

# The habitat suitability of Timor friarbird (*Philemon inornatus*) in Western Timor Island, Indonesia

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**Abstract.** Paga B, Pudyatmoko S, Wijayanti LR, Yuda P, Sulaksono N. 2022. The habitat suitability of Timor friarbird (*Philemon inornatus*) in Western Timor Island, Indonesia. *Biodiversitas* 23: 703-713. Timor friarbird is an endemic bird to Timor Island. The population of this bird has been declining due to land cover changes as a result of massive anthropogenic pressures. This study aimed to assess the suitability of Timor friarbird's habitat by using 12 ecogeographical variables. The sources of data included Sentinel 2A satellite imagery and remote sensing-based algorithms. The bird's presence was analyzed by using a combination of line transect with point count methods. Ecological Niche Factor Analysis (ENFA) model was applied to obtain habitat suitability value as well as coefficient of marginality (M) and specialization (S). These results showed that the Timor friarbird needs a habitat with a different value from the average of the entire habitat. High specialization value indicated that the species has a narrow ecological niche. Factors influencing habitat suitability included the distance from roads, the presence of mangroves, primary and secondary dryland forests, rivers, and low-density settlements. About 75% of the study area is classified as unsuitable habitat, and only 22% is suitable with range classes of suitability from marginal to optimal habitat. Areas with less anthropogenic pressure on the land cover will be preferred more by the bird. Improvement of unsuitable habitat and protection of suitable habitat, therefore, will be the most important strategy for Timor friarbird conservation.

**Keywords:** Habitat suitability, marginality and specialization, Timor friarbird

## INTRODUCTION

Timor Island landscape was dominated by dry season forest and non-forest (Lesmana et al. 2000). The dry season forest harbors a high endemicity level of flora and fauna (Lesmana et al. 2000; Paga et al. 2021). However, the biogeography of dry season forests is only partially understood (Prieto-torres et al. 2018). Overall, there are 35 bird species on the island (Stattersfield et al. 1998), and seven endemic species, including Timor friarbird (*Philemon inornatus*) (Coates and Bishop 2000; Paga et al. 2021).

Distribution of Timor Friarbird birds is scattered on the island of Timor (Monk et al. 2000), from the lowlands to the highlands (2400 m asl) (Coates and Bishop 2000). It was first recognized in 1944 (Mayr 1944). According to the traditional life of the Timorese, this species has become an identity in their daily activities (Paga et al. 2021). The bird has a body size of 24 cm and is classified as a chirping bird (Coates and Bishop 2000).

Currently, the population density of this bird is very low with 1 individual per 2 Ha (Paga 2012). But, it has not been considered as a protected animal under the government regulation (No P.106/MENLHK/SETJEN/KUM.1/12/2018) (KLHK 2018), and The International Union for Conservation of Nature's (IUCN) has classified it as Least Concern (BirdLife International 2018). Many species of the Meliphagidae family are threatened by

humans (Goulding et al. 2019). Various anthropogenic disturbances continue to occur in the form of hunting, forest conversion, and habitat fragmentation (Monk et al. 2000). This change causes declines in the forest (Miettinen et al. 2011, Margono et al. 2014), and strong habitat fragmentation (Fisher 2011), which can change the spatiotemporal of species occurrence (Barrantes et al. 2016).

Natural forests as sources of food, shelter, and reproductive sites of Timor friarbird have disappeared (Prior et al. 2013; Oppel et al. 2017; Bain et al. 2020). Unfortunately, the species adaptability to forest loss has not been known. This study is important in identifying the consequence of habitat change on the habitat suitability of the Timor friarbird. This information is the basic knowledge for effective decision-making for habitat conservation (Wauchope-drumm et al. 2019; Chiatante et al. 2019). This study aims to assess landscape factors that contribute to the habitat suitability of the Timor friarbird and to determine whether the western part of Timor Island is the optimum habitat for the species.

## MATERIALS AND METHODS

### Study area

The study area covers 1662.91 km<sup>2</sup> of Kupang City and of Kupang District, East Nusa Tenggara Province,

Indonesia (Figure 1). The Kupang City has the highest population size and density (2413 people/km<sup>2</sup>), compared to Kupang District (73 people/km<sup>2</sup>) (BPS-Statistics of Nusa Tenggara Timur Province 2020).

The climate of the study area is characterized by a long dry season period of  $\pm 7$ -8 months (April-November), with an annual rainfall of  $\pm 1450$  mm (Mulyani et al. 2014). This area is one of the driest regions in Indonesia. About 18% of the area above 500 meters receives more rainfall, compared to  $\pm 60\%$  of the steep hilly-highland (100-500 m) and  $\pm 22\%$  area below 100 meters (Fisher 2012; Pujiono et al. 2019). Rainfall and topography are factors that affect the number of natural water sources, therefore, they limit the distribution of island dwellers, both humans and wildlife (Pudyatmoko 2017). The study area is surrounded by steep hills and highlands (Amfoang, Camplong, Amarasi).

