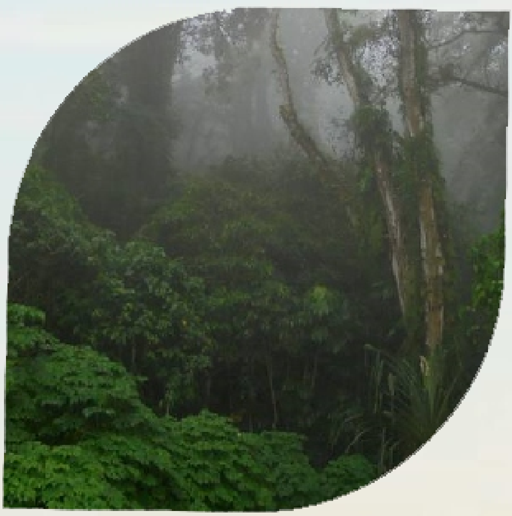
Ecology

Of Bedugul Basin Bali



Authors:

Sutomo
I Dewa Putu Darma
Wawan Sujarwo
Arief Priyadi
Farid Kuswantoto
Rajif Iryadi

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(A compilation of ecological studys conducted in Bedugul by Bali Botanical Garden researchers)

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Sutomo, Jesus C. Fernandez,
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Design and layout:
Nur Rizzal Rosiyan

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FOREWORD

Mountain forest has become the last sanctuary for most of Bali's biodiversity, as well as the whole of Java Island. This ecosystem is important given that most of the lowland forests in Indonesia have been disturbed and degraded. Forest areas in the Bedugul Basin are among the remaining tropical mountain rainforests in Bali and they play significant roles in maintaining the ecosystem, preventing erosion, preserving biodiversity, and functioning as a water source and buffer zone for the surrounding areas including the lower areas of Bali.

However, mountain rainforests are becoming more and more threatened as its extent and vegetation cover have declined due to the increased human activities, climate change and natural disasters. This is also true for Bedugul, especially in forest areas near Beratan and Buyan Lakes, and also Mt. Pohen, which are increasingly exposed to tourism activities and other anthropogenic disturbances. Hence, ecological research in these areas of Bedugul Basin is needed to assess and also anticipate any potential changes so that its natural resources could be protected and sustained in the era of changing climate.

This book is a compilation of relevant research works that were conducted in Bedugul Basin from 2005 up to 2017. Most of these research works were conducted by the authors themselves and their colleagues as researchers at Bali Botanical Garden. The relatively new study of species distribution modelling (SDM) using Biodiversity and Climate Change Virtual Laboratory (BCCVL) for *Dacrycarpus imbricatus* (which is one of the characteristic species of the area) is also introduced in this book. Another important and recent research output included in this book is the exploration of the autecology of an important endemic species, *Pinanga arinasae,* which is only found on Mt. Tapak, Bedugul.

Our Centre is glad to publish this book entitled “ECOLOGY OF BEDUGUL BASIN.” I believe that it should fill some of the research gaps in the ecological-ethnobotanical aspects of the plant community of high elevation landscapes in Indonesia in particular, and in Asia in general. I believe that this would be a useful reference to the scientific community in this field. I congratulate the authors of this book for their dedication to contribute to the body of knowledge on ecological-ethnobotanical research.

Bogor, September 2018

Dr. Ir. Irdika Mansur, M.For.Sc.

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Sutomo, Farid Kuswantoro & Rajif Iryadi
Bali Botanical Garden-Indonesian Institute of Sciences (LIPI), Candikuning Baturiti
Tabanan 82191

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Fardilla D. & Sutomo. (2013) Ecological Studies in Tropical Forest of Mt. Pohen Bali Indonesia. Lambert Academic Publishing, Germany.

A. Geological, Biophysical and Social Conditions

Bedugul is a high plateau at the centre of the Island of Bali, about 70 km north from Denpasar (Figure 1) and situated between two districts, namely: Tabanan to the south and Buleleng to the north.The altitude range from 1000 to 2000 m above sea level (asl). According to Schmidt and Fergusson's climate classification, the Bedugul area falls under the type-A classification (high rainfall with no distinct rainy season). It receives a rainfall average of 2000 mm/year, with 155 rainy days/per year average, and has temperatures ranging from 11.5 to25°C (Figure 2).

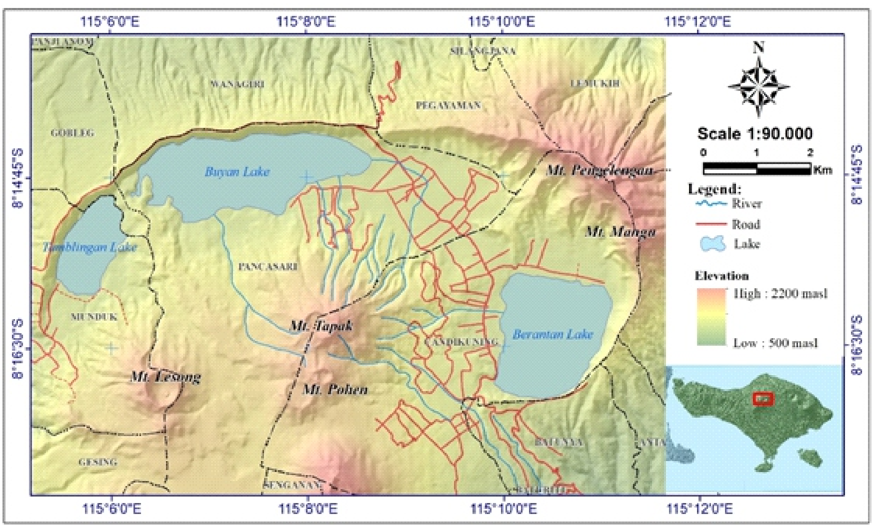

Figure 1. Map showing the location of Bedugul highland in Bali. Map created by Rajif Iryadi based on the Topographic Map of National Mapping Agency of Indonesia

NAME: AWS_Okt CITY: CDK, TABANAN STATE: BALI
ELEV: 1294 m LAT: 8° 12' 00" S LONG: 115° 12' 00" E

TEMPERATURE (°C), RAIN (mm), WIND SPEED (m/s)

DAY	MEAN TEMP	HIGH	TIME	LOW	TIME	HEAT DEG DAYS	COOL DEG DAYS	RAIN	AVG WIND SPEED	HIGH	TIME	DOM DIR
1	18.9	20.4	3:30p	17.8	11:45p	0.0	0.6	63.6	1.0	9.8	12:30p	SSW
2	19.1	23.3	2:45p	17.4	3:30a	0.2	0.9	1.2	0.5	5.4	8:00p	SSW
3	19.1	23.3	1:30p	16.9	11:45p	0.3	1.0	1.0	0.6	5.4	11:00a	NE
4	19.5	24.7	11:45a	16.7	5:45a	0.5	1.7	7.0	0.5	4.9	11:15a	ENE
5	19.4	25.1	1:30p	16.4	3:15a	0.5	1.6	28.6	0.6	5.4	11:30a	S
6	19.1	23.8	1:15p	16.8	1:00a	0.5	1.3	3.0	0.3	4.9	2:45p	SSW
7	18.8	23.6	1:45p	16.2	2:30a	0.6	1.2	2.6	0.3	4.5	8:15a	ENE
8	18.4	21.8	12:30p	16.6	2:30a	0.5	0.6	3.0	0.2	4.9	3:00p	NNE
9	19.0	24.2	2:15p	15.9	11:00p	0.5	1.3	2.6	0.6	5.4	1:45p	SSW
10	19.3	24.1	9:15p	15.4	6:45a	0.7	1.6	3.0	0.4	5.4	6:30p	SSW
11	19.4	24.7	10:45p	17.7	1:15p	0.1	1.2	1.8	0.6	8.0	4:45p	N
12	19.3	23.3	12:30a	18.0	1:15p	0.0	1.1	1.8	0.7	8.9	6:45a	SSW
13	19.2	22.3	12:15a	17.3	1:30p	0.2	1.1	0.4	0.8	7.2	9:00a	NNE
14	19.3	24.7	8:45p	17.6	6:00a	0.1	1.1	0.0	0.8	8.0	10:45a	NE
15	19.3	25.2	9:30p	16.4	2:15p	0.3	1.3	0.2	0.5	6.3	8:15p	NE
16	19.5	24.9	7:00p	17.2	8:45a	0.3	1.5	2.6	0.6	5.8	2:15p	NE
17	18.9	24.4	7:45p	16.2	9:15a	0.8	1.4	74.4	0.3	4.5	6:15p	SE
18	17.7	23.6	7:00p	15.8	3:15p	0.9	0.5	7.6	0.2	4.5	7:30p	ENE
19												
20												
21	19.6	23.1	10:15a	17.2	12:00m	0.2	0.9	0.8	0.0	0.0	---	---
22	19.4	24.1	1:15p	16.8	12:00m	0.3	1.4	0.2	0.0	0.0	---	---
23	18.7	24.1	12:15p	15.9	2:45a	0.7	1.1	20.6	0.0	0.0	---	---
24	18.6	22.9	11:00a	16.7	5:45a	0.5	0.7	6.8	0.0	0.0	---	---
25	17.9	21.3	10:30a	13.9	12:00m	1.0	0.6	3.0	0.0	0.0	---	---
26	16.9	22.8	10:30a	12.4	4:15a	2.2	0.8	0.8	0.0	0.0	---	---
27	18.2	23.5	11:15a	13.7	5:15a	1.5	1.3	0.2	0.0	0.0	---	---
28	18.4	24.0	10:15a	15.3	7:00a	0.9	1.0	0.2	0.0	0.0	---	---
-	18.9	25.2	15	12.4	26	14.1	28.8	237.0	0.4	9.8	1	SSW

Max >= 32.0: 0
Max <= 0.0: 0
Min <= 0.0: 0
Min <= -18.0: 0
Max Rain: 74.40 ON 02/17/18
Days of Rain: 25 (> .2 mm) 14 (> 2 mm) 4 (> 20 mm)
Heat Base: 18.3 Cool Base: 18.3 Method: Integration

Figure 2. Weather data for Bedugul areas in February 2018.Weather station based inside the Bali Botanical Garden and managed by the Plant Registration Division (Mr. Agung K. & Rajif Iryadi).

The Bedugul area was created from ancient volcanic activities (LIPI 1992) which now resembles an endorheic drainage basin in which Bedugul is situated. An endorheic drainage basin is an area where, due to its concave shape, does not have an outlet of water or river flow channel outside of the area. There are not many places in the world that have this feature but Indonesia is fortunate to have some of these areas. The Bedugul endorheic basin has a size of 12 x 7 km and is an oval-shaped feature. Geology of this endorheic basin comprises volcanic bedrock belonging to ancient Buyan-Beratan *breksi* and *tufa* (Fardilla and Sutomo 2013). The Bedugul area is undulating to mountainous. Most of Bedugul area's geomorphology has been transformed by volcanic activity. However, the geomorphology of lowland areas near the lakes has been transformed by the alluvium deposition (Figure 3).

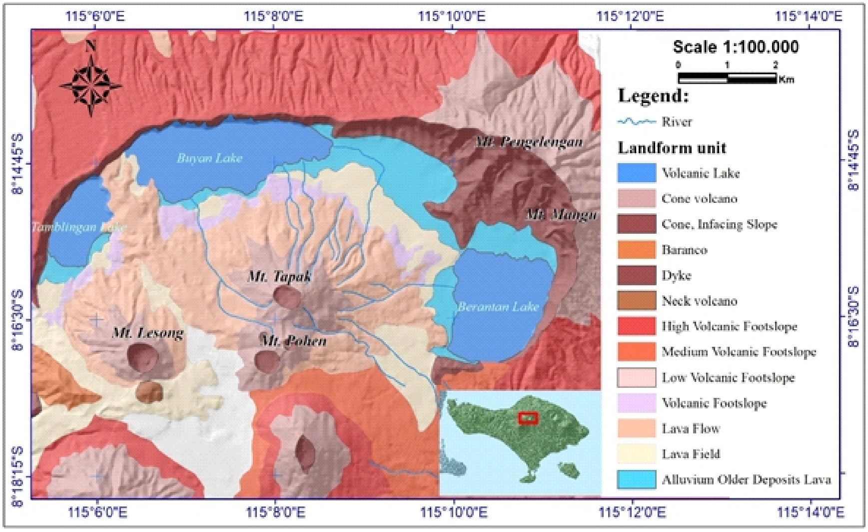

Figure 3. Bedugul Basin landform units. Map created by Rajif Iryadi based on Geology & Topography Map.

