The Habitat Susceptibility of Bali Starling (*Leucopsar rothschildi* Stresemann 1912) Based on Forest Fire Vulnerability Mappin in West Bali National Park

F Pramatana¹, L B Prasetyo², and S B Rushayati³

¹,²,³ Forest Resource Conservation and Ecotourism Departement, Faculty of Forestry, IPB

Email: fadlan.pramatana@gmail.com

Abstract. Bali starling is an endemic and endangered species which tend to decrease of its population in the wild. West Bali National Park (WBNP) is the only habitat of bali starling, however it is threatened nowadays by forest fire. Understanding the sensitivity of habitat to forest & land fire is urgently needed. Geographic Information System (GIS) can be used for mapping the vulnerability of forest fire. This study aims to analyze the contributed factor of forest fire, to develop vulnerability level map of forest fire in WBNP, to estimate habitat vulnerability of bali starling. The variable for mapping forest fire in WBNP were road distance, village distance, land cover, NDVI, NDMI, surface temperature, and slope. Forest fire map in WBNP was created by scoring from each variable, and classified into four classes of forest fire vulnerability which are very low (9,821 ha), low (5,015.718 ha), middle (6,778.656 ha), and high (2,126.006 ha). Bali starling existence in the middle and high vulnerability forest fire class in WBNP, consequently the population and habitat of bali starling is a very vulnerable. Management of population and habitat of bali starling in WBNP must be implemented focus on forest fire impact.

1. Introduction

According to International Union for Conservation of Nature and Natural Resources (IUCN) red list, Bali starling (*Leucopsar rothschildi* Stresemann) [22] is categorized to the critically endangered species. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) put the Bali starling in Appendix 1 which is categorized as a critically endangered species and it is not allowed for free traded. Bali starling is also protected by government of Indonesia through the Minister of Agriculture decision No. 421/Kpts/Um/8/70 on 26 August 1970. In addition, Bali starling is one of the 14 Indonesian priority species which the population in the wild has to increase 3% a year. However, the Bali starling population tend to decrease every year which lead to be categorized as a rare and critically endangered species [22].

West Bali National Park (WBNP) is the only one habitat of Bali starling. Long time ago, Bali starling can be found widely in the most WBNP area, however, only 6 individuals of Bali starling were recorded on 2001 [16]. Forest fire is suggested as the factor causing the constricting home range of Bali starling. It may contribute to unsecure environment for Bali starling reproduction believed One of them that causes bali starling home range decreased is forest fire and on 2001, the species only 6 in the wild, so stated for secure reproduction very difficult [6].
Forest fire have occurred almost every year in WNBP. In the period of 2009-2014, forest fires destroy about 32 ha of WNBP [20]. Forest fire has negative impact on local and national development, such as to the biodiversity, livelihood, and healthy [18]. The study of forest fire mapping, home range and habitat of Bali starling in WBNP is very important for the in situ conservation of Bali starling. Geographic Information System (GIS) can be used for mapping the vulnerability level of forest fire. This study aimed to analyze the causes of forest fire, and to map out the vulnerability level of forest fire in WBNP, in relation to and to estimate the habitat threatened of Bali starling. It hopes to contribute to as basis for the habitat management of Bali starling in WNBP.

2. Methods

2.1. Materials
Research field was conducted in West Bali National Park (WBNP) Bali Province on March 2016. Supporting materials used for collecting and processing data were camera, binocular, global positioning system, administration bali map, landcover map, bali road map, bali village map, landsat 8 path/row 117/66, software ArcGIS 10.3, and erdas imagine 2014, DNRGPS.

2.2. Map Interpretation and Field Observation
Interpretation of map data was carried out to obtain the map of as follows: surface temperature, village distance, road distance, Normalized Difference Vegetation Index, Normalized Difference Moisture Index, slope, and vegetation cover. Data of fire area groundcheck, landcover groundcheck, and bali starling distribution were collected by field observation.

2.3. Data Processing and Analysis

2.3.1. Distance Map
Distance map used in the mapping of forest fire was road distance and village distance to WNBP. Assuming, the risk of forest fire will be low when forest area is far from road, village, and river [3].