### Procedures

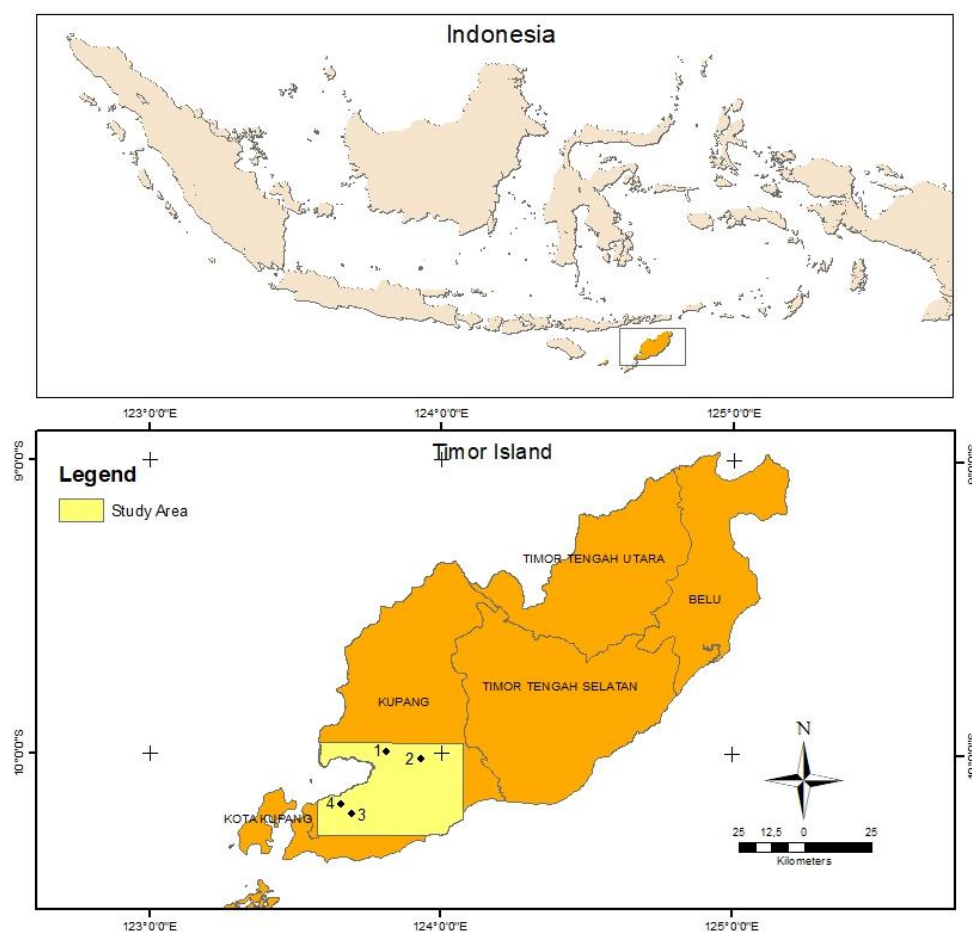
The ecological Niche Factor Analysis (ENFA) is applied to determine the habitat suitability of the bird (Hirzel et al. 2002; Hirzel et al. 2004). It was calculated by comparing the ecogeographical variables values or cell niche in one area species (species cells distribution) and the value of the total cells in the entire study area.

### Data collection

Ecological Niche Factor Analysis (ENFA) requires two large sets of data; presence-only species data as the response and Ecogeographical Variables (EGV) (Hirzel and Arlettaz 2003; Dolgener et al. 2014).

### Data of ecogeographical variable

The ecogeographical data were obtained from satellite imagery with a cell resolution of 10 meters, which covers 166,291 ha with a total of 16,629,100 grid cells. The image was processed as thematic raster map data for ecogeographic variables and a Binary or Boolean Raster Map for presence data (Hirzel et al. 2002). The satellite image used was Sentinel MSI 2A (Multiple Spectral Instrument-level 2A) (Immordino et al. 2019), which produced 12 raster bands, namely; (1) Coastal aerosol raster; (2) Blue; (3) Greens; (4) Red; (5) Red edge1; (7) Red edge2; (7) Red edge3; (8) Near-Infrared; (8A) red edge8; (9) Water vapor; (11) Shortwave Infrared1; and (12) Shortwave Infrared2 (Suhet 2015). The main data sourced from Remote Sensing (RS) Sentinel 2A satellite imagery on October 15, 2020, with 0-3% cloud cover, were downloaded from <http://scihub.copernicus.eu> with software ESA-SNAP 8.0.3 (European Space Agency-Sentinel Applications Platform) (Mora 2019).