The slopes range from 0-3%, 3-8%, 8-15% and more than 40% (in the mountainous area). The mountainous area consists of a complex of mountains and hills, slopes and riverbanks. This area is located south of Lake Beratan comprising of Pohen, Tapak, Lesong, Pengelengan, Pucuk, and two more mountains that geologists categorize as newly formed mountains, namely the Beratan and Sanghyang Mountains (Fardilla and Sutomo 2013).

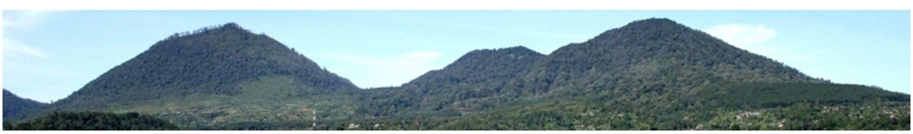

Figure 4. Left to right: Mt. Pohen, Mt. Tapak and Mt. Lesong one of significant elements of the Bedugul Basin, Bali. Photo credit: Mustaid Siregar.

The main soil type of the Bedugul area is andosol, which is characterized by its high sensitivity to erosion and landslides(Sunarta *et al*. 2018). Volcanic eruption caused material to be distributed into a volcanic cone, with slopes varying from medium to steep around the Bedugul area as regosol (entisol), the material was then developed into non-crystalline soil classified as andosol (Sukarman & Dariah 2014). Effective depth of Bedugul soils is up to and sometimes more than 90 cm. There are springs from the mountain areas such as from Tapak and Lesong that are used by local villagers for their daily needs. However, the most important hydrological feature of Bedugul area is the existence of three endorheic basin lakes, namely: Beratan, Buyan and Tamblingan (Figure 5). These lakes exist at an altitude of 1214-1231 masl.

Figure 5. Lake Tamblingan, one of the three lakes located in Bedugul. Photo credit: Sutomo

In general, Bedugul has two ecosystem types, namely: natural ecosystem and man-made. Patches of natural ecosystem here includes all the vegetation in natural forest (primary and secondary), whereas the man-made ecosystem is comprised of vegetation in replanted forest, farmland, agriculture and settlements. Bedugul also has three conservation areas, namely: Batukahu Nature Reserve, Protection Forest and Botanic Garden. The first two areas are *in-situ* conservation areas and the last one is the *ex-situ* conservation area. The nature reserve area is a natural ecosystem. The protection forest, which is mostly man-made ecosystem consisting of replanted forests but with some small remnant parts of natural ecosystem. The botanic garden, "Eka Karya", is entirely a man-made ecosystem (Fardilla and Sutomo 2013).

Figure 6. Majestic type of tropical rain forest located on Mt. Pengelengan, Bedugul, Bali. Photo credit: Sutomo

Figure 7. View of Mt. Pohen from Candikuning Village in Bedugul Bali. Photo credit: Sutomo

Most Bedugul dwellers are farmers, while the rest of them are either trader in local markets or work in the tourism sector. The main tourism sites in Bedugul are the three volcanic lakes of Beratan, Buyan and Tamblingan, as well as the beautiful Bali Botanical Garden (Sunarta *et al*., 2018; Setiadi & Siringoringo, 2017). Farmers usually till their land in the hills and up to the border with the forest at an altitude of more than 1000 m asl. They commonly plant coffee (*Coffea arabica* and *C. robusta*) using multiple cropping system. Not less than 28 species are planted with coffee, including *Erythrina subumbrans*, avocado (*Persea americana*), jackfruit (*Artocarpus integra*), clove (*Syzygium aromaticum*), *Leucaena leucocephala*, orange (*Citrus aurantium, C.microcarpa*), guava (*Psidium guajava*), *Syzygium aqueum, S.malacensis, S.cummini, Aglaia odorata, Arenga pinnata, Calliandra calothyrsus, Mangifera foetida, Jathropa curcas, Durio zibethinus*, as well as other species (Abdulhadi, 2005).

Figure 8. View of Lake Buyan from Pancasari Village in Bedugul, Bali. Photo credit: Sutomo

Balinese Hindus recognized the "*Tri-Hita Karana*" (three sources of happiness) and "*Kalpataru*" (Trees of Life) concepts. The "*Tri-Hita Karana*" concept defines the harmony within man (*pawongan*), with Gods (*parahyangan*) and with environment (*palemahan*) (Ardika, 2005). Bedugul is considered to be one of the sacred places in Bali. This notion is mirrored in the existence of numerous *Pura* (prayer places) in the area. But one Pura is considered to be the holiest known (*Pura Ulun Danu Beratan*) which literary means "*Pura* on top of water" because it is located on the surface of Beratan lake (Fardilla and Sutomo 2013).

Figure 9. Ulun-Danu Beratan Temple, overlooking the Beratan Lake in Bedugul. Photo credit: Sutomo

As many as 45 species of animals have been recorded in Batukahu nature reserve in Bedugul. Some of the dominant species include barking deer (*Muntiacus muntjak)*, forest pig (*Sus vitatus*), wildcat (*Felis bengalensis*), scaly anteater (*Manis javanica*), hedgehog (*Hystrix branchura*), black monkey (*Presbytis pyrrhus*), long-tailed macaque (*Macaca fascicularis*), forest hen (*Gallus varius*), owl (*Tyto alba javanica*), fruits bats (*Pteropus edulis*), and eagle (*Haliastur Indus*) (KSDA, 2005).

Java and Bali Islands were predominantly covered by majestic forests during the Pleistocene period. By the late Pleistocene period, the depression and compression of montane forest vegetation started to occur. Disturbance to forest vegetation can be traced back at least4,000 years ago and it is presumed that people are associated with this disturbance (Whitten *et al.* 1996). Anthropogenic disturbance would likely be one of the factors that could alter the current successional trajectory of forests. Although legally protected, forests in these islands have been experiencing an escalation of pressures from human activity (Smiet 1992). The main threat to the nature reserve in Bedugul is the over-extraction of forest products. These products range from wild species for ornamental purposes, parts of tree species for planting media and fuel wood. Most of the nature reserve area that is bordered with settlements and farmland has been disturbed by these activities. Non-timber forest products such as the extraction of the tree fern *Dicksonia blumei* that is use as planting media for orchid growing is widely sold in local markets. Similarly, extraction also reaches to various plant species that are used as ornamental plants and are sold in local markets or even more widely, such as vanda orchid (*Vanda tricolor*), Bali's slipper orchid (*Paphiopedillum* sp.) and bird's nest fern (*Asplenium nidus*). Other species are also exploited, especially those with edible fruits such as *Passiflora* sp.

B. Endemic, rare and exotic invasive plants of Bedugul

Pinanga arinasae Witono*, an Endemic Plant of Bedugul*

The Bedugul area contains one endemic plant species namely *Pinanga arinasae* Witono. This species was considered as the only palm species endemic to the Bali Island (Arinasa, 2009). Witono *et al*. (2002) suggested that the species was only living on Mt. Tapak in Bedugul. However, recent botanical exploration has discovered that the species was also present in Pilan Forest, the proposed site for Gianyar Botanic Gardens in Gianyar regency, Bali (Wahyuni *et al*., 2017). Known locally as Nyabah or Jabah, fruit, stems and the leaf sheaths of this ornamental palm species were culturally important for Balinese people (Witono *et al*., 2002).

Figure 10. Specimens of *Pinanga arinasae* in Bali Botanic Garden. Photo credit: Farid Kuswantoro.

Conservation attempts for this species have already been conducted in the Bali Botanic Gardens and Gianyar Botanic Gardens. The newly developed Gianyar Botanic Gardens have adopted *P. arinasae* as its logo. Bali Botanic Gardens have already propagated this palm and reintroduced it to Mt. Pohen in Bedugul (Arinasa, 2009).

Invasive Plants in Bedugul

As a tourist destination, the Bedugul area is prone to invasive alien plant species. Anderson *et al.* (2015) believed that tourism could facilitate the spread of exotic plant species. In this chapter, we have listed 12 invasive alien plant species that are commonly found in the Bedugul area (Table 1). Accepted names of plant species was acquired from *The Plant List* (2013) while life-form and place of origin was extracted from Tjitrosoedirjo *et al*. (2016) and Setyawati *et al*. (2015).

Table 1. List of invasive alien plant species commonly be found in Bedugul areas.

Plant Species	Plant Family	Life Form	Origin
Ageratina riparia (Regel) R.M. King & H. Rob.	Compositae	Shrub	Mexico
Brugmansia suaveolens (Humb. & Bonpl. Ex Willd.) Bercht. & J. Presl.	Solanacee	Shrub	Tropical & sub-tropical America
Calliandra calothyrsus Meisn.	Leguminosae	Shrub	Central America
Chromolaena odorata (L.) R.M. King & H.Rob.	Compositae	Shrub	Central and south America
Eichhornia crassipes (Mart.) Solms.	Pontederiaceae	Aquatic	Tropical south America
Ipomea cairica (L.) Sweet	Convolvulaceae	Climber	Africa & Asia
Ipomea indica (Burm.) Merr.	Convolvulaceae	Climber	Pantropical
Lantana camara L.	Verbenaceae	Shrub	Tropical America
Passiflora ligularis Juss.	Passifloraceae	Climber	South America
Spathodea campanulata P. Beauv.	Bignoniaceae	Tree	Tropical Africa
*Sphagneticola trilob*ata (L.) Pruski	Compositae	Herbaceous	Tropical America

Most of the exotic invasive plant species in this list belong to Compositae (Asteraceae) family, followed by Convolvulaceae with two species (Figure 11). Shrubs were the most common life form found in this list with 42% of the exotic species, followed by climbers with 25% (Figure 12). Tropical America including Mexico, Central America and South America respectively is the most common place of origin of the exotic invasive plant species in the list (Figure 13).

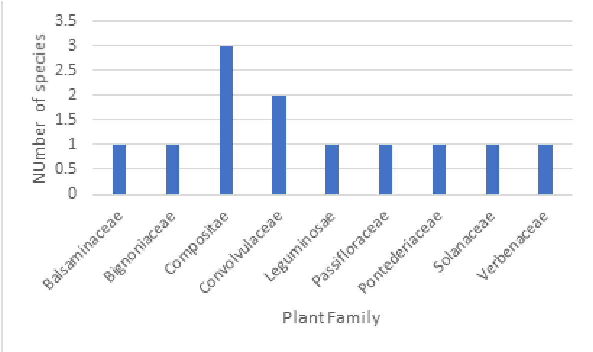

Figure 11. Family of Exotic Invasive Plant Species (IAPS) present in the Bedugul area.

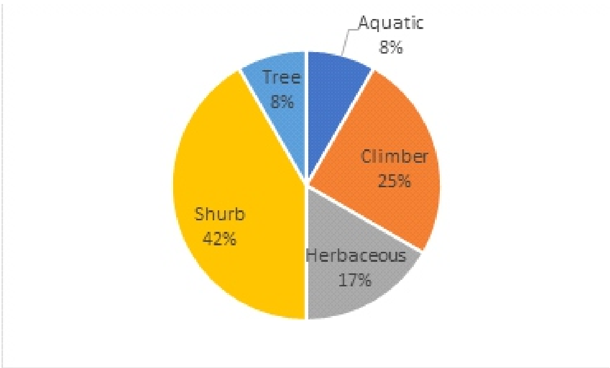

Figure 12. Life-form of Exotic Invasive Plant Species in Bedugul.