2.3.2. Land Cover
Land cover map was created by processing the landsat 8 path/row 117/66 with supervised classification in software Erdas imagine 2014. The map accuracy was evaluated by groundcheck observation.

2.3.3. Surface Temperature
The surface temperature map was created base on the band 10 from landsat 8. The surface temperature was calculated by the formulas as follow:

\[ L_{\lambda} = (\text{Radiance multi band 10} \times \text{Digital number}) + \text{Radiance add band 10} \]

\[ T = \frac{K2}{\ln \left( \frac{K1}{L_{\lambda} + 1} \right)} , \text{and} \ C = T - 273,15 \]

Remarks:
T : Efective temperature (K)
K2 : Calibration constants 2
K1 : Calibration constants 1
L_{\lambda} : Radiation spectral (W/(m2*ster*μm))
C : Temperature (°C)
2.3.4. Normalized Difference Vegetation Index (NDVI)
Vegetation Index (NDVI) is an index describing the vegetation level at the certain location [18]. NDVI map was obtained based on the formula as follow:

\[
\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}
\]

Remarks:
- NDVI : Normalized Difference Vegetation Index
- NIR : Band 5 on landsat 8
- RED : Band 4 on landsat 8

2.3.5. Normalized Difference Moisture Index (NDMI)
Moisture index was used for evaluation of element moisture differentes in the landscape [7]. NDMI value was obtained from normalized band 4 and band 5 on landsat 7 [13]. From landsat 8, NDMI value was obtained from normalized band 5 and band 6 with the formula as follow:

\[
\text{NDMI} = \frac{\text{NIR} - \text{SWIR 1}}{\text{NIR} + \text{SWIR 1}}
\]

Remarks:
- NDMI : Normalized Difference Moisture Index
- NIR : Band 5 on landsat 8
- SWIR 1: Band 6 on landsat 8

2.3.6. Slope
Slope map was obtained by processing STRTM data with spatial analyst slope in software ArcMap 10.3 and it was divided by class. It was indicated that WBNP area with low level of slope and high accessibility tend to be more risk to forest fire.

2.3.7. Vulnerability of Forest Fire
Variable and scoresystem that used for mapping of forest fire vulnerability was referred to Arianti and Hadi M [3] which is presented in Table 1.

| Variable          | Value (%) | Class                        | Score |
|-------------------|-----------|-------------------------------|-------|
| Road distance     | 18        | Distance<500 m                | 5     |
|                   |           | 500 ≤ distance<1000 m        | 4     |
|                   |           | 1000 ≤ distance<1500 m       | 3     |
|                   |           | 1500 ≤ distance<2000 m       | 2     |
|                   |           | Distance ≥ 2000 m             | 1     |
| Village distance  | 18        | Distance<1000 m               | 5     |
|                   |           | 1000 ≤ distance<2000 m       | 4     |
|                   |           | 2000 ≤ distance<3000 m       | 3     |
|                   |           | 3000 ≤ distance<4000 m       | 2     |
|                   |           | Distance ≥ 4000 m             | 1     |
| Land cover        | 13        | Savanna (Very dry)            | 5     |
|                   |           | Coastal forest and monsoon forest (Dry) | 4 |
|                   |           | Lowland forest (moist)        | 3     |
|                   |           | Mangrove (Dampish)            | 2     |
|                   |           | Water (Wet)                   | 1     |

| Variable          | Value (%) | Class                        | Score |
|-------------------|-----------|-------------------------------|-------|
| Temperature       | 18        | Temperature<20 °C             | 1     |
|                   |           | 20 ≤ temperature<22 °C        | 2     |
|                   |           | 22 ≤ temperature<24 °C        | 3     |
Vulnerability of forest fire value was obtained by this formula:

\[
NKK = a \cdot S(RD) + b \cdot S(VD) + c \cdot S(LC) + d \cdot S(ST) + e \cdot S(NDVI) + f \cdot S(NDMI) + g \cdot S(S)
\]