**Figure 1.** The study area in the western part of Timor Island, Indonesia (Yellow Square); 1. Bipolo; 2. Camplong; 3. Baumata; 4. Bandara El Tari, Kupang, East Nusa Tenggara Province, Indonesia

The four categories of an environmental descriptor included; (i) topography: elevation and slope (Erfanian et al. 2013; Mora 2019); (ii) biotic: EVI (enhanced vegetation index) (Lara et al. 2018; Vijith and Dodge-Wan 2020); distance to a secondary dryland forest (SDLF), primary dryland forest (PDLF), and mangrove, (iii) abiotic: normalized difference water index (NDWI) (Xue and Su 2017), and distance from natural or artificial water sources, (iv) anthropogenic: distances from settlements and roads and agricultural activities (Table 1).

#### *Data of Timor friarbird presence*

The collection of Timor friarbird presence data was carried out from August 2019 to October 2020, on three landscapes (Table 2) (Bibby et al. 2000). Transect lines were placed systematically based on the sampling plot design through Hawth's Analysis Tools for ArcGIS 10.2. Meanwhile, point counts were placed randomly outside the transect line based on the probability of bird presence. The distance between the transect lines was 500 m and between points on the line was 250 m. The birds observed in the transect line were recorded and the coordinates of their encounter were noted (Bibby et al. 2000). The transect length of each landscape was 2.2 km in Baumata, 3.95 km

in Bipolo and 5.3 km in Camplong. The width of the transect was 100 m (Bibby et al. 2000; Buckland 2006). Total length of the transect in three landscapes was 133,250 m (Table 2). The number of total point count was 819 points. Observations were made at each point for 5-10 minutes. Bird observations were carried out between 05.00 am-06.00 pm. Bird observations were repeated three times (September 2019, January and August 2020) in each habitat type. Points of Timor Friarbird presence were modeled with a raster map (0;1) (0: absent, 1: present) in a pixel resolution of 10 x 10 m with a coordinate projection system [EPSG 32751] WGS 84/UTM zone 51S also known as Boolean map.

#### **Data analysis**

ENFA used two data sets. First, a global collection that stores descriptor values for all cells in the study area to describe habitat characteristics and human disturbance quantitatively. This data set is called Ecogeographical Variable (EGV). Second, the species data that has stored values on all cells occupied/not occupied by a bird in the study area as a response variable (Hirzel et al. 2002; Hirzel and Lay 2008; Erfanian et al. 2013).

**Table 1.** Echogeographic variable descriptors used in the ENFA analysis

No of variable (Var.)	Name of EGV variable	Description	Reference
1	Slope	Quantitative value of land slope	Hirzel et al. (2004); Erfanian et al. (2013)
2	Elevation	Quantitative value of altitude	Hirzel et al. (2004)
3	EVI	Optimized quantitative value of the greenness index	Lara et al. (2018); Vijith and Dodge-Wan (2020)
4	Agriculture	Quantitative value of the feature index of the agricultural or open land and non-crop vegetation	Erfanian et al. (2013); Mora (2019)
5	NDWI	Quantitative value of the water body feature index to describe the presence of water features	Xue and Su (2017)
6	Distance to SDLF	Euclidean distance from SDLF	Hirzel et al. (2004); Immordino et al. (2019)
7	Distance to PDLF	Euclidean distance from PDLF	Hirzel et al. (2004); Immordino et al. (2019)
8	Distance to mangrove	Euclidean distance from mangrove	Hirzel et al. (2004); Immordino et al. (2019)
9	Distance to artificial water source	Euclidean distance from dams, check dams and ponds	Hirzel et al. (2004); Immordino et al. (2019)
10	Distance to Settlement	Euclidean distance from settlement	Hirzel et al. (2004); Immordino et al. (2019)
11	Distance to road	Euclidean distance from main road	Hirzel et al. (2004); Immordino et al. (2019)
12	Distance to river	Euclidean distance from river	Hirzel et al. (2004); Immordino et al. (2019)

**Table 2.** Typology of the presence of the Timor friarbird estimation

Typology of location	Baumata landscape	Bipolo landscape	Camplong landscape
Grid area (ha)	374	1659	2184
Conservation area (ha)	36.21	308.60	696.60
Distance from Kupang (central point from Eltari airport) (km)	5.3	26.1	34.4
Topography	Low	Low-high	Middle-high
Elevation (m asl)	211-263	10-50	240-480
Habitat type	Lowland forest	Lowland forest	Lowland forest
Transect Length (m)	6800	31600	42000
Total Point Count	62	246	511

ENFA produced a global marginality coefficient (0-1), which described how far the optimum condition of the species is to the average of the study area, and specialization value (0-infinity). A marginalization value close to 0 indicates that the habitat characteristics favored by the species are identical to global habitat characteristics. It indicates a generalist species (Hirzel et al. 2002; 2004). Marginality value near 1 indicated that the species niche is different with the conditions of the study area. Negative results indicated that the species was present in habitat conditions below the global average habitat value, while positive results indicated that they preferred habitat values above the global average habitat value.

The ecogeographical variables contribution on the habitat suitability was examined from the score matrix from Biomapper software. Another output is the habitat suitability map with various classes (Hirzel et al. 2002). The habitat suitability map is a prognosis of habitat suitability classes and the extent of each class (Hirzel et al. 2002; 2006; Hirzel and Lay 2008).

