ecosystem services in urban areas of small islands in termsof carbon sequestration. However, the values are most likely an underestimation due to soil / sediment carbon was not included. Belowground carbon in soil / sediment in tropical mangrove ecosystem have been estimated to be 49 to 98% of total ecosystem carbon stocks [32,36]. Given the significant economic values of mangroves in urban area of small islands, mangrove conservation in urban area of small islands should be considered in the carbon trade in order to mitigate climate change through carbon sequestration [37].

The potential of mangrove in urban area of small islands are not limited on carbon storage, but also habitat for many marine biota. Previous study found that Ambon is habitat for 17 species of fish, 33 species mollusc, and 40 species of crabs [38]. This marine biota can be found at various strata of mangrove vegetation from top canopy to roots or sediment. For example, many species of mollusc and crabs can be found in roots and sediment (substrate), fish in water column, and birds, reptile in vegetation (canopy). Other ecological functions of mangrove is used as spawning ground, nursery ground, and feeding ground for many fauna such as fishes.

3.3. Problems and Management challenges

The study identified four main problems of the mangrove ecosystem in urban areas of small islands: mangrove deforestation and degradation and plastic debris. Mangrove areas in the world have been lost at a dramatic rate between 3.58% and 8.08% (39). About 50% of the global mangrove area decreased in the past 50 years [40,41,48]. Indonesia is one of the highest rates of mangrove deforestation and degradation. About 40% of mangrove in Indonesia was deforested and degraded with a deforestation rate between 1-3 % y$^{-1}$ [25,42]. Mangrove deforestation in urban areas of small islands was mostly due to mangrove conversion into infrastructure development such as ports, shops,
and settlements. Another cause of mangroves degradation was illegal logging (cut trees) for firewood or building material (Table 4) which mostly occurred in the satellite city of Tual (63%) and in the main city of Ambon (37%). Mean 84 stem of mangrove trees have been cut in Tual annually and mean 50 stems of mangrove trees have been cut in Ambon.

Multiplying carbon stocks by the mangrove cover (area) in 1999 to 2019 revealed that carbon stocks in Ambon decreased from 7,577 Mg C (27,807 Mg CO₂e) to 6,975 Mg C (25,600 Mg CO₂e). This has resulted in annual emission of 110 Mg CO₂e or equivalent to US$ 7,724 y⁻¹. These values will much higher if soil carbon is included in the calculation because a large proportion of carbon (up to 98%) was stored in soil [32,34]. Annual carbon emission resulted from mangrove deforestation was 0.07-0.21PgCO₂e, it is equal with 10-31% of annual emission from land-use and land cover change [34]. This suggests that avoiding mangrove conversion into other land use and strengthening conservation actions of carbon-rich mangrove in urban areas of small islands should be a high-priority strategy to mitigate climate change through carbon sequestration.

Carbon storage in mangrove was not only influenced by mangrove cover, but also influenced by the status of mangrove vegetation health [33]. This study confirmed that carbon stock in urban areas of small islands (Table 3) was significantly correlated with the parameter of vegetation health of mangrove (Table 2). This mean that converting mangrove into other land use such as modern market, settlement, aquaculture, and agriculture will not only reduce mangrove cover, but also affect the vegetation health of mangrove, which in turn reduce its carbon stocks. It was estimated that avoiding mangrove deforestation would reduce emission up to 31% and will help the Indonesia government to achieve national target in reducing GHG [34].

This study revealed that plastic pollution was more prominent in main city of Ambon (23%) than in satellite city of Tual (10%). Mean density of plastic in Ambon was 144 item m⁻². The highest density of plastic debris occurred in Passo and Wayheru, 276 item m⁻² and 214 item m⁻², respectively (Table 4). This may related to location of mangrove in Passo is just next to modern market and closed to settlement and traditional market. The study found macroplastic (mean density 81 item m⁻²), mesoplastic (mean density 103 item m⁻²), and microplastic (mean density 247 item m⁻²). The density of macroplastic, mesoplastic, and microplastic across study area was vary from 9.7 item m⁻² to 455 item m⁻² (Table 4). About 61% of plastic debris was distributed in Zone A (landward), followed by Zone C / Seaward (33%) and Zone B / middle (5%). This suggesting that landward (Zone A) of mangrove was the most polluted zone with the density of plastic debris up to 466 items m⁻². The main sources of plastic debris could be from land, rather than from sea. This can be explained by this study that the high density of plastic in landward (Zone A). Plastic remain for long time in mangroves ecosystem, only few of plastic in mangrove transported into sea [43]. The study demonstrated most plastic debris were retained by roots, branches, or seedlings of mangrove. Plastic debris caused mortality of mangrove especially seedlings which many of its dragged by the plastic or block the sunlight in turn prevent photosynthesis [44,45].

| Location | Cut trees (stem ha⁻¹) | Plastic coverage (%) | Density of macroplastic (item m⁻²) | Density of mesoplastic (item m⁻²) | Density of microplastic (item m⁻²) | Density of all plastic (item m⁻²) |
|----------|----------------------|----------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| Waiheru  | 50                   | 24.17                | 58.33                            | 127.67                           | 455.33                           | 213.78                           |
| Passo    | 0                    | 20.83                | 225.67                           | 234                              | 369.33                           | 276.33                           |
| Nania    | 120                  | 14.40                | 32                               | 39.33                            | 148.67                           | 73.33                            |
| Suli     | 0                    | 12.67                | 9.67                             | 11                               | 16.33                            | 12.33                            |
| Lateri   | 45                   | 28.34                | n/a                              | n/a                              | n/a                              | n/a                              |
| Tawiri   | 83                   | 36.17                | n/a                              | n/a                              | n/a                              | n/a                              |
| Inner Un | 50                   | 12.50                |                                  |                                  |                                  |                                  |