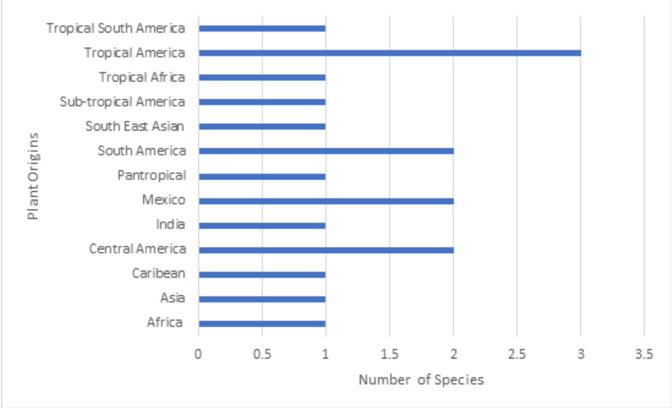

Figure 13. Origin of Exotic Invasive Plant Species in Bedugul.

Additional information on the exotic invasive plant species in this list are presented as follows:

1. *Ageratina riparia* (Regel) R.M.King&H.Rob.
   Formerly known as *Eupatorium riparium* this species was known as Irengan in Java (Tjitrosoedirdjo *et al*., 2016). This species was very common in Bedugul, being found along roadsides, forest edges, and in gardens. Easily spreading, *A. riparia* is an important weed species and have been naturalized in many places in Java and Bali (Tjitrosoedirdjo *et al*., 2016).

Figure 14. IAPS in Bedugul *Ageratina riparia* (vernacular name: Irengan). Photo credit: Farid Kuswantoro

2. *Brugmansia suaveolens* (Humb. &Bonpl. ex Willd.) Bercht. &J.Presl
   Brugmansia suaveolens was commonly found along roadsides throughout the Bedugul area. The white and fragrant flowers of this species are attractive which has made this species a popular ornamental plant. The species also grows spontaneously in the low maintained areas in Bedugul (Figure15).

Figure 15. *Brugmansia suaveolens.* Photo credit: Farid Kuswantoro

3. *Calliandra calothyrsus* Meisn
   Populations of *C. calothyrsus* are commonly found along roadsides throughout Bedugul. The species also occurs in low maintained areas such as moorlands and abandoned properties. This legume species is usually present alongside other invasive alien plant species such as *Ipomoea* sp. This species is also present in Bali Botanic Garden, both within and at the edge of the garden.

Figure 16. Flowers of *C. calothyrsus.*Photo credit: Farid Kuswantoro

4. *Chromolaena odorata* (L.) R.M.King&H.Rob
   This Asteraceae species was distributed throughout the Indonesian archipelago (Tjitrosoedirjo *et al*., 2016). In Bedugul, we can see this species grow up to 3 meters high. Populations of this invasive species, for example, can be found along the roadside near popular tourism spot of Beratan Lake, along with *B. suaveolens, Spathodea campanulata* and *Ipomoea indica.*

Figure 17. *Chromolaena odorata* with its flower (Right). *C. odorata* as high as 3 m tall in Bali Botanical Garden, Bedugul (Left). Photo credit: Farid Kuswantoro & Sutomo.

5. *Eichhornia crassipes* (Mart.) Solms

   The water hyacinth is one of the most famous aquatic invasive plant species in the world. Tjitrosoedirdjo (2005) listed this species as important aquatic invasive alien species in Indonesia. *E. crassipes* and other aquatic plant species once covered a vast portion of Buyan Lake in Bedugul, and contributed to extensive silting of the lake. However, a lake normalization effort which included eradication of the species using heavy machinery was recently conducted by the government.

Figure 18. *Eichhornia crassipes* (Vernacular name: Eceng Gondok). Photo credit Farid K.

6. *Impatiens balsamina* L.
   Impatiens balsamina has been commonly used as an ornamental plant. In Bedugul, this plant species can be found living on the moorlands, road and riversides, and other low maintained places. This species was also recorded to be growing spontaneously alongside *A. riparia* and other invasive exotic plant species at Bali Botanic Garden.

Figure 19. *Impatiens balsamina* can be found living alongside *A. riparia* in Bedugul. Photo credit: Farid Kuswantoro

7. *Ipomoea cairica* (L.) Sweet and *Ipomoea indica* (Burm.) Merr.
   In Bedugul, these climber species can be found together or separately. The species usually present in low maintained land and along the roadside together with other invasive plant species such as *C. calothyrsus*. In Bali Botanic Gardens, the two species are present on the riverside and at the edges of the botanic garden.

Figure 20. *Ipomoea indica* (left) and *Ipomoea cairica* (right). Photo credit: Farid Kuswantoro.

8. *Lantana camara* L.
   Lantana camara with its colourful flowers has great ornamental value. This species is one of the most important terrestrial invasive plant species globally and is included as one of the 100 worst invasive organisms in the world (Tjitrosoedirdjo *et al*., 2005; Lowe *et al*., 2000). This species can be found forming clumps in low maintained land in Bedugul.

9. *Passiflora ligularis* Juss.
   Passiflora ligularis is listed as 100 worst invasive organisms in the world (Lowe *et al*., 2000). *Passiflora ligularis* was present around the edge of Bali Botanic Gardens. Fruit of the species are usually found scattered on the forest paths of the area which suggests they might be dispersed by the mammals living in the forest.

Figure 21.*Lantana camara*. Photo credit: Farid Kuswantoro.

10. *Spathodea campanulata* P.Beauv.
    This tree species was usually planted as an ornamental plant due to attractive flower color. In Bedugul, *S. campanulata* was mainly planted along roadsides and is typically present with other invasive plant species such as *C. odorata*, *B. suaveolens*, *I. cairica* and *I. indica*. The narrow seed of this species with its wing-like structure could easily be dispersed by wind.

Figure 22. Tree and Flowers of *S. campanulata*. Photo credit: Farid Kuswantoro.

11. *Sphagneticola trilobata* (L.) Pruski
    Sphagneticola trilobata is listed as as 100 worst invasive organisms of the world (Lowe *et al*., 2000). The attractive yellow flower is highly ornamental. In Bedugul, *S. trilobata* is usually present in open, low maintained areas such as roadsides, along rivers and in moorlands.

Figure 23. *Sphagneticola trilobata*. Photo credit: Farid Kuswantoro

II. Landscape Ecology of Bedugul

Sutomo & I Dewa Putu Darma
Bali Botanical Garden-Indonesian Institute of Sciences (LIPI), Candikuning Baturiti Tabanan 82191

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Hanum S. F. & Darma D. P. (2005) Rencana Pengelolaan Lansekap Kawasan Tri-Danau Beratan-Buyan-Tamblingan. In: Simposium Analisis Daya Dukung dan Daya Tampung Sumber Daya Air di Kawasan Tri-danau Beratan, Buyan dan Tamblingan (eds P. E. Hehanusa, R. Abdulhadi and M. Siregar) pp. 109-20. UPT Balai Konservasi Tumbuhan Kebun Raya "Eka Karya" Bali - LIPI, Kebun Raya Bali.

A. Edge Effects

Edge effects refer to biotic or abiotic differences that occur at the border of a fragment of habitat relative to interior habitat area (Gehlhausen *et al*., 2000). Edge effects can be commonly seen as the gradual change of microclimate and vegetation patterns from the edge to the forest interior. Edge effects may affect structure, function and composition of the forest, and even lead to degradation of forest fragments (Harper *et al*., 2005). The extent of the edge effect occurring in a habitat fragment can be estimated by measuring the depth of edge effects or depth of edge influence (DEI). Chen *et al*. (1995) defined DEI as the distance, which is a change in the value of a variable that is measured before the variable will be constant over the increase in the distance from the edge into the forest interior. By estimating DEI in Forest Hill Pohen, we can determine the width of the buffer zone forest in the region, which is needed to protect the condition of Batukahu Nature Reserve (CA) ecological forest interior from exposure to different microclimate edge forests due to the opening of the road (Fardilla and Sutomo 2013).

The Geothermal Power Plant (PLTPB) in Bedugul still generates both positive and negative impacts. Although it meets Bali's electricity demand, the PLTPB Bedugul, which operates within the Batukahu conservation area or “Cagar Alam”(CA), is feared to have negative impact on the integrity of ecosystems in this conservation area. Constructions of paved roads on Pohen Hill have contributed to forest fragmentation of Pohen Hill. The corridor roads built through the forest result in edge effects in the forest areas bordering the road. One of the effects of road corridors are the different microclimate conditions, primarily associated with changes in solar radiation, temperature and wind at the border (Davies-Colley *et al*., 2000). The different microclimate conditions at the edge of a forest are one of the most well known edge effects (Forman, 1995).

Figure 24. Corridor road inside the forest of Mt.Pohen Bedugul. Photo credit: Sutomo

The establishment of roads and pathways from the entrance to the drilling well through the forest contributes to the decrease in tree species diversity especially *Dacrycarpus imbricatus* due to the clearance of 53.88 ha of protection forest. On the other hand, this also leads to the increase in the number of species, especially exotic and weed species. The opening of the forest creates a gap where direct sunlight reaches the floor and encourages the germination of species that were dormant as a soil seed bank, especially grasses (Poaceae) (Aubert *et al.* 2003; Austin and Pausas 2001; Pena 2003). An example of the condition near the drilling well is diagramatically described in Figure 24. This is the third drilling well inside the protection forest. It is said that this area is inhabited by *Dacrycarpus imbricatus* as there are still some trees remaining. This drilling well literally "cut and cleared" a large portion of the forest located at an altitude of 1,500 m asl. Common species found near this point are *Homalanthus gigantheus*, *Vernonia arborea*, *Engelhardia spicata, Syzygium racemosum, Polyosma integrifolia, Astronea spectabilis,Cyathea contaminans, C. latebrosa, Celtis* sp., *Platea* sp., *Ardisia* sp., *Ficus* sp. and *Moutia puya* (Fardilla and Sutomo 2013).

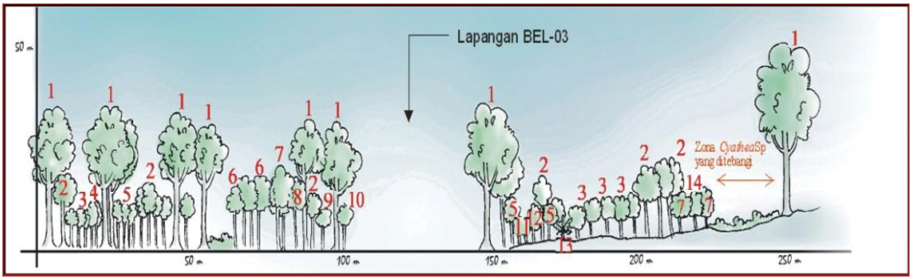

Figure 25. Profile diagram from a part of a drilling well (BEL-03) on Pohen Mountain, Batukahu Nature Reserve. Numbers refers to species composition: 1. *Dacrycarpus imbricatus* 2. *Lepophetalum* sp. 3. *Homalanthus giganteus* 4. *Engelhardtia spicata* 5. *Vernonia arborea* 6. *Ardisia* sp. 7. *Platea* sp. 8. *Toona sureni.* 9. *Syzygium* sp. 10. *Polyosma* sp. 11. Melastomataceae 12. *Moutia puya* 13. *Cyathea* sp. 14. *Celtis* sp.(Fardilla and Sutomo 2013)

Fardilla and Sutomo (2011) studied edge effects in Bedugul particularly in the forest of Pohen Hill in September and October 2010. This forest is a part of the Batukahu Nature Reserve. Batukahu Nature Reserve is located at 8° 10' - 8° 23 'S and 115 ° 02' - 115 ° 15 'E, and is administratively located in Candikuning Village, Baturiti Tabanan regency, Bali. Pohen Hill forest has an extensive area of 388.2 ha and is located at the altitude of 1,520–1,600 m asl with 5-35 ° slopes. The road corridor divides the forest with a width of about4 m.

The study revealed that all microclimatic variables showed gradual changes with increasing distance from the edge into the forest interior (Figure 25). Air temperature, wind speed and light intensity significantly decreased up to 40 m from the edge of the road, while relative humidity was increasing into the forest interior. ANOVA and MANOVA test results showed that all microclimate variables were correlated significantly with distance from the road (Table2).

Although the tree vegetation variables showed a trend of gradual change with increased distance from the edge to the forest interior, but the value varies along transect. This shows that there is variability of the sample points in the vegetation pattern. Changes in vegetation variables are generally seen up to the depth of 60 m. ANOVA and MANOVA test results showed that only tree height variables correlated significantly with distance from the road edge.