Evaluation of model accuracy was measured by the values of absolute validation index (AVI), contrast validation index (CVI) and Boyce Index (Hirzel 2004; Hirzel et al. 2004). An AVI (0-1) indicates how well this model distinguishes areas of high with low habitat suitability (Hirzel and Arlettaz 2003; Hirzel 2006). Meanwhile, CVI (0-0.5) shows how accurate the model is (Hirzel and Arlettaz 2003), and boyce-index value assessed the extent of the predictive power (-1 to 1).

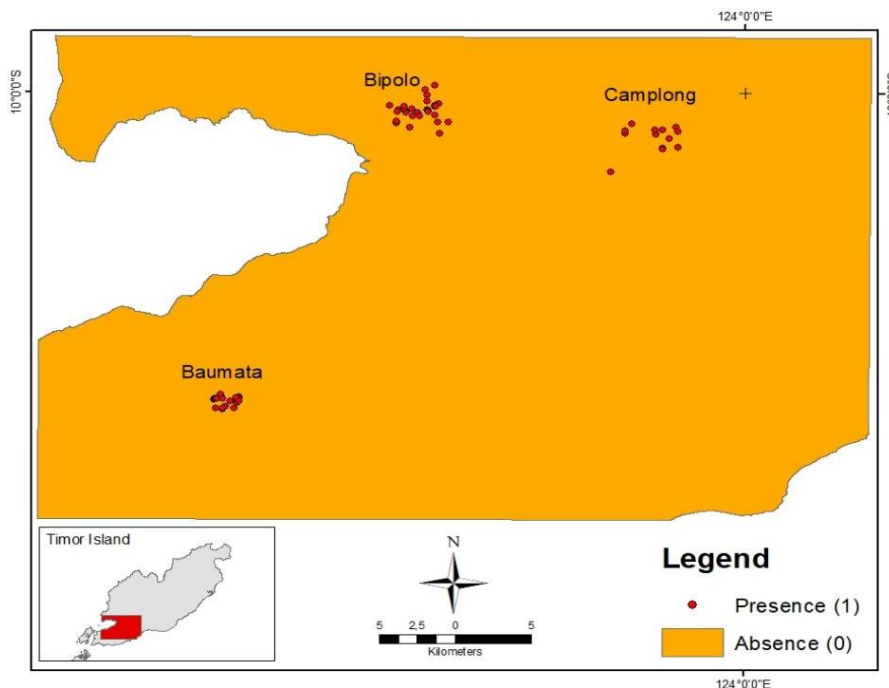
## RESULTS AND DISCUSSION

### The score of matrix marginality and specialization of the Timor friarbird's habitat

The calculation of marginality and specialization matrix score for Timor Friarbird habitat is based on the 73 pixels where the species present, including Camplong 20, Bipolo 33, and Baumata 20 (Figure 2).

The overall marginality (M) is 0.92. It means that the Timor friarbird habitat was very different from the average conditions in the study area. The specialization (S) value is 8, or the tolerance value is 0.124, indicated a low tolerance and a narrow habitat niche. According to the calculation of the 12 existing factors, the first 3 contributed 93% of eigenvalues. The first was the marginality factor which contributed 41%, while the second and third factors of specialization contributed 52% (Table 3). The results explained 96.5% of information that can be used to determine the habitat suitability map.

Nine variables had negative values and three positives. A negative value indicated that the species preferred to choose a lower value than the average condition. The variables with a high absolute value were the distance from the road (-0.635), mangrove (-0.419), NDWI (-0.310), distance to a river (-0.297), slope (-0.293) and distance to PDLF (-0.212). Other variables, such as elevation (-0.115), agriculture (-0.102), distance from SDLF (0.063), distance to artificial water sources (-0.007) and distance to settlement (-0.102) showed an absolute value close to zero, which means that they were not significantly different from the average condition of the area.



**Figure 2.** Binary map of Timor friarbird presence in 73 locations; Baumata (20), Bipolo (33), and Camplong (20) Landscapes

**Table 3.** Marginality and specialization values of Timor friarbird's ecogeographical variables based on ENFA analysis results

No. var.	Ecogeography variable	Marginality	Spec.1	Spec.2
		Factor1 41%	Factor2 39%	Factor3 13%
1	Slope (5)	-0.293	0.050	0.008
2	Elevation (7)	-0.115	0.205	0.355
3	Evi (12)	0.279	-0.006	0.033
4	Agriculture (10)	0.019	-0.028	-0.011
5	NDWI (3)	-0.310	-0.023	0.037
6	Distance to SDLF (11)	0.063	-0.424	0.028
7	Distance to PDLF (6)	-0.212	0.369	0.090
8	Distance to mangrove (2)	-0.419	-0.547	-0.703
9	Distance to artificial water source /others (9)	-0.007	-0.029	-0.344
10	Distance to settlement (8)	-0.102	0.458	-0.215
11	Distance to road (1)	-0.635	-0.092	0.443
12	Distance to river (4)	-0.297	0.347	-0.084
	Marginality:	0.918		
	Specialisation:	8.083		
	Tolerance (1/S):	0.124		

### Habitat suitability map

The main ENFA output showed that factors 1-3 had a 93% contribution percentage for the total of factor eigenvalues and was able to explain 96.5% information. Therefore, it was sufficient to make the Timor friarbird habitat suitability map (Figure 3).