Table 4. Plastic pollution and illegal logging (cut trees) in urban areas of small islands
Other problems faced by mangrove were over sedimentation and oil spill [46,47,48,52,53]. It was reported that sedimentation in Ambon was very high with sediment accretion rate of 3 cm y\(^{-1}\) and annual sedimentation area was 5.43 ha y\(^{-1}\) [46,47,48]. Sedimentation in Ambon is due to upland development for housing or settlement and agriculture [49]. In some cases, coastal sedimentation is good for improving soil fertility and creating mudflat (new habitat) for mangrove [50,51]. However, over sedimentation in Ambon may hamper seedling growth and survival. Oil spill is another tremendous threat of mangroves in urban area due to human activities in the port and sea transportation such as ship reparation (40%), washing (20%), painting (20%), and discard used oil (20%) [52]. Oil pollution drove water quality decline and heavy metal may increase, which in turn affect mangrove growth, health, and survival [53]. For example, our visual observation showed that planted mangrove in some areas of Ambon Bay was unsuccessful may be due to oil pollution.

The interview survey resulted that most of respondent (97%) around mangrove forest in urban area was at productive ages (15 – 50 year old) and they have good education, mostly senior high school (83%) and only 3% was elementary school (Figure 3a). However, around 27% of the respondent was unemployment, followed by students (18%), housewife (16%), fisherman / farmers (10%), and 24.6% was self-employment and work at various sectors (Figure 3b). Many respondents do not have fix income because they were unemployment (27%) and work in the informal sector (4.4%). This result is supported by income analysis showed that 80% of respondent has low income (IRD 1 – 2 million m\(^{-1}\)), 2% has middle income (IRD 2 – 3 million m\(^{-1}\)), and only 1% of respondent has high income (IRD 3 - 4 million m\(^{-1}\)). This is another challenge for mangrove management and conservation due to one of the root causes or the driving factors of deforestation and forest degradation is economic difficulty or low income / poverty [54,55].
Figure 3. Characteristics of education (a) and livelihood (b) of respondents around urban mangrove areas

All of respondents have good knowledge about the ecological functions of mangrove (e.g. as habitat of fishes, crabs, and other fauna) and ecosystem services of mangrove (e.g. wave breaker, land protection, water filter). This is due to they have good education and good access to information which help them to improve their knowledge and perception on mangrove ecosystem [47,56]. The sources of information or knowledge about mangrove were from friends (43%), NGO (23%), television (18%), government (14%), and school (Figure 4c). Respondents were not only have good knowledge on mangrove, but also they get benefit from mangrove ecosystems such as sources of their livelihood (3.23%), land protection e.g. wave breaker, abrasion, etc. (9.68%), fire wood (14.52%), building material and equipment (21.77%), and get all benefit of mangrove (50.81%). Having a lot of benefit from mangrove, about 88% of respondents stated that it is very important to conserve mangrove ecosystem, 12% said important, and only 1% said it is not important (Figure 4a). However, their perception was inconsistent with what they do (e.g. they still throw away their rubbish into coastal area and still cut mangrove trees) and what they want, or we can say it was just “talk the talk, but not yet walk the walk”. For example, our interview survey found that 94.35% of respondent agree the conversion of mangrove into other land use because it is provide more economic benefit than mangroves. This finding indicates that although urban societies have good knowledge of mangrove, their participation in mangrove conservation is relatively low. They only interested in conservation actions such as mangrove planting only if they get incentive to do it, only few people who voluntarily participate in mangrove conservation [47].
Figure 4. Perception of respondent to mangrove conservation (a), the conditions of mangroves (b), and the sources of their knowledge about mangrove (c).

The interview survey showed that most of the respondents (95%) were interested in mangrove training and they stated that they have the responsibility in mangrove management and restoration (67%). Around 83% of respondents believed that the condition of the mangrove ecosystem is getting better, still good (9%), not much change (7%), and only 4% said that the mangrove condition is getting worse (Figure 4b). In contrast, our images analysis showed that the mangrove area decreased (chapter 3.1) and vegetation analysis revealed that mangrove vegetation was degraded (Table 2). The perception of respondents may be influenced by some conservation actions such as public campaigns or awareness, mangrove planting, and beach clean-up. A current research showed that mangrove planting did not result in significant long-term mangrove area increase or tree survivorship [57,58]. It is important to evaluate to what extent these conservation actions extend to ensure that it is effective to improve public perception and provide significant effects on mangrove ecosystem.

4. Conclusions
Mangrove forests in urban areas of small islands have a good potential to offset carbon emissions through carbon sequestration and storage. However, in the last two decades (2009-2019) mangrove cover decreased at the rate up to 0.75% y⁻¹ and the status of mangrove vegetation health was poor particularly in main urban area (main city). Tremendous threats such as mangrove deforestation and degradation and plastic pollution were faced by urban mangrove forests in small islands. Mangrove forests in main urban area (main city) face greater threats than in satellite urban areas (satellite city). Society around urban mangrove forests in small islands has good knowledge and perception on
mangrove ecosystem, but their participation on mangrove conservation is low. This management challenge require new approach which not only effective to improve knowledge and perception of society, but also to encourages them to participate in mangrove conservation. Given the significant carbon sequestration and storage of mangroves in urban area of small islands, its threats, and management challenge, avoiding mangrove conversion and strengthen conservation actions of carbon-rich mangrove in urban areas of small islands should be a high-priority strategy for better mangrove management and climate change mitigation.

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