Remarks:
NKK : Vulnerability of forest fire score
(a - g) : Variable value
S(RD) : Road distance
S(VD) : Village distance
S(LC) : Land cover
S(ST) : Surface temperature
S(NDVI) : Normalized Difference Vegetation Index
S(NDMI) : Normalized Difference Moisture Index
S(S) : slope

Final map was created based on the variable combination and it was analyzed by multiplying the variable value and score value of each variable. The result was divided to vulnerability class by formula as follow:

\[
Class\ interval = \frac{\text{maximum value} - \text{minimum value}}{\text{Total class}}
\]

The forest fire vulnerability was classified into different levels based on the scoring as follow:

- Vulnerability forest fire very low level : \(100 \leq x \leq 200\)
- Vulnerability forest fire low level : \(200 < x \leq 300\)
- Vulnerability forest fire middle level : \(300 < x \leq 400\)
- Vulnerability forest fire high level : \(400 < x \leq 500\)

2.4. Bali Starling Distribution

The distribution data of Bali starling was obtained by Ad hoc survey method. Ad hoc method was carried out by searching information of Bali starling from local people in WBNP. Next, field survey of
Bali starling in the wild was done to verify the existence of the species [12]. The data of bali starling distribution was combined with previously obtained map. The final map expressed the habitat and population susceptibility of Bali starling in WBNP.

3. Results and Discussion

3.1. Variable Factor for the Evaluation of Forest Fire Vulnerability in WNBP

3.1.1. Road Distance

WNBP is located in the area which is accesible to public transportation. WNBP was passed by the main road from Gilimanuk port to Tabanan and Denpasar city. Consequently, it lead to the very easy access to get WNBP. The area and proportion road distance value to WNBP total area was presented in Table 2.

In the recent five years period (2009-2014), the forest fire in WNBP mostly occured in the area with has interval road distance <500 m (88.24%). It is the fact that un-managed local community surrounding the WNBP area might be as an important factor for the forest fire vulnerability in WNBP.

| No. | Road distance (m) | Area (Ha) | Proportion (%) | Forest Fire |
|-----|------------------|-----------|----------------|-------------|
| 1.  | Distance < 500   | 5 005.113 | 26.29          | 30          |
| 2.  | 500 ≤ distance < 1000 | 4 352.032 | 22.86          | 4           |
| 3.  | 1000 ≤ distance < 1500 | 2 991.992 | 15.72          | 0           |
| 4.  | 1500 ≤ distance < 2000 | 2 250.028 | 11.82          | 0           |
| 5.  | Distance > 2000  | 4 436.063 | 23.30          | 0           |

3.1.2. Village Distance

The area of WBNP covered “enclave” of some villages, such as Gilimanuk village and Sumberklampok village, which are exist before WNBP is defined as national park. Furthermore, WNBP area was also surounded by many villages, such as Pejarakan village, Melaya village, and Blimbingsari village, which all of them commonly have direct acces to WNBP. The area and proportion village distance value was presented in Table 3.

| No. | Village distance (m) | Area (Ha) | Proportion (%) | Forest Fire |
|-----|----------------------|-----------|----------------|-------------|
| 1.  | Distance < 1000      | 2 474.040 | 12.99          | 12          |
| 2.  | 1000 ≤ distance < 2000 | 3 709.119 | 19.48          | 1           |
| 3.  | 2000 ≤ distance < 3000 | 3 613.733 | 18.98          | 1           |
| 4.  | 3000 ≤ distance < 4000 | 3 022.745 | 15.88          | 6           |
| 5.  | Distance > 4000      | 6 219.888 | 32.67          | 14          |

During period of 2009-2014, the forest fire in WNBP mostly occured in the area with interval village distance >4000 m which it is about 41.18%. It was an interesting that forest fire occured in the longest distance from the villages. It is indicated that WNBP is categorized as an open access area which local people can enter MNBP area very easily.