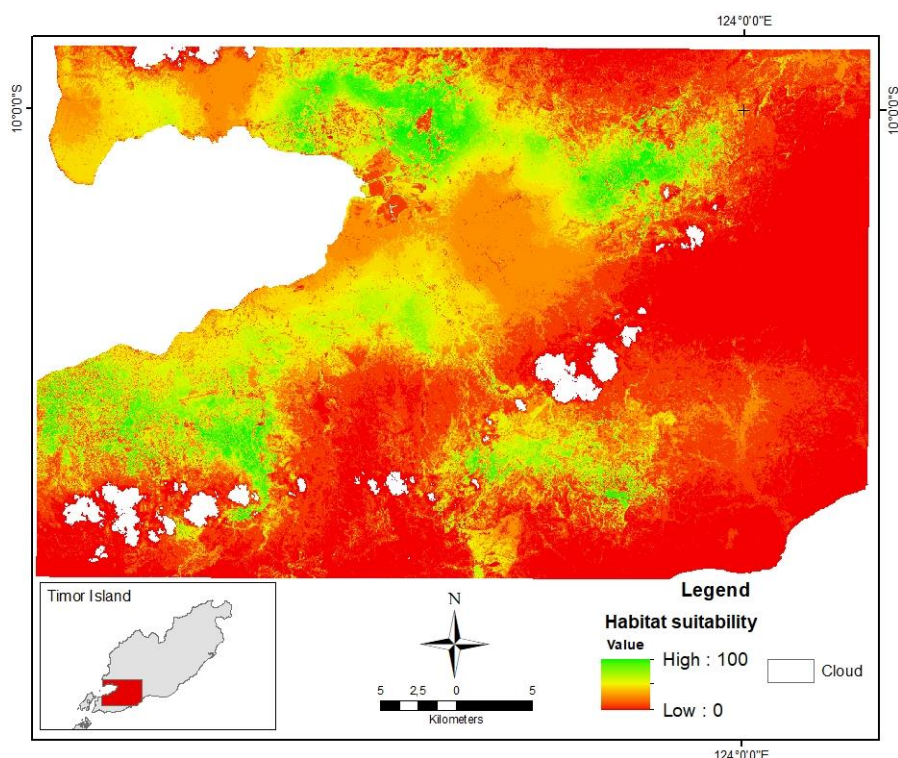
Figure 3 showed the red area was not suitable habitat, while those closer to green were more suitable. The low suitability areas were dominant in the highlands (>200 m asl) of West Timor Island, such as hills, steep, and mountains around the Bipolo landscape from North to East. They are connected to the Fatuleu, Amfoang, Nunsanen, Camplong, as well as the southern part of Kupang bay in the Amarasi region, which are connected to the Baumata landscape. Conversely, suitable habitats (marginal to optimal) were dominant in the lowland areas (<200 m asl) of the Bipolo landscape and its surroundings compared to others on the west side of the Kupang bay lowlands bordering Kupang City and some lowlands in the western region of the Camplong bordering Naibonat, East Kupang Sub-district, Kupang District.

### Validation model

The AVI value is 0.557 indicated that this model can distinguish areas of high from of low habitat suitability. Meanwhile, the CVI indicator: 0.414 and Boyce-index value: 0.652 showed that the model was accurate and the completed predictions were consistent with attendance distribution in the evaluation data set.

### Reclassification of habitat suitability map

Reclassification in habitat suitability maps with a lower number of classes helped to identify the habitat space used by the bird. The habitat suitability map (HS; 0-100) (Figure 4) were divided into 5 classes, namely unsuitable, marginal, moderate suitability, optimally suitable (Figure 5). The size of each class is presented in Table 4.