Based on the Principal Component Analysis (PCA) results, eigenvalues for the first two components explained 63% of the microclimate variation that occurs in the forest of Mt. Pohen (Table 2). Stevens (1992) states that the weight of the variable meaningful for a given sample size is when the value is more than 0.45. The microclimate variables that have most weight in explaining the PCI axis was light intensity (-), while for PC II axis the main

Table 2. ANOVA and MANOVA test of microclimate variable and vegetation to distance with road edge(* $p< 0.05$, ** $p< 0.01$, *** $p< 0.001$).

Variable	*F*	*p*	r^2	*r*
ANOVA				
Air Temperature	6.319	0.0036**	0.5872	–0.7663
Relative air humidity	23.568	0.0001****	0.8116	0.9009
Wind velocity	5.702	0.0063**	0.4143	–0.6437
Light intensity	4.143	0.0239*	0.5421	–0.7363
Tree basal area	4.572	0.0650	0.3636	–0.6030
Tree height	9.757	0.0142*	0.5495	0.7413
Number of species	4.450	0.0679	0.3575	0.5979
Density	2.082	0.1871	0.2065	0.4544
MANOVA				
Microclimate	5.836	0.038*		
Tree vegetation	1.268	0.241		

variables were air temperature (-), relative humidity (-) and wind speed (+). Sample points are identified by distance and plotted on the axis of PC I and PC II by difference of the value of the microclimate variable. Figure 27 shows the PCA grouping of sample points. Sample points that are less than 40 m from the edge, clustered on the PC I axis, indicate areas with high light intensity, high temperatures, high wind speeds and low air humidity.

The study concluded the road corridor through the forest of Mt. Pohen affects the microclimate on the edge of the forest. Edge effect is detected from the microclimate gradient from the edge to the forest interior. Light intensity gradients are very sharp near the edge of the forest. Matlack (1993) states that exposure to sunlight in the edge area is the main controller of microclimate variables such as air temperature and air humidity and soil moisture. Air temperature, air humidity and the wind speed at the edge of the area shows that the gradient is not so sharp compared to the intensity of the light. This suggests that these three variables are playing more control for the depth of edge effects in Bukit Pohen forest. Tree vegetation patterns in the forest tend not to be controlled by edge effects, but more influenced by other factors such as disturbance and planting activities. Edge of the forest in this region is Rasamala (*Altingia excelsa*) tree plantations of the same age, while the interior is disturbed forest by wildfires in 1994 and is currently undergoing a process of secondary succession.

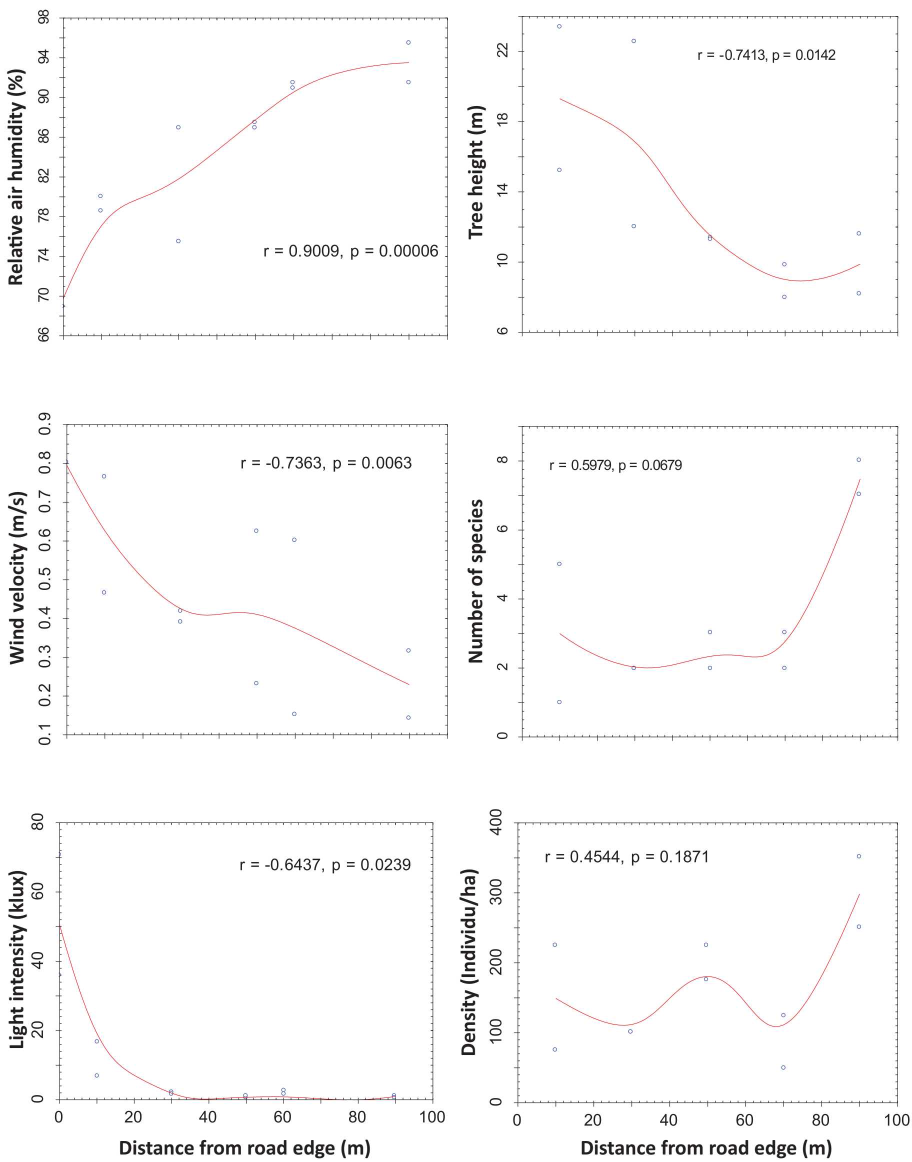

Figure 26. Gradual change of microclimate and vegetation patterns along 100 m transect from road edge to the forest interior on Mt. Pohen Bedugul. Legend: Y axis on the left is light intensity, Y axis on the right is density. X axes left and right is the distance from road edge.

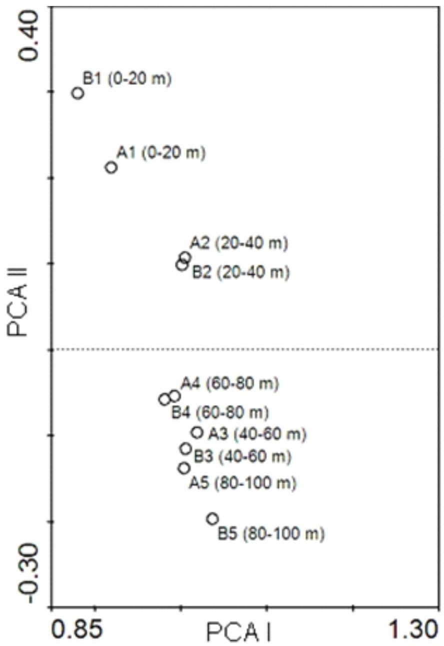

Figure 27. PCA ordination for every sample points based on microclimate variable on Mt. Pohen Bedugul Bali.

Table 3. Results from *Principal Component Analysis* (PCA) 0f the microclimate variable.

Component	1	2
Eigenvalue	0.902	1.506
% explained cumulative variance	22.6	63.0
Variable quantification		
Air temperature	0.354	−0.503
Relative air humidity	0.354	−0.503
Wind velocity	0.494	0.524
Light intensity	−0.702	0.408

Based on the PCA analysis, the edge effect as measured by microclimate variables was detected to a depth of 40 m from the edge of the road. These results are in line with the findings of Young and Mitchell (1994) and Davies-Colley *et al*. (2000) that the influence of the edge of the microclimate measured to depths of 40-50 m in Podocarpus forest and this creates fragments adjacent to the open land. Edge effect of the roadside measured to a width of 40 m has implications for the conservation of forests in the Bukit Pohen interior. Based on the results of their study, Fardilla & Sutomo (2011) suggest that Pohen Hill forest should have a buffer with a width of at least 40 m to protect the interior condition of the forest from ecological changes of microclimate due to the opening of the forest for road construction.

B. Landscape planning for "Tri-Danau" area of Bedugul

In general, landscape means the whole character of the land or site as part of the earth including all living things, whether they are natural, non-natural or both, and the environment which supports it. Lakes can be defined as a vast pool of water with low to high water fluctuations. Landscape management is defined as an action to ensure the regularity of the landscape and to harmonize the changes deemed necessary for economic and social reasons (Hanum and Darma 2005).

There are many aspects to consider when landscape planning, such as land use determination. Determination of suitable land uses is done through landscape assessment. This assessment aims to establish a balance between the needs for creating land uses that will benefit the community and the protection of the natural resources and culture of the local community. In landscape assessment, the four major landscape issues are landscape resources, landscape hazards, development suitability, and human impact on the environment (Hanum and Darma 2005).

In 2017, a landslide from Bukit Tapak in Bedugul hit parts of Bali Botanical Garden which destroyed several of its bridges and uprooted some trees. In early 2018, a landslide recurred around Pohen Hill and claimed two casualties. According to Sutyarto (2002), based on its lithology, stratigraphy and topography structure, the Bedugul area is prone to landslides. Avalanches can occur at thecaldera edge, remaining hills and sub-resin cones. The landslide types experienced in the area are mud flows, soil creeps, slumping and debris avalanches.The problem of landslides is closely related to the use of land above the landslideas population increases and the pressures placed on the land can result in changes to soil properties and likelihood of land slipping. The picture below gives an overview of land use change in Bedugul area between 2000 and 2017. In just 18 years, there has been changes in land use in Bedugul area (Figure 28). Rice fields or "sawah" in the Bedugul area increased from 6,402 ha in 2000 to 33,459 ha in 2017. Among the three lakes in Bedugul, Lake Beratan is the most strategic location because of its location on the edge of the highway, which provides ready access for developers and farmers. Thus, most of the land around this lake has undergone land use changes.

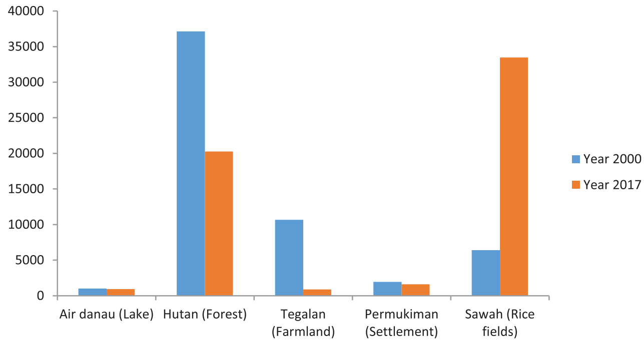

Figure 28. Graph showing size change in area of several land use in Bedugul area (based on the two maps shown in Figure29).

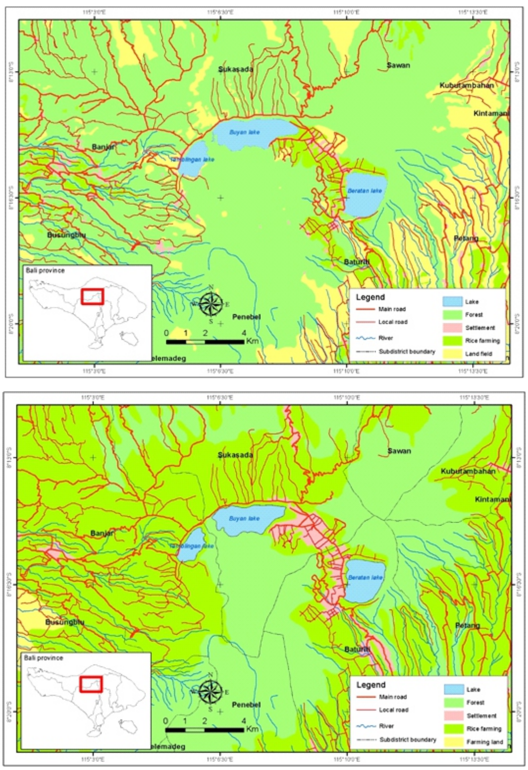

Figure 29. Land use change in Bedugul area between year 2000 and 2017. Map created by Sutomo and Luthfi Wahab based on Landsat image analysis using ENVI and ARCGIS.