3.1.3. Land Cover

According to landsat 8 OLI/TIRS analysis on 19th January 2016, vegetation cover on WBNP was classified into 6 classes; those are savanna, water, lowland forest, mangrove, monsoon forest, and data deficient; with the accuracy assessment value is 85.05%. The accuracy assessment was in accordance with the United States Geological Survey, which state that overall accuracy value must be greater than 85% [2]. The area and proportion vegetation cover in WBNP was presented on Table 4.
Table 4. The area and proportion vegetation cover in WBNP

| No. | Vegetation Cover  | Area (Ha) | Proportion (%) | Forest Fire |
|-----|-------------------|-----------|----------------|-------------|
| 1.  | Data deficient    | 113.239   | 0.59           | 0           |
| 2.  | Savanna           | 1 573.765 | 8.17           | 18          |
| 3.  | Water             | 4 786.330 | 24.86          | 0           |
| 4.  | Lowland forest    | 1 380.634 | 7.17           | 0           |
| 5.  | Mangrove          | 392.067   | 2.04           | 0           |
| 6.  | Monsoon forest    | 11 008.296| 57.17          | 16          |

In the past five years (2009-2014), forest fire in WBNP mostly occurred at savanna (52.94%) and monsoon forest (47.06%). This finding was reasonable phenomenon, because savanna commonly is characterized as a dry area which is very easy to burn out. The forest fire in monsoon forest also occurred mainly in the dry season. By long dry season, vegetation is getting dry and it is more accessible to get fire.

3.1.4. Surface Temperature

According to band 10 (thermal) analysis from landsat 8 OLI/TIRS on 19th January 2016, surface temperature value in WBNP was in the interval 16.15-31.07 °C. The area and proportion of surface temperature value in WBNP was presented on Table 5.

During years of 2009-2014, forest fire in WBNP occurred in the area with interval surface temperature 20-22 °C. Nurdiana and Risdiyanto [11] stated that hotspot will appear on the surface temperature interval 18-28 °C, especially 24-26 °C. Consequently, most of the WNBV area has high risk to become hotspot.

Table 5. The area and proportion surface temperature in WBNP

| No. | Surface Temperature    | Area (Ha) | Proportion (%) | Forest Fire |
|-----|------------------------|-----------|----------------|-------------|
| 1.  | Temperature < 20 °C   | 1 858.727 | 9.78           | 0           |
| 2.  | 20 °C ≤ temperature < 22 °C | 9 793.651 | 51.51          | 6           |
| 3.  | 22 °C ≤ temperature < 24 °C | 5 304.998 | 27.90          | 15          |
| 4.  | 24 °C ≤ temperature < 26 °C | 1 365.168 | 7.18           | 9           |
| 5.  | Temperature > 26 °C   | 689.654   | 3.63           | 4           |

3.1.5. NDVI (Normalized Difference Vegetation Index)

Interval of NDVI value is between -1 to 1. The vegetation has NDVI value between 0 to 1, and non vegetation has NDVI value between -1 to 0. The potential burned-out vegetation increase when the level of NDVI value is low. Based on the Table 5, NDVI value in WBNP area was in the interval -0.27 until 0.60. The area and proportion the distribution of NDVI value in WBNP was presented on Table 6.

Table 6. The area and proportion of NDVI value in WBNP

| No. | NDVI Value     | Area (Ha) | Proportion (%) | Forest Fire |
|-----|----------------|-----------|----------------|-------------|
| 1.  | NDVI < 0.36    | 7 111.110 | 37.36          | 19          |
| 2.  | 0.36 ≤ NDVI < 0.43 | 3 120.733 | 16.39          | 12          |
| 3.  | 0.43 ≤ NDVI < 0.50 | 7 464.974 | 39.22          | 3           |
| 4.  | 0.50 ≤ NDVI < 0.57 | 1 241.472 | 6.52           | 0           |
| 5.  | NDVI > 0.57    | 2.391     | 0.01           | 0           |
| 6.  | Data Deficient | 95.255    | 0.50           | 0           |

Latest five years on 2009-2014, the most groundcheck forest fire in WBNP on interval NDVI value < 0.36 with the proportion 55.88%. Forest fire groundcheck which the NDVI
value < 0.5 have a high potential to burned-out. This potential will be increased if the located at west region in WBNP, cause the rainfall value smaller than east region in WBNP [20].