**Figure 3.** Habitat suitability map of Timor friarbird in the Western Part of Timor Island, Indonesia



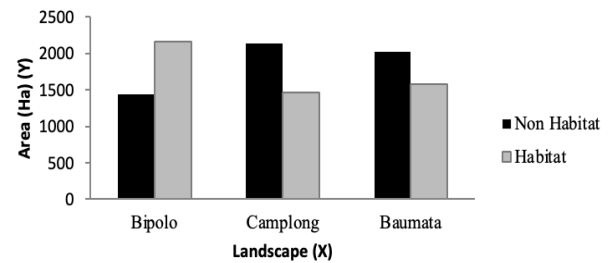
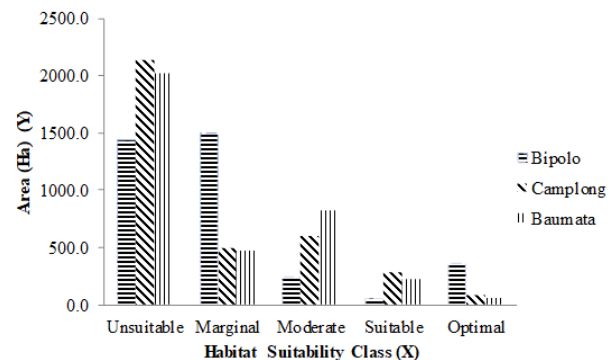
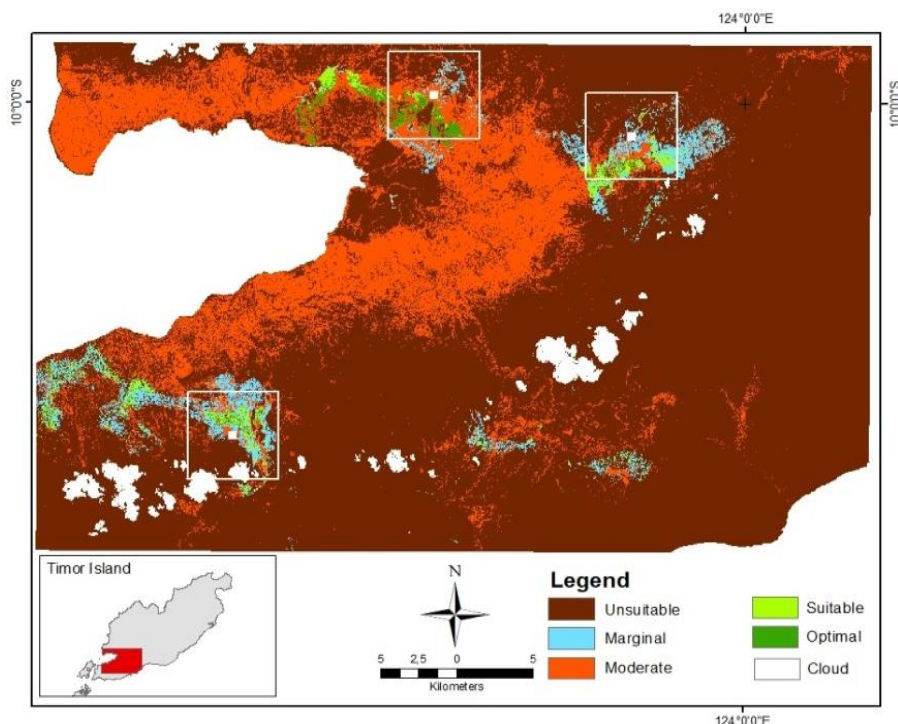
**Table 4.** Reclassification of Timor friarbird's habitat suitability map

Reclassification	Intervals	Area (Ha)	Percentage (%)
Unsuitable	0-27	124253.81	74.7
Marginal	28-45	30261.75	18.2
Moderate suitable	46-68	4392.02	2.6
Suitable	69-90	1284.51	0.8
Optimal/high suitable	91-100	933.77	0.6
Cloud cover factor	-	5165.14	3.1
Total		166291	100

The total area of Timor friarbird habitat was 36,872.05 ha (22.2%), and consisted of a marginal class, moderate suitability, optimal, while not suitable habitat was 125,253.81 ha (77.1%).

The distribution of the Timor friarbird habitat was dominant in the Bipolo Landscape around the Bipolo Natural Recreation Area (NRA), Sulamu bordering the West and Central Fatuleu Sub-districts. The northern boundary of these two sub-districts had a mountainous topography and steep hills with the highest peak being Mount Fatuleu 875 m, while the southern boundary was a lowland area, covering 4000 ha of tidal mudflats with 1400 ha covered by mangrove forests (Trainor and Hidayat 2014). From the habitat evaluation grid covering an area of 3600 ha in each landscape (Figure 4), Bipolo had a larger habitat area for the Timor friarbird (2162.87 ha) compared to Camplong (1460.62 ha) and Baumata (1577.3 ha) (Figure 5). According to the total area of the habitat

evaluation grid in the three landscapes, which was 10,800 Ha, 5599.2 Ha was unsuitable habitat, while 5200.8 ha was suitable in the form of various classes (Figure 6).

**Figure 5.** The area (ha) of the Timor friarbird habitat and non-habitat in the study area**Figure 6.** Land area (ha) based on Timor friarbird habitat suitability class in each study landscape**Figure 4.** Five classes of Timor friarbird habitat suitability maps (3600 ha evaluation grid, white square)

## Discussion

Timor Friarbird has been known to coexist with humans and also predominated almost all lowlands in the area. The pattern of 'Mamar' a traditional wisdom agroforest around springs (Pujiono et al. 2021) settlements and agricultural activities around natural water sources or rivers, such as the Baumata and Camplong springs, 'Overlaps' wildlife habitats.