The management concept that can be best applied in the Bedugul area is the zoning concept (starting from the lakes and spreading out). This zoning system (Figure 30) is done in order of management priorities and stages, and consists of the following: (1) lake, (2) border of the lake, (3) core zone, (4) buffer zone, and (5) utilization zone. The purpose of this system is to avoid conflicts between tourism interests and conservation.

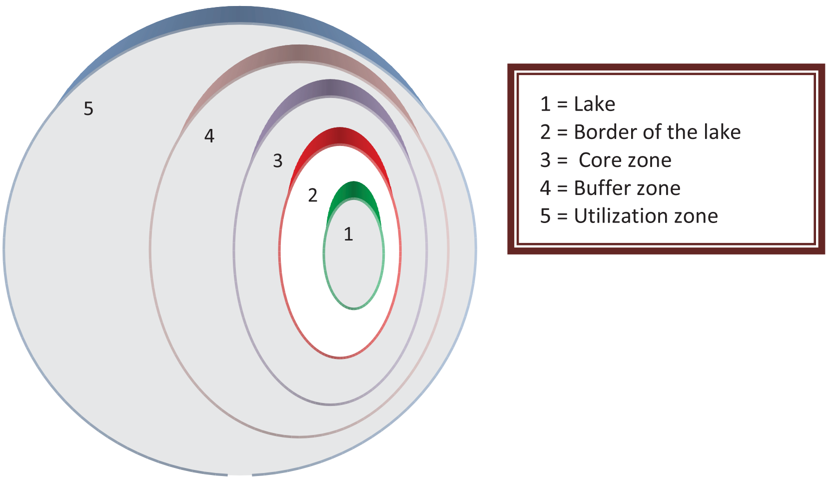

Figure 30. Concept of zonation that can be applied for Bedugul area (Hanum and Darma 2005)

The core zone is a closed area and may only be entered with certain permits, among them is to conduct research. The buffer zone is an area that serves to protect the core area from damage caused by human activities. This location can be a place for research, training and education, as well as ecotourism and sustainable use of renewable natural resources. Buffer zone management is aimed at sustainable use of natural resources while providing benefits to local communities. Local residents can enter to pick up wooden branches for firewood, but are not allowed to cut down trees. In addition, local residents can also take non-timber forest products such as passion fruit and also asplenium. The buffer area is a limited area, open to visitors in limited numbers so that the facilities provided are very simple such as footpaths and camping places. Various activities that are ecologically accountable can be done here. In this area tourists can do activities such as enjoying the scenery of trees and lakes, camping and observing the bird life of the area. The zone of utilization is an area devoted to various types of human activities such as intensive tourism, agriculture and housing. The placement should be based on the land capability class for a specific designation.

Currently, the land around the Beratan lake is filled with houses, stalls, intensive tourism and agricultural activities. The surrounding slopes are still covered with trees. From the concept of zoning, the area around the lake should be used as a border. Ideally, the border width is 50 m from lake edge and planted with trees to minimize occurrence of erosion.The area around Lake Buyan and Tamblingan can still be managed well according to the existing planning because there is still not much development going on around these areas. If the area will be used as a tourist place, it should be done in the buffer zone. For farms with a slope of less than 15%, it is advisable to use an agroforestry system. Agroforestry is defined as a common name for a land use system and technologies where woody plants such as trees are intentionally planted in the same land management unit as agricultural land. Therefore, within this system, there are ecological and economic links.

III. Vegetation Ecology of Bedugul

Sutomo, I Dewa Pt. Darma, Wawan Sujarwo & Arief Priyadi
Bali Botanical Garden-Indonesian Institute of Sciences (LIPI), Candikuning Baturiti Tabanan 82191

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Sutomo, Undaharta N. K. E., Bangun T. M. & Lugrayasa I. N. (2012) Studi Komposisi dan Dinamika Vegetasi Pohon Hutan dengan Pembuatan Plot Permanen 1 Ha di Gunung Pohen Cagar Alam Batukahu Bali. Bumi Lestari 12, 366-81.
Sutomo & Darma I. D. P. (2011) Canonical Corespondence Analysis of Plant Community at Buyan-Tamblingan Lake Forest Areas Bali. In: Konservasi Tumbuhan Tropika: Kondisi Terkini dan Tantangan ke depan (eds D. Widyatmoko, D. M. Puspitaningtyas, R. Hendrian, I. Fijridiyanto, A., J. R. Witono, R. Rosniati, S. R. Ariati, S. Rahayu and T. N. Praptosuwiryo) p. 429. UPT BKT Kebun Raya Cibodas-LIPI, Cibodas, Jawa Barat.

A. Vegetation on the periphery of three lakes Beratan, Buyan and Tamblingan Bedugul

Darnaedi *et al*. (2005) states that the Tri-Danau Beratan, Buyan and Tamblingan areas are rainwater catchments which are very important for people's lives in Bali. Communities around the Tri-Lake area use lake water for household uses, farming and fishing, as well as being tourist attraction and a place for research and passive recreation. The types of plants that are naturally encountered in the forest area around Tri-Lake which can maintain and regulate the water cycle include Cemara Pandak (*Dacrycarpus imbricatus* (Blume) de Laub.), Cemara Geseng (*Casuarina junghuhniana* Miq.), and several types of bamboo such as *Dendrocalamus asper* (Schult.) Backer, *Gigantochloa apus* (Schult.) Kurz, and *Schizostachyum brachycladum* (Kurz) Kurz. On the other hand, the presence of vegetation around the waters of the lake can determine the quality of water and its environment. Augusta (2015) states that conservation of water resources needs to be managed properly because some aquatic plants have rapid growth, and can affect ecosystems and sedimentation of the lake. Ward *et al*. (1993) reveals the diversity of aquatic plants can enrich the diversity of their established habitat, including the aquatic fauna community. Darma *et al*. (2017) conducted a vegetation analysis on the periphery of the three lakes Beratan, Buyan dan Tamblingan and surrounding locations.

Table 4. Physical environment of the three lakes in Bedugul Basin.

Physical parameters	Lakes		
	Beratan	Buyan	Tamblingan
Elevation (mdpl)	1,231	1,214	1,214
Light intensity (Lux)	473.45	776.92	1051.33
Depth (m)	20.8	62.8	35.5
Relative air humidity (%)	77.38	63.24	77.16
Lake width (km^2)	4.21	5.16	1.42
Surface temperature (°C)	21.4	21.2	21.2
Air temperature (°C)	23.53	23.64	24.88
Water volume (million m^3)	48.45	135.52	24.82

Source: Hehanusa (2005).

Vegetation observed at the edge of the waters of Beratan Lake, Buyan and Tamblingan included 35 aquatic and terrestrial plants species, consisting of 19 tribes and 24 genera. This finding, based on Shannon-Wiener (H') diversity index, considers the three lakes as moderately diverse. The diversity index in each of the lake was 2.56 in Beratan, 2.31 in Tamblingan, and 2.25 in Buyan, with a overall H value of 2.69. These diversity values indicate that the vegetation of the lake has regenerated following disturbance by natural conditions and human activities.

Based on their growth form, the plant species in the Tri-Lake area can be grouped into three, namely: (1) plants growing on the shore of the lake which are further classified as (a) upright growing plants. These are 'emergent' plants which produce leaves and flowers above water level when flooded (*Ageratum conyzoides*, *Colocasia* sp., *Cyperus digitatus*, *C. distans, C. haspan, C. imbricatus, Echinochloa colona*, *Echinochloa* sp, *Oenanthe javanica*, *Plantago major*, *Polygonum* spp., Kepupung (local name in Bali), and *Schoenoplectiella mucronata*); and (b) prostrate to low growing plants. These are submerged plants which can be completely flooded for some period (*Alternanthera philoxeroides, Centella asiatica, Commelina diffusa, Drymaria villosa, Mentha arvensis, Myriophyllum aquaticum, Panicum repens, Potentilla* sp., *Lindernia* sp., *L. ciliata, L. adscendens* and *Spilanthes* sp.); (2) plants that grow with roots in mud and with leaves floating on the surface of water (*Nymphoides indica*); and (3) plants that float freely on the water of the lakes (*Azolla pinnata, Eichhornia crassipes, Pistia stratiotes* and *Salvinia adnata*).

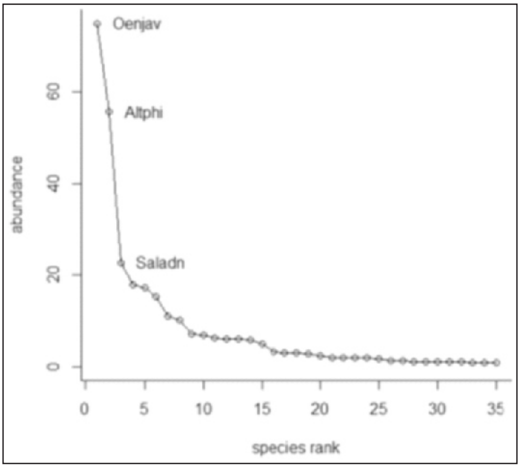

Figure 31. Rank abundance curve of plant species on the periphery of the three lakes Beratan, Buyan and Tamblingan.Note: Altphi = *Alternanthera philoxeroides*, Oejav = *Panicum repens*, Saladn = *Salvinia adnata*

Figure 31 shows that the existing 35 species in three lakes and the types of vegetation constituents are not evenly distributed. In other words, there are clear dominant species among them. Based on the calculation of the proportion in the abundance curve, there are nine species that dominate almost 80% of the surroundings in the three lakes. The dominant species according to ranking are *Oenanthe javanica*, *Alternathera philoxeroides*, *Salvinia adnata, Myriophyllum aquaticum, Echinochloa sp., Mentha arvensis, Azolla pinnata, Centella asiatica*, and *Cyperus imbricatus*. The first three types cumulatively constitute 50.9% of dominance in the three lakes.

The types of plants found in this study are mostly known as a weeds (Soerjani *et al*., 1987). The explosion of certain plant populations on the surface of the lake such as *S. adnata* causes many impacts, especially on the abundance of other species. Floating plants in particular may hinder the development of other plants. They can obstruct oxygen circulation from air to water, their rate of water loss due to evapotranspiration is much greater than evaporation, and their biomass can double in just a week or two. In addition, floating plants such as *Salvinia* also play a role in blocking the infiltration of sunlight that is indispensable in the process of photosynthesis of other aquatic plants, eventually leading to reduced dissolved oxygen levels in water bodies (Owens *et al*., 2005). *Salvinia adnata* in Lake Buyan needs to be observed as an invasive alien plant species.

This plant, reportedly originating from Brazil, was identified outside its original habitat for the first time in 1939 and in 2014 designated as one of the

100 most invasive species in the world. *Salvinia adnata* is a sterile fern water plant and reproduces vegetatively via ramets. The combination of high growth rates with slow decomposition rates decreases the availability of nutrients for other plant species. This seems to be related to the dominant phenomenon of the species in Lake Buyan. The invasive nature of *S. adnata* in Indonesia is also reported in Ranu Pani, Bromo-Tengger-Semeru National Park area (Hakim & Miyakawa, 2015). This species was observed in mid-2011 as a small population on the outskirts of the lake.By the end of the same year, this species had covered 75% of the lake body. The dominance of *S. adnata* in Lake Buyan appears to be related to eutrophication as demonstrated as a key process in Lake Ranu Pani.

B. Community ecology of forest plants in Bedugul

All organisms and their environments are dynamic, meaning that between them there is always some interaction that produces change. Soerianegara and Indrawan (1982) stated that the forest community is a living and growing system because the community is formed gradually through several stages of plant invasion, adaptation, aggregation, competition and mastery, a reaction to the place of growth and stabilization. Changes in forest communities always occur even in a stable forest. For example, when there is a fallen tree, the canopy is opened in this area so that the sun can reach the forest floor which may encourage seeds in the soil seed bank to germinate and for other plant species to grow, especially light-demanding or shade intolerant species. Community structure is always changing in time and place. There are changes that can be observed over a short time, but there are also changes that can only be observed over the scale of years to decades. One approach to studying the dynamics of community structure is through observations and measurements within permanent plots.