3.1.6. NDMI (Normalized Difference Moisture Index)
NDMI variable is one of the vegetation index that use to know moisture value in the research location [9]. NDMI value in WBNP region at interval -0.151 until 0.401. The area and proportion distribution NDMI value in WBNP will be described on Table 7.

| No. | NDMI Value       | Area (Ha)    | Proportion (%) | Forest Fire |
|-----|------------------|--------------|----------------|-------------|
| 1.  | NDMI < 0.25      | 10 454.358   | 54.92          | 32          |
| 2.  | 0.25 ≤ NDMI < 0.30 | 5 723.189   | 30.07          | 2           |
| 3.  | 0.30 ≤ NDMI < 0.35 | 2 718.040   | 14.28          | 0           |
| 4.  | 0.35 ≤ NDMI < 0.40 | 45.216     | 0.24           | 0           |
| 5.  | NDMI > 0.40      | 0.205        | 0.001          | 0           |
| 6.  | Data Deficient   | 95.172       | 0.50           | 0           |

In the period of 2009-2014, the forest fire in WBNP was occurred in the area that has NDMI value <0.25 with the proportion 94.12%. The NDMI value of <0.25 was categorized as low level score. If the level of NDMI value is low, the potential forest fire is increased.

3.1.7. Slope
Slope was included as variable of forest fire vulnerability in WBNP. Slope value was analyzed base on the SRTM data. Assuming, if the slope value is low level or the area has high open access to local people, the potential forest fire might be increased. The area and proportion distribution slope value in WBNP was described on Table 8.

| No. | Slope         | Area (Ha)    | Proportion (%) | Forest Fire |
|-----|---------------|--------------|----------------|-------------|
| 1.  | Slope < 8%    | 10 977.122   | 57.66          | 24          |
| 2.  | 8% ≤ slope < 15% | 3 174.247   | 16.67          | 2           |
| 3.  | 15% ≤ slope < 25% | 2 219.675   | 11.66          | 8           |
| 4.  | 25% ≤ slope < 40% | 1 884.360   | 9.90           | 0           |
| 5.  | Slope > 40%   | 782.490      | 4.11           | 0           |

In the period of 2009-2014, the most forest fire in WBNP occurred in the area that has slope value <8% with the proportion 70.59%. Based on the land cover, the forest fire occurred in the savanna and monsoon forest which have low level of slope. The level of slope is also related to the accessibility. The lower slope level, the easier of accessibility, and consequently the potential forest fire might be increased.

3.2. Forest Fire Vulnerability
Based on the scoring of each variable, the forest fire vulnerability was classified into four classes, there are very low, low, middle, and high class (Table 9). According to hotspot clasification by NASA active fire data, the hotspot value in WBNP was <75%. It is indicated that the forest fire in WBNP was not because of hotspot point, but due to the open access factor and the vegetation characteristic which was very dry. Table 9 showed that the most of forest fire occurred in the middle level of forest fire vulnerability (6 778.656 ha). The area and proportion forest fire level in WBNP will be described on Table 9.
Table 9. The area and proportion forest fire level in WBNP

| No.  | Forest Fire Vulnerability Level | Area (Ha) | Proportion (%) | Forest Fire |
|------|---------------------------------|-----------|---------------|-------------|
| 1.   | Very low                        | 9.821     | 0.07          | 0           |
| 2.   | Low                             | 5 015.718 | 35.76         | 0           |
| 3.   | Middle                          | 6 778.656 | 48.34         | 16          |
| 4.   | High                            | 2 126.006 | 15.16         | 18          |
| 5.   | Data deficient                  | 94.245    | 0.67          | 0           |

In the period of 2009-2014, the forest fire in WBNP occured in the area that has a middle and high level of forest fire vulnerability classes, and it was 100% confirmed by groundcheck observation. The result showed that model of forest fire vulnerability in WBNP can be used as a predicted tool for the forest fire assessment in WBNP with high validation value (>80%). The susceptible area in WBNP is 8.905 ha which was classified to middle and high level of forest fire vulnerability. The vegetation characteristic and open access area of WBNP should be managed properly for endemic species habitat.