The birds known to live in lowland to highland habitats but prefer a relatively narrow environment. ENFA showed that the bird habitat was dominated by forested areas in the Bipolo landscape, compared to the other two locations (Camplong and Baumata). Their marginality value indicated that this species lives in a very special habitat relative to its reference set. Based on the ecological niche category, the Timor friarbird's habitat had been classified as a "specialist species". This is consistent with Hirzel et al. (2002; 2004) that the specialist could only live in narrow habitat space. Previously, the distribution of Timor friarbird was restricted in geographical range (Coates and Bishop 2000).

The bird lives in a very limited range of habitats under conditions that differ partly from the study area. The specialist has been supported by its special characteristics in the form of a long and sturdy beak to pick up nectar on a large or deep flower crown like *Bombax ceiba* and insects on the bark of trees. Honeyeaters select flowers by size and sturdiness of available perches such as *Eucalyptus* spp., feed on large inflorescences (Recher and Davis 2011), which flowered more abundantly, had cup-shaped flowers (Recher et al. 2016). This is in line with Scoble and Clarke (2006), that nectarivorous birds (family Meliphagidae) prefer flowers that contain large amounts of nectar. It is a better predictor of bird visitation (Chmel et al. 2021).

The closer the road, the more it is selected by the birds in their daily activities. This species's presence was highest near the road (3-37 m) compared to a distance of more than 142 m (Paga 2012). Timorese builds houses on the left and right sides of the road. Road verges in transformed landscapes have been important habitats for plants (Arenas et al. 2017; Grobler and Campbell 2022). These areas generally contain some trees and poles with a height of more than 12 m. More open canopy and forest edge plant blooms increase the abundance of nectarivorous species (Sementili-Cardoso et al. 2020). The vegetation is generally composed of flower-producing plant species and insects, such as *Gliricidia sepium*, *Ceiba pentandra*, *Spondias* sp., which were planted as a road boundary or a border of land ownership. Other tree species are *Cassia siamea* and *Tectona grandis* which are commonly found at the edges of PDLF and SDLF. The Timor friarbird requires a minimum of seven trees with pole and sapling-level vegetation as a food source and cover as a habitat (Paga et al. 2021).

The "specialist" bird has not chosen all roads as its habitat. It prefers a flat road located near the river and close to the mangrove forest and an area with low settlement density. Such road conditions are more dominantly found in Bipolo landscape, which is closer to the mangrove forest. Meanwhile, the Baumata and Camplong landscapes are located at a distance of more than 3 km from the

mangrove forest. These landscape portraits have implications for the availability of the Timor friarbird habitat, which is dominantly wider in the Bipolo than Baumata and Camplong (Figures 5 and 6). Building main roads in natural habitats threaten the survival of species and communities (Maseko et al. 2017, 2019). The major roads with high-traffic experience have low encounters or negative bird abundance due to the noise (Carvalho and Mira 2011; Kociolek et al. 2011; Møller et al. 2011; Summers et al. 2011; McClure et al. 2013; D'Amico et al. 2015; Jack et al. 2015; Ascensao et al. 2019; Cooke et al. 2020; Schwartz et al. 2020). Meanwhile, smaller roads that are further away from noise have increased the presence of birds (Cooke et al. 2020). Anthropogenic noise and high-traffic roads tend to be avoided by songbirds (Polak 2014). In semi-arid and arid areas, noise pollution from roads and traffic interferes with the vocal communication of birds and can cause rapid genetic effects (Dean et al. 2019). The avian can be substantially affected by roads (Bishop and Brogan 2013), roads and wildlife have important implications and utility for the conservation of indigenous, or management of, exotic wildlife (Sadleir and Linklater 2016; Dean et al. 2019).

The distance from the mangrove affects the habitat suitability for the Timor friarbird. The closer to the mangrove forest, the higher the species presence to forage for flowers, insects, and fruit in the tight crevices of the mangrove canopy. This area is also the main habitat for estuarine crocodiles (*Crocodylus porosus*), so it is the safest area for the Timor Friarbird habitat from the threat of massive poaching that recently (Paga et al. 2021).

This species prefers locations with lower NDWI and near rivers. Artificial water sources had very little contribution to the suitability of the Timor friarbird habitat (Table 3). Rivers are beneficial to birds in hot conditions and contribute to habitat degradation (Landman et al. 2012; McKechnie et al. 2012; Abdu et al. 2018). The scarcity of water resources is a major determinant of the structure of animal and plant communities in dry environments (Smit et al. 2019).

Areas close to riverbanks have sufficient groundwater supplies for vegetation growth in the dry season (Paga 2012). Riverbanks habitats have unique vegetation characteristics and capable of maintaining bird species diversity (Hillman et al. 2016; Nimmo et al. 2016; Zimbres et al. 2017; Liang et al. 2018), and beneficial for ecosystem function in the tropics (Luke et al. 2019) with stable temperatures (Li et al. 2013). At a distance less than 1 km from the river, the presence of the Timor friarbird was higher and decreased with a farther distance (>1 km) from the river (Paga 2012). The presence of such land cover becomes a suitable habitat space for the species to obtain food resources, cover, shelter, and nesting places.