Mountain forests in Bedugul are one of the last remaining refuges of biodiversity on Bali island, as well as in Java island more generally and also on other Indonesian Islands. This type of ecosystem is important as most of Indonesia's lowland forests have been ecologically damaged and have experienced extinction of several species. An estimated 31,818 ha out of 127,271 ha or 25 percent of the total land area in Balihas undergoneland function conversion. Changes in the function of forestland are caused by several things, such as the encroachment by community groups living near the forest and the use of forest areas for development outside the forestry sector, as well as illegal logging and fires.An average of 350 ha forest land in Bali burns annually (KSDA 2005). Similarly, the condition of the forest on Mount Pohen Batukahu Nature Reservehas also experienced wildfire. Forest fires that occurred in 1994 damaged some forest ecosystems in Mount Pohen, constituting about 30.5 ha. Thus, it is important to do an inventory and floristic analysis in the forest area of Mount Pohen in Batukahu Nature Reserve to monitor the vegetation dynamics over time. Monitoring will be devoted to a relatively intact part of the forest. It is intended that this intact forest area could become a reference area in the restoration of forest areas damaged by forest fires in Mount Pohen in 1994, as well forest damaged as by other activities.

The practice of establishing permanent sample plots have been proven to be very useful for quantifying biodiversity, measuring impacts and monitoring forest dynamics over time (Condit *et al*., 1996). Quantitative inventories using permanent sample plots (PSPs) have been widely applied in forests in Indonesia, but most of them are made in lowland forests in Kalimantan (Clearly *et al*., 2006; Cleary and Mooers 2004; Kartawinata *et al*., 2006; Riswan and Kartawinata 1991). However, mountainous forests are increasingly threatened nowadays because of human activities, such as the mountain forests of India (Davidar *et al*., 2007) and Indonesia, including those of Halimun Mountain National Park in Java where a a permanent plot has been established (Suzuki *et al*., 1997). However for the mountain forest areas of Bali, no such plots have been established. Having a permanent sample plot in the Pohen Mountain area will facilitate the monitoring of plant biodiversity and vegetation dynamics after the forest fire in 1994. The permanent sample plot is a very important tool in monitoring the changes and structure of forest dynamics, long-term tree growth, and other important data that will be used in evaluating ecological condition and models. From the silvicultural aspect, permanent sample plots will be able to provide data on the increment of tree volumes and basal areas, as well as the dynamics of the forest structure. The results of the monitoring will provide very important information forthe planning of forest management and restoration activities.

Sutomo *et al*. (2012) conducted a study using PSP in Mt. Pohen. The plot location was chosen based on the preliminary survey and the literature study was also completed with a study of the area map. The plot was an intact forest located at the northern part of the mountain since the southern part has been damaged by fire. The plot was 1 ha with a sub-plot size of 20 x 20 m, based on the calculation of area-type curves and calibrations with similar areas in other locations which also have permanent sample plots (Herben 1996; Suzuki *et al*., 1997). The plot was created within a slope of 60-70 ° situated in an altitude between 1600 - 1700 m. The coordinates of the outer plots of 1 ha plot and each sub-plot were recorded by GPS device (Garmin GPS Map 76 csx). There were five lines in different altitudes with distances between rows of 20 m in height so the first 5 sub plots in row 1 were at an altitude ± 1600 mdpl, row 2at an altitude of 1620 mdpl, row 3 at an altitude of 1640 mdpl, row 4 at an altitude of 1660 mdpl and row 5 at an altitude of 1680 - 1700 mdpl. The differences in altitude were used as the differentiating factor of each sub-plot on each line to determine if there are differences in the structure and composition of tree vegetation along each line at different heights in this 1 ha permanent plot.

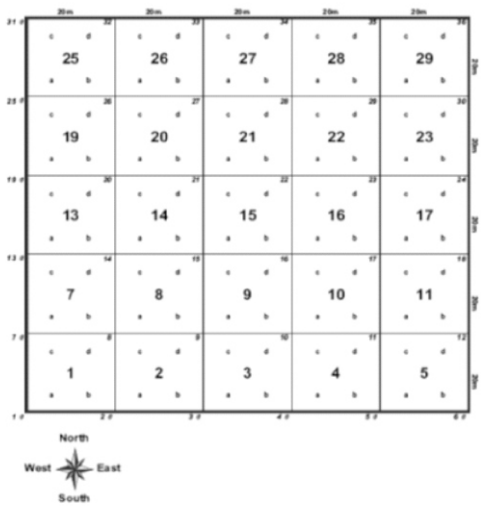

Figure 32. Lay out of the PSP with sub-plots inside a one ha PSP in Mt. Pohen, Bedugul.

Figure 33. Trees inventory inside PSP in Mt. Pohen, Bedugul. Photo credit: Sutomo

Trees included in the inventory were those with at least have 20 cm stem diameter. Plant total height and height to the first major free branch (TBBC/*tinggi batang bebas cabang*) were measured. Next, trees were marked by indicating plot and tree numbers that were measured, e.g IV.6 means plot number 4 and tree number 6. The tree position in the plot 20 x 20 m was also drawn on millimeter square graph paper and redrawn with Corel Draw. Their results showed that a plot of 1 ha with 25 sub-plots sized at 20 x 20 m was sufficient to represent the vegetation type in Mount Pohen, as seen in the species-area curve (Figure 32). There were 24 species of trees included in 19 tribes in 1 ha plot (Table 5).

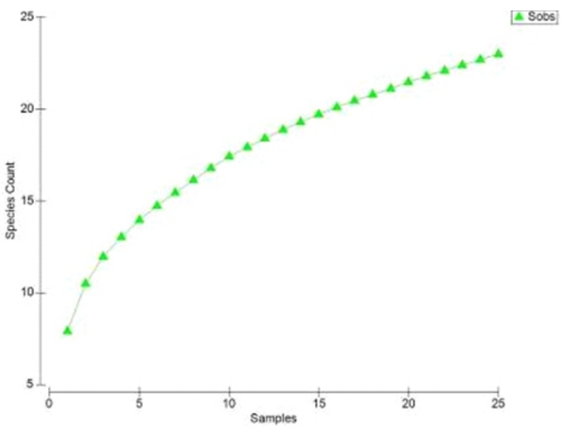

Figure 34. Species Area Curve (SAC) of trees in the1 ha PSP on Mt. Pohen, Bedugul. Each sample represents an area of 400 m^2.

In terms of floristic composition, highland forest typically has a lower tree species diversity than lowland forests. In the montane zone (above 1,500 m dpl) of the West Halimun Mountain area in Java, a 1-ha permanent plot had 46 tree species (Suzuki *et al*., 1997). Several species or genera found at Mount Halimun were also found in the 1-ha permanent plot at Mount Pohen in Bali (1600 - 1700 mdpl), such as *Myrsine hasseltii*, *Homalanthus giganteus*, *Platea* sp., *Podocarpus imbricatus*, *Polyosma integrifolia*, *Symplocos* sp. *Weinmannia blumei*, *Acronychia trifoliata*, *Breynia microphylla*, *Claoxylon* sp., *Engelhardia spicata*, *Glochidion rubrum*, and *Litsea* sp. Tree species that were not found in the forest area of Mount Pohen Nature Reserve but found in Mount Halimun included *Altingia excelsa* and *Schima wallichii*.

Most of the species found in Mount Pohen such as *Homalanthus giganteus*, *Platea* sp., and *Podocarpus imbricatus* are typically plant species in secondary forests, which have been disturbed in the past. These plant species exist as a

Table 5. List of tree species inside the 1 ha PSP on Mt. Pohen, Bedugul.

Species name	Families
Acronychia trifoliata Zoll.	Rutaceae
Ardisia sp.	Myrsinaceae
Breynia microphylla (Kurz ex T. & B.) M.A.	Euphorbiaceae
Casuarina junghuhniana Miq.	Casuarinaceae
Celtis sp.	Ulmaceae
Claoxylon sp.	Euphorbiaceae
Crypteronia paniculata Bl.	Crypteroniaceae
Engelhardia spicata Lech. ex Bl.	Juglandaceae
Ficus sp.	Moraceae
Glochidion rubrum Bl.	Euphorbiaceae
Gordonia amboinensis Miq.	Theaceae
Litsea sp.	Lauraceae
Lophopetalum javanicum (Zoll.) Turcz.	Verbenaceae
Mischocarpus pubescens Blume	Sapindaceae
Myrsine hasseltii Bl. Ex Scheff.	Myrsinaceae
Homalanthus giganteus Z. & M.	Euphorbiaceae
Platea sp.	Icacinaceae
Podocarpus imbricatus Bl. (*Dacrycarpus imbricatus*)	Podocarpaceae
Polyosma integrifolia Bl.	Saxifragaceae
Sloanea siguns (Blume) K.Schum	Elaeocarpaceae
Symplocos sp.	Symplocaceae
Vernonia arborea Buch. Ham.	Asteraceae
Weinmannia blumei Planch.	Cunoniaceae

result of both natural and human disturbance events in the past such as landslides, volcanic activity or fire (van Steenis 1972; Whitten *et al*., 1996). However according to van Steenis (1972), *Podocarpus imbricatus* and *Casuarina junghuhniana* are actually long-lived pioneer types present due to long past disturbances in the region. This type of dominance is only temporary as these pioneer species will be gradually replaced by other species because regeneration of such species cannot occurin a dense forest. However, the species turn over will result in more diverse forests as dominance by pioneer species subsides, with the assumption that "no further disturbances occur". This change however will take centuries to occur, and perhaps the forests will remain dominated by the long-lived pioneer species in the event of recurring disturbances and may never become a climax forest (Walker and del Moral 2008).

Pioneer trees such as *Podocarpus imbricatus* are found to coexist with Claoxylon-Homalanthus-Vernonea-Cryptomeria-Polyosma-Myrsine and Acronycia. Spatial patterns of distribution and plant associations are important characteristics of an ecological community. The phenomenon that most of these species live together with groups of certain species may occur as a result of biological interactions between such species as either positive or negative associations, or as a result of the same or different responses of a species to its environment or its abiotic factors, as well as the response to disturbance to the forest ecosystem. In terms of groundcover plants, Sutomo (2014) found as many as 69 species which belong to 47 families inside the 1-ha PSP atMt. Pohen, Bedugul (Table 6).

Table 6. Groundcover species and their Families with their Importance Value Index/IVI in a 1-ha permanent sample plot in Mt. Pohen, Bedugul.

Species	Family	IVI
Selaginella sp.	Selaginaceae	40.28
Athyrium esculentum (Retz.) Copel	Woodsiaceae	11.07
Ardisia humilis Vahl.	Myrsinaceae	9.76
Piper sp.1	Piperaceae	8.81
Pteris sp.	Pteridaceae	7.28
Pilea sp.	Urticaceae	7.02
Polypodium sp.2	Polypodiaceae	6.85
Polypodium sp.1	Polypodiaceae	6.59
Polyosma integrifolia Bl.	Saxifragaceae	6.48
Cyclosorus sp.1	Thelypteridaceae	6.44
Rubiaceae	Rubiaceae	6.03
Clauxylon sp.	Euphorbiaceae	5.86
Cyathea sp.	Cyatheaceae	5.42
Flacourtia sp.	Flacourtiaceae	4.85
Symplocos odoratissima (Bl.) Choisy.	Symplocaceae	4.56
Hedychium coronarium Koen.	Zingiberaceae	4.52
Asplenium tenerum Forst.	Aspleniaceae	4.17
Cyperus sp.1	Cyperaceae	3.96
Helicia sp.	Proteaceae	3.79
Strobilanthes sp.	Acanthaceae	3.42

Table 6. Continued.

Species	Family	IVI
Athyrium asperum (Bl.) Mild.	Woodsiaceae	3.22
Nephrolepis coerdifolia (L.) Pr.	Woodsiaceae	2.92
Calamus ciliaris Bl.	Arecaceae	2.70
Poaceae	Poaceae	2.35
Rubus sp.	Rosaceae	2.06
Acronychia trifoliata Zoll.	Rutaceae	1.80
Pandanus sp.	Pandanaceae	1.72
Goodyera reticulata (Bl.) Bl.	Orchidaceae	1.43
Smilax sp.	Smilacaceae	1.43
Laportea sp.	Urticaceae	1.42
Litsea sp.	Lauraceae	1.38
Cyclosorus sp.2	Thelypteridaceae	1.32
Medinilla sp.	Melastomaceae	1.26
Asplenium sp.1	Aspleniaceae	1.16
Omalanthus giganteus Z & M.	Euphorbiaceae	1.06
Gynura sp.	Asteraceae	1.01
Melastoma sp.	Melastomaceae	0.84
Piper sp.2	Piperaceae	0.78
Desmodium sp.	Fabaceae	0.74
Pteris tripartita Sw.	Pteridaceae	0.69
Asplenium nidus L.	Aspleniaceae	0.64
Crypteronia sp.	Crypteroniaceae	0.64
Dysoxylum nutans (Bl.) Miq.	Meliaceae	0.64
Podocarpus imbricatus Bl.	Podocarpaceae	0.64
Psyhotria sp.	Rubiaceae	0.64
Vernonia arborea Buc. Ham.	Asteraceae	0.64
Asplenium sp.2	Aspleniaceae	0.42
Vittaria ensiformis Sw.	Vittariaceae	0.42
Blumea sp.	Asteraceae	0.37
Cyperus sp.2	Cyperaceae	0.37
Platea sp.	Lauraceae	0.37
Urticaceae spesies 3	Urticaceae	0.37
Acanthaceae spesies 4	Acanthaceae	0.32
Adiantum sp.	Pteridaceae	0.32
Arisaema sp.	Araceae	0.32

Table 6. Continued.

Species	Family	IVI
Begonia sp.	Begoniaceae	0.32
Breynia sp.	Euphorbiaceae	0.32
Calanthe sp.	Orchidaceae	0.32
Gynostemma sp.	Cucurbitaceae	0.32
Cyathea latebrosa (Wall.) Copel.	Cyatheaceae	0.32
Elaeocarpus sp.	Elaeocarpaceae	0.32
Ficus sp.	Moraceae	0.32
Geniostoma sp.	Loganiaceae	0.32
Not yet identified	-	0.32
Lophopetalum javanicum (Zoll.) Turcz.	Celastraceae	0.32
Malvaceae spesies 5	Malvaceae	0.32
Myrsine hasseltii Bl. ex. K. Scheffer.	Myrsinaceae	0.32
Pinanga kuhlii Blume.	Arecaceae	0.32
Polygala sp.	Polygalaceae	0.32

Figure 35 shows the results of Non-metric Multidimensional Scaling (NMDS) ordination analysis from Sutomo (2014). In general, most of the groundcover species are clumped tending to co-occur in the same subquadrats, with only a few showing solitary pattern (tending not to be clumped with other species).

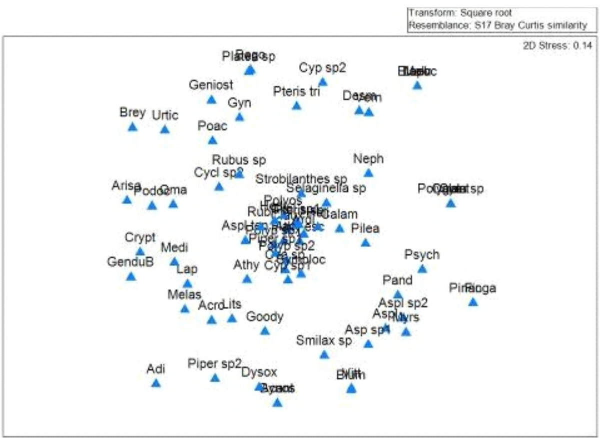

Figure 35. Ordination analysis using NMDS of groundcover species distribution in a 1-ha permanent sample plot in Mt. Pohen, Bedugul.

According to Barbour *et al*. (1980), a Shannon index of 0-2 is categorized as a low level of diversity; thus the diversity of understorey plants in Mt Pohen area is relatively low at ± 2.6 (based on the Shannon Diversity Index). There was a low diversity of groundcover vegetation (lower vegetation) in this PSP as it was within the intact part of Mt. Pohen forest, with a fairly dense canopy cover. Thus the sunlight intensity that touches the forest floor was not abundant so that not many species can grow other than the shade tolerant types such as ferns, among others, *Selaginella* spp. (Barata 2000; Gomez-Pompa and Vazquez-Yanes 1981).

In the Buyan and Tamblingan Lake forest areas, Sutomo and Darma (2011) also investigated the relationship of plant community with their environmental factors. Vegetation was sampled by establishing transects through the forest and using circular plots of 10 m radius to measure the existing tree species (number of individuals, height and girth of each tree). Within the 10 m circular plot, a nested circular plot with 2 m radial was also made to measure the groundcover species (species, number of individual) (Kent and Coker 1992). A total of 30 plots in Buyan and Tamblingan were developed and the distance between plots was at least 50 m. Data were assessed using a multivariate analysis with CANOCO, ecological analysis software.Within CANOCO, a Canonical Correspondence Analysis (CCA) was used to identify the distribution of species along the environmental gradients (ter Braak 1986). The CCA axes were evaluated statistically using a Monte Carlo permutation test. The CCA analysis was done using CANOCO program V.4.5 (ter Braak and Smilauer 2002).

The study results shows that mean species diversity was different between these two areas (Figure 36). The Buyan area had higher diversity index (2.0) compared to Tamblingan (1.6). Their CCA analyses provided clearer views of the species distribution along some environmental gradients. Species were distributed mainly along two gradients namely elevation and slope (Figure 37). The influence of altitude to species distribution was significant. Elevation gradients in axes 1 were capable to explain 42.8% of the total variability of species with a correlation value of 0.8. The slope angle of the area also played significant role in the species distribution. Slope gradient in axes 2 was able to explain 19.1% of the total variability of species with a correlation value of 0.7.

Overall, the CCA diagram (Figure 37) revealed that all species located in the right of the vertical axis are the species that are positively affected by elevation and those which are located on the left side of the axis are negatively affected by elevation (i.e. tend to found at lower altitudes). Furthermore, species, which are located above, of the horizontal axis are species, which are positively affected by slope, and the reverse is true for those, which are located

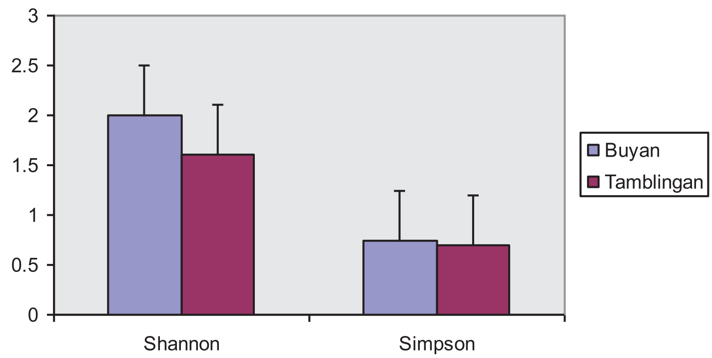

Figure 36. Graph showing species diversity index (y axis) based on Shannon and Simpson index at Buyan and Tamblingan Lakes.

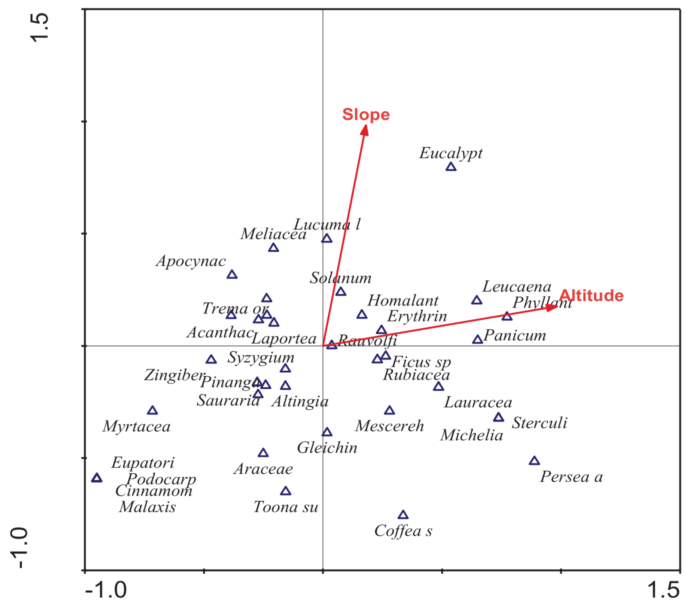

Figure 37. Ordination diagram derived from the Canonical Correspondence Analysis showing distribution of species on the gradients of slope and altitude.

below the horizontal axis. The length of the environmental arrows also indicates the strength of the correlation. So, the distance from the central axis reflects the changes in the condition of the environmental gradients. For example, *Rauvolfia* was found at the lowest altitude, and then as the elevation became higher, other species such as *Ficus benjamina, Erythrina* sp., *Homalanthus* sp., *Panicum reptans, Leucaena leucocephala* and *Phyllanthus* sp. were found. Similar concept was also applied for the slope arrow. *Rauvolfia* sp. was not only found at the lowest elevation but also found on the less steep areas. As the slope became steeper, species such as *Laportea stimulans, Solanum* sp.*, Lucuma* sp. and *Eucalyptus* sp. were found at the steepest area in the sampling sites.

Results from this study are important as baseline data for managers of conservation areas in order to develop a management and site rehabilitation plan. For rehabilitation purposes, species selection is an important part of the process. Native species that are less aggressive are preferred than exotic and aggressive invasive species and such species should also be positively correlated with elevation and slope gradients (Fierke and Kauffman 2006; Keeley *et al.* 2005; Kunwar 2003). This can be drawn from the CCA diagram. *Eucalyptus*, *Homalanthus*, *Rauvolfia*, *Leucaena*, and *Erythrina* are the tree species that are correlated with the two gradients and are potentially to be used as favourable species for rehabilitation purposes.

C. Autecology of plant species in Bedugul

Autecology is the study of one species in relation to its environment, which comprises other organisms and abiotic factors (Jongman *et al.* 1987). Invasive species cause problems to local ecosystems and their native species. Invasive species have affected nitrogen availability in soils (Bao *et al.* 2009), threatened the mangrove ecosystem in Bangladesh (Biswas *et al.* 2007), and influenced plant diversity in riparian ecosystem in Oregon (Fierke and Kauffman 2006). In order to be able to control other potentially troublesome exotic invasive species, there is a need to understand first what factors limit their growth and development. However, information regarding limiting environmental factors for other problematic alien invasive species is still inadequate (Kunwar 2003), particularly in Indonesia. Thus,to remove or effectively control invasive species, , further studies and assessment of the invasive species are required.Thus, autecology studies are important because the data will act as baseline information that will guide the development of management plans, including rehabilitation and restoration programs. One example is weed management to reduce the domination of exotic pioneer species and promotes the establishment of native species (Fardilla and Sutomo 2013).

Invasive Species Cyperus rotundus

Fardilla and Sutomo (2013) conducted an autecology study at Mt. Pohen Bedugul specifically on nutgrass (*Cyperus rotundus* L.), one of the most

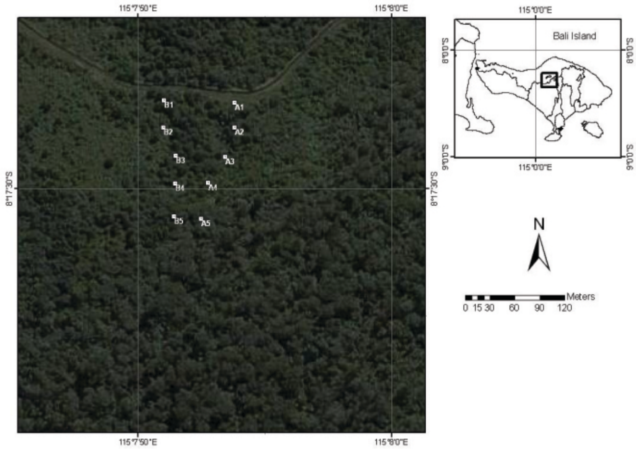

Figure 38. Research site and sampling points in Mt. Pohen forest as seen through Google Earth and Google Maps™ 2011.

invasive weeds in the world, in relation with other plant species of the forest edges within Mt. Pohen forest. *Cyperus rotundus* has purple-brown, bisexual flowers. The fruits are achenes and adult plants grow up to 1 m tall. The leaves are dark green, grass-like, with a prominent vein on the underside. It has red-brown spikelet with up to 40 individual flowers (Backer and van den Brink 1963; van Steenis 1972). *Cyperus rotundus* is distributed throughout Atlantic Europe, western and eastern Mediterranean, Balkan Peninsula, Minor and Central Asia, tropical Arabia, Africa, North and Southern America, and Australia. Physical or environment measurement, which correlated with invasive species distribution, is of important value to understand the autecology of these species in order to control and manage them.

Fardilla and Sutomo (2013) used linear mixed-effect models to show the relationship between the distance from forest edge with the measured microclimatic variables, and the relationship between *C. rotundus* abundance with the main microclimatic variables. They also conducted canonical correspondence analysis (CCA) ordination to see the influence of microclimatic factors on vegetation composition and association of *C. rotundus* with other plant species. Their result suggested that light intensity significantly decreased from forest edge to interior. They also found a similar trend for ambient air temperature. Wind speed was also significantly decreased along the forest edge. For the humidity data, they used the arcsine square-root transformation. In contrast, humidity significantly increased from the forest edge to interior. Detailed results of microclimatic gradients from forest edge to interior can be seen in Figure 39.

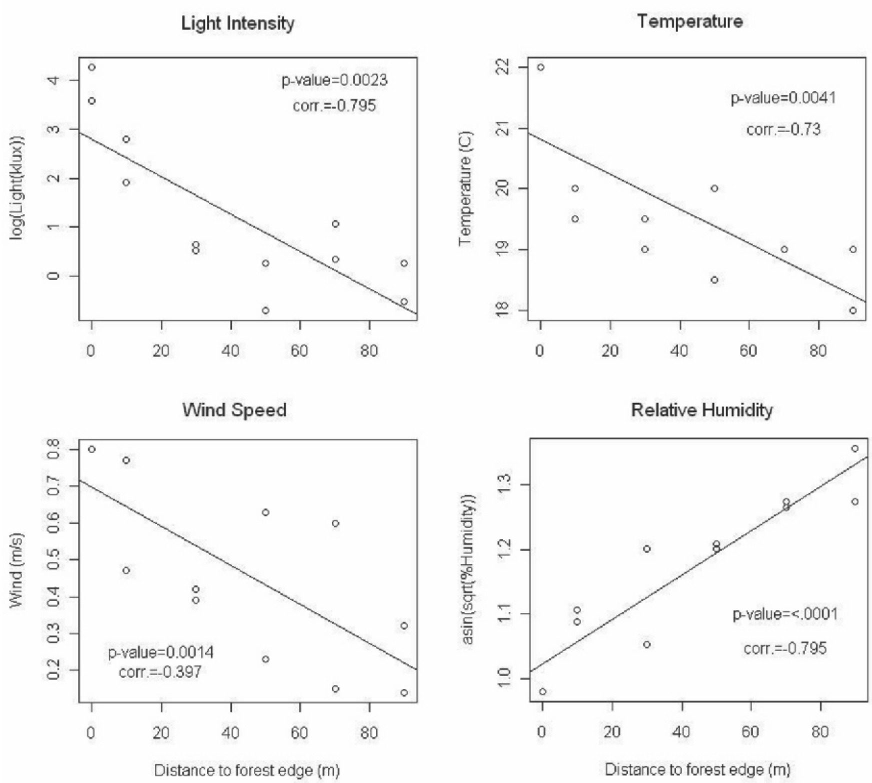

Figure 39. Microclimatic gradients along forest edge to interior in Mt. Pohen forest.

The CCA ordination suggested that CCA axis 1 explained 46% of the total variance, while CCA axis 2 explained 29.5%. Temperature and wind speed were the main microclimatic factors that explained vegetation composition in the study site (Figure 40). Referring to Figure 41, plot A1 and B1 which were plots near the road showed highest light intensity and temperature values. This value was decreasing as the plots moved to forest interior. In Figure 41, *C. rotundus* was located near light intensity and temperature arrows. Therefore, *C. rotundus* seemed to have a kind of relationship with light availability and temperature as the main microclimatic factors that regulate its abundance and distribution. Figure 41 showed that *C. rotundus* abundance had a significant correlation with light availability, but not with temperature.

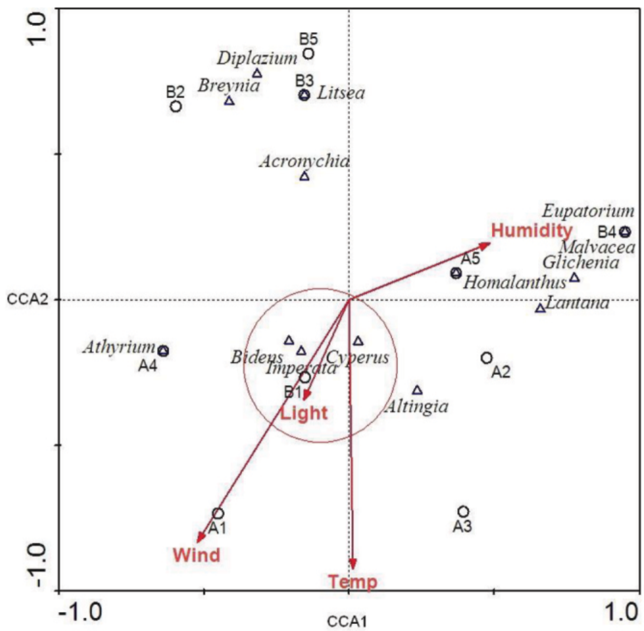

Figure 40. CCA ordination of vegetation and microclimatic factors at the study site in Pohen mountain forest in relation to the first two CCA axes.

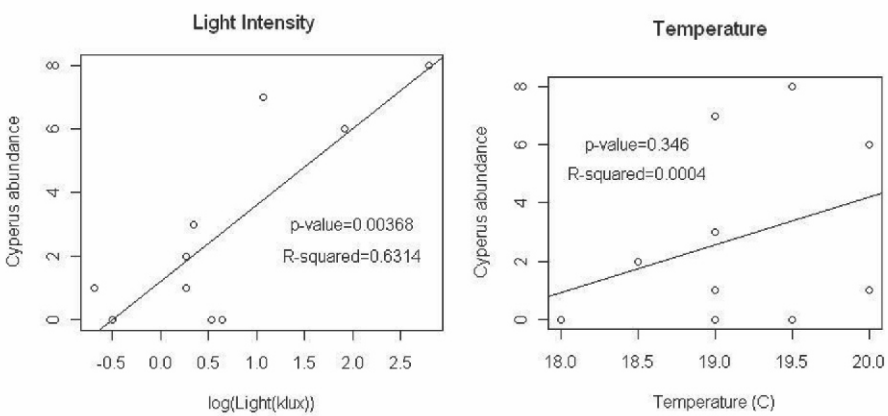

Figure 41. Relationship between light intensity and temperature with *C. rotundus* abundance in the study site.

Cyperus rotundus in their sampling location in Mt. Pohen tends to present close together with *Imperata cylindrica* and *Bidens biternata*. Other groups were also apparent such as *Lantana camara* and *Glichenia linearis*, and group of trees and their seedlings such as *Litsea* sp. and *Acronychia trifoliata*. There were also fern and tree species that tended to be solitary such as *Athyrium asperum* and *Homalanthus gigantheus* respectively, which are known as characteristic species of disturbed sites in Indonesia. The phenomenon that some species tends to co-occur together may be the result of biological interaction between them or perhaps indicating similarity in responding to disturbances and abiotic factors in their habitat. Therefore, species co-occurrence observations may be seen as the first attempt to detect species interaction (i.e. facilitation and inhibition) and niche process that could be responsible for structuring the community(Walker and del Moral 2008). By taking advantage of the results from exploring the few species that are strongly associated, the study may become more effective in the role of species interaction throughout the community succession post-disturbances.

In order to be able to control other potentially troublesome exotic invasive species, it is important to understand first what factors limit their growth and development. *Lantana camara* for example, is intolerant to frequent soil disturbance, and this rapidly spreading, fire-resistant exotic species is also unpalatable and poisonous to animals and has become weed elsewhere. Meanwhile, soil moisture stress and competition with the adult plant was proposed as one of the possible factors regulating the population of *Eupatorium* spp. *Cyperus rotundus* elsewhere has been known to populate sandy places, humid rivers bank and cotton and rice fields. In natural conditions, it develops on loamy and damp solonetzic soils, especially on alluvial "cultural" layer of irrigated crops. It develops better on friable, well-aerated, sandy and argillaceous unsalted soils. It is depressed on heavy and salted soils (Soerjani *et al*. 1987). *Cyperus rotundus* also known as a light-loving plantthus in sunlit places it forms over-ground shoots 6 times larger and the number and length of rhizomes increase by 1.5 times compared with shady ones. It is dispersed to new territories mainly via surface water flow and, to the lesser degree, with manure, bird excrements, by wind and wheels of agricultural instruments and transport. To promote establishment of native species, control of weeds including *C. rotundus* is needed to be done. Management control of *C. rotundus* can be done manually by removing the tuber by making shallow tillage.This tillage activity must be done at frequent interval. Physical control can be done by making a barrier using plastic polyethylene mulch. Weed suppression can also be done by using allelopathic plant such as those from Brassicaceae family. Application of the Luken succession management theory (Luken 1990) can also be used to control

C. rotundus by changing its resource availability. This study has also shown and confirmed previous finding that *C. rotundus* is a light demanding species. Hence, the use of shade from tree canopy is an important action to suppress *C. rotundus* and kick start the vegetation succession sequence and site recovery.

Endemic species Pinanga arinasae J.R.Witono

Indonesia has the most number of *Pinanga* species in the world. This palm genus consists of about 120 species, 40 species of which exist in Indonesia. In Java and Bali, there are three species of *Pinanga* namely *P. javana, P.arinasae*, and *P. coronata* (Uhl and Dransfield 1987). Nyabah, or Jabah (*Pinanga arinasae* J.R.Witono) is one of the Pinanga species endemic to Bali. Its morphology is closely related to the single-stemmed *Pinanga javana* from Java, and is generally found as solitary palm growing on mountain slopes. The palm's known distribution encompasses Western and Central Bali, namely mount Merbuk, Mount Tapak and Mount Pengelengan which belong to Bedugul area (Witono 2003).

The most noticeable morphological features of the palm is its beautiful crown with erect stem, 10-12 m tall. The whole leaf arrangement is 250-330 x 240 cm with leaf-sheath of up to 110 cm long, smooth and bright green color. The early flowering period of Nyabah is at 12-14 years of age. The flower grows inside of its leaf-sheath and the sheath will drop when the flower opens. *Pinanga arinasae* is mostly used by local people for ornamental purposes. “Cukup” is the traditional umbrella made of leaf sheath of *P.arinasae*. Locals also use the young fruits as a food substitute of areca nut (*Arecha cathecu*; Arinasa 2013).

Based on the 1997 expedition searching for *P. arinasae* on Mt. Tapak, it was noted that populations of saplings and mature plants are rarely found in the field. However, their seedlings are abundant. This phenomenon needs investigation as it will concern the species sustainability in the wild. Other threats to the sustainability of the *P. arinasae,* as well as other plants such as *Begonia* in Mt. Tapak and Bedugul forest, are forest conversion and land use change, as well as illegal logging (Satyanti and Siregar 2012). Meanwhile, *ex-situ* conservation efforts, which begin with exploration activities, are greatly neglecting habitat data and the species distribution patterns. As a result, acclimatization and propagation of the species often encounter problems due to scant habitat data.

There are little published literature available on *P. arinasae*. Most literature on this species focused on its taxonomy. This is understandable because this species was only discovered in 2000 and formally described in