3.3. Bali Starling Distribution

Bali starling population in the wild is very low and it is included into the critically endangered species list [14]. To support the sustainable wildlife, it needs the region which have all of the necessary things; such as food, water, healthy air, mineral, cover, breeding site, and caring site [15]. The trees which the most used by Bali starling for daily activity, such as perch and sleep, are pilang (Acacia leucophloea) and walikukun (Schoutenia ovata). Furthermore, talok (Grewia koordersiana), tekik (Albizia lebbeckoides), kemloko (Phyllantus emblica), and kesambi (Schleira oleosa) were used by Bali starling for getting food; such as caterpillar, ant, and termite [15]. Based on Rianto [16], Bali starling was found in Teluk Brumbun on 1998 and 2002-2005 where the area was dominated by pilang (Acacia leucophloea), walikukun (Schoutenia ovata), and talok (Grewia koordersiana) trees.

Based on the survey in the wild area, Bali starling appeared in some location, such as Lampu Merah resort, Teluk Brumbun resort, Cekik Gilimanuk resort, and Labuan Lalang. Bali starling distribute in the wider area due to the addition of food shelter distribution and breeding activity. As the result, the population and distribution of Bali starling increased. The habitat distribution and population susceptibility of Bali starling map in WBNP was showed in Figure 1.
Figure 1 showed that Bali starling was found in four location. One of them appeared in the area that has middle level of forest fire vulnerability, and the rest of three appeared in the area that has high level of forest fire vulnerability. Accordingly, the management of forest fire is needed in order to conserve the wild life of Bali starling in WBNP. The forest fire will contribute to the extinction of species. Basically, the prevention of forest fire is better than handling of fire. When the forest fire factor has been identified, the forest fire prevention should be to do in the first step [17]. If the forest fire have already done in the worse condition, it is very hard to handle eventhough it uses the high technology [1]. The information of fire source is a key factor for the high successfull of forest fire prevention [1]. Type of forest fire in WBNP is surface fire. According to De Bano et al. [4], surface fire is fire that burn the litter, undergrowth, plant on the forest floor, waste, and the other fuel on the forest floor.

One of prevention activity for the forest fire management is participation of local people. Local people is very important in the forest fire management, because local people may play as source of forest fire, as well as may act asagent of forest fire early prevention [1]. Management strategy for forest fire base on local people was used for alternative solution in Afrika and Asian country [8].

4. Conclusions and Recommendations

4.1. Conclusion

- The most influence factor for forest fire vulnerability in WBNP were road distance, slope value, and land cover.
- The vulnerability of forest fire in WBNP was classified into four classes, i.e. very low level (9 821 ha), low level (5 015.718 ha), middle level (6 778.656 ha), and high level (2 126.006 ha).
- Bali straling appeared on four location, one of them was found in the middle level of vulnerability firest fire area, and the rest of three were found in the high level of forest fire vulnerability area.

4.2. Recommendation

- Vulnerability forest fire prevention must base on local people.
- Local people in WBNP must be given the counseling about forest fire, environment, and forest fire regulation.
- It needs special attention in the dry season due to increased potential forest fire in savana and moonson forest of WBNP.
- It needs supporting facilities and infrastructure for prevention and handling of forest fire in WBNP, especially in the area that has high level of forest fire vulnerability.

References

[1] Akbar A, Sumardi, Purwanto RH, Sabarudin MS 2011 Studi sumber penyebab terjadinya kebakaran dan respon masyarakat dalam rangka pengendalian kebakaran hutan gambut di areal Mawas Kalimantan Tengah. Jurnal penelitian hutan tanaman 8(5):287-300
[2] Amalina P 2015 Pemetaan kerawanan kebakaran hutan di Taman Nasional Way Kambas, Bogor: Bogor Agricultural University
[3] Arianti I 2006 Pemodelan Tingkat dan Zona Kerawanan Kebakaran Hutan dan Lahan Menggunakan Sistem Informasi Geografis Di Sub Das Kapuas Tengah Propinsi Kalimantan Barat, Bogor Agricultural University Sekolah Pascasarjana Institut Pertanian Bogor
[4] DeBano, L.F., D.G. Neary and P.F. Ffolliott 1998 Fire’s effects on ecosystems (New York: John Wiley & Sons Inc) p 333
[5] Hadi M 2006 Pemodelan spasial kerawanan kebakaran di lahan gambut: studi kasus kabupaten bengkalis, provinsi riau, Bogor Agricultural University
[6] Heikilä T V, Gronovist R, and Jurveius M 1993 *Hanbook on forest fire control. Forestry training programme publication 21* (Finland: National board of education of the government of Finland)

[7] Herbei M, Dragomir L, Oncia S 2012 Using satellite images LANDSAT TM for calculating normalized difference indexes for the landscape of Parang Mountains *GeoCAD*. 13: pp 158–167.

[8] Karki, S 2002 *Community involvement and management of forest fires in southeast Asia* (Bogor: Project fire fight southeast asia)

[9] Mukti A 2015 *Pemetaan kerawanan kebakaran hutan di Taman Nasional Alas Purwo* [undergraduate theses] (Bogor: Bogor Agricultural University)

[10] Miardini A and Nugroho N P 2013 *Pemetaan kawasan rawan kebakaran hutan dengan menggunakan teknologi penginderaan jauh dan sistem informasi geografis Teknologi pengelolaan DAS* (Surakarta)

[11] Nurdiana A and Risdiyanto I 2015 *Indicator determination of forest and land fires vulnerability using Landsat-5 TM data (case study: Jambi Province)* *Procedia Environmental Science* 24: pp 141-151

[12] Nurwatha P F 2013 *Modul pelatihan identifikasi, inventarisasi, dan monitoring avifauna (burung)* *Pelatihan inventarisasi & monitoring floran & fauna* (Bandung)

[13] Price M and Tinant J 2000 *Prediction of thistle infested areas in Badlands National Park using a GIS model. Rapid City, SD, South Dakota School of Mines and Technology* [Internet]. [diunduh 2016 Juli 31]. Tersedia pada: http://sdspacegrant.sdsmt.edu/nasaepscor/PriceMThistleGISPaper.htm.

[14] Putra I K A, Watiniasih N L, Nuyana I N 2014 *Perilaku harian burung jalak bali (Leucopsar rothschildi) periode breeding pada relung yang berbeda di Bali Bird Park, Gianyar, Bali.* *Jurnal Biologi* 18(1): pp 1-4.

[15] Riany C F and Aunurohim 2013 *Populasi burung jalak bali (Leucopsar rothschildi, Stresemann 1912) hasil pelepasliaran di Desa Ped dan hutan Tembeling Pulau Nusa Penida, Bali.* *Jurnal sains dan semi POMITS* 2(2): pp E186-E190.

[16] Rianto T 2006 *Review faktor pembatas ekologi dalam upaya pengembalian populasi liar jalak bali (Leucopsar rothschildi) taman nasional bali barat. Cekik. Bali.*

[17] Saharjo B H 2003 *Pengendalian Kebakaran Hutan dan Lahan Yang Lestari: Perlukah Dilakukan?*. Laboratorium Kebakaran Hutan dan Lahan. Silviculture Departement. Faculty of Forestry. Bogor Agricultural University.

[18] Samsuri 2008 *Model spasial tingkat kerawanan kebakaran hutan dan lahan (studi kasus di wilayah propinsi Kalimantan Tengah)* [master theses] (Bogor: Bogor Agricultural University)

[19] Sudiana A and Diasmara E 2008 *Analisis indeks vegetasi data satelit NOAA/AVHRR dan TERRA/AQUA-MODIS. Seminar on Intelligent Technology and Its Applications.*

[20] TNBB 2013 *Evaluasi review rencana pengelolaan taman nasional bali barat* (Gilimanuk)

[21] ______ 2015 *Statistik tahun 2014 balai taman nasional bali barat* (Cekik)

[22] Yunanti B D 2012 *Teknik penangkaran dan analisis koefisien inbreeding pada jalak bali (Leucopsar rothschildi Stresemann, 1912) di Mega Bird Orchid Farm Bogor, Jawa Barat* [undergraduate theses] (Bogor: Bogor Agricultural University)