Slope contributed to the suitability of the Timor friarbird's habitat. This species preferred land that tends to be flat and lightly sloping, at 3-15% (flat to sloping land) (Paga 2012). The landscape with a dominant flat to gently sloping slope can be found in the Bipolo lowlands on the southern side of the Fatuleu Mountains, compared to Baumata and Camplong, which had a dominant topography

of >15%. In the Baumata area, flat and sloping land can only be found around the Baumata NRA, covering 36.21 ha. Topographical complexity creates climate gradients that break down regional climate patterns into local scale microclimates (Dobrowski et al. 2011). These conditions create a variety of habitats and give species a greater opportunity to move with climate change. Topography is very important in an era of climate change because changes in temperature and rainfall regimes will significantly change forest ecosystems and species assemblages (Coristine and Kerr 2011; Robillard et al. 2015; Stralberg et al. 2015). Topography controls the hydrological conditions, where moisture and nutrients are required to support high-quality habitat that accumulates in the sunken lowlands (Bale et al. 2020).

The SDLF has no significant contribution on habitat suitability, meanwhile the distance variable from primary forest affected the habitat suitability. The closer to the primary forest, the higher the occupancy of this species. Specialist nectarivorous birds were most frequent in the primary forest and undisturbed forest (Alvarez-Alvarez et al. 2018; Chiawo et al. 2018). This species for foraging activities, especially insects in dense tree canopy crevices, during the day before resting under a dense vegetation canopy. They performed this behavior in order to avoid hot temperatures during the day. Preliminary studies have shown that birds and other animals living in hot and arid savanna environments use thermally buffered microsites to avoid extreme temperatures (Hetem et al. 2012; McKechnie et al. 2012; Potter et al. 2013; Briscoe et al. 2014; Scheffers et al. 2014). This area and its surroundings are significantly used by the species' for rest and social activities after eating in the morning (Paga et al. 2021). Most songbird settle in breeding areas with uneven habitat quality and social attractiveness (Broughton et al. 2020). In order to conserve on a landscape scale of native bird species, a minimum forest cover thresholds required are at least 40-50% of primary forest types with a more open canopy cover (Martensen et al. 2012; Banks-Leite et al. 2014; Morante-Filho et al. 2015; Ochoa-Quintero et al. 2015). Forest type and structural heterogeneity have a more direct influence on the distribution of bird species (Bale et al. 2020; Maseko et al. 2020).

Not all settlement areas were selected as "specialist" habitats, but only a few had characteristics suitable for this species, namely low-density areas, settlements close to roads with low levels of vehicle and human mobility. Furthermore, there is evergreen vegetation throughout the year on the left and right sides of the road forming a linear vegetation line as a forest area that function as natural or semi-natural habitats for birds (Bennett et al. 2014; Pasher et al. 2016; Zimbres et al. 2017; Sullivan et al. 2017; Hall et al. 2018). This areal can function as a corridor for birds that move in and out of settlements with least 7 individuals tree or pole vegetation as a source of feed and cover (Paga et al. 2021).

The greenery value as EVI has a significant effect on the Timor friarbird habitat suitability. This species prefers an area with higher EVI than average. This is because green areas provide more fruit and insects for the birds.

The existence of food resources together with reproduction place, cover and shelter was very dependent on vegetation. Vegetation in tropical deciduous forests is influenced by rainfall patterns as a strong determinant of the new growth of this resource (Kushwaha et al. 2011; Butt et al. 2015). Although many bird species avoid agricultural areas (Sekercioglu 2012), this species is commonly found in a specific agricultural area, such as cashew plantations. Their activities in the plantation include nectar forage, insects and cashew fruit, social activities under shady tree crowns, and shelter (Fontúrbel et al. 2021).

According to this study, the landscape forest habitat of Bipolo to Tanjung Toda, which has been relatively undisturbed by anthropogenic activities, was a critical habitat for the survival of the endemic Timor friarbird bird population in the future. The relocation in the central government cluster of East Nusa Tenggara Province to the Naibonat area, East Kupang, near the Kupang Bay tidal lowlands, needs to consider the critical habitat existence of this species.

This species currently has Least Concern status by IUCN, however there are real threats that have caused its decline of the size of suitable habitat (only 22.2%). For the conservation of this specialist bird, a more systematic monitoring program is needed, and other bio-ecological studies as well as habitat development priorities in areas that support the availability of specific environments suitable for this species. These efforts require multi-stakeholder collaboration (government, tribal-cultural and religious communities, industry and business, environmental groups, research and education institutions) as well as cross-country (Indonesia and Timor Leste), because the species is located in two countries, one island as habitat for endemic bird species and on Timor island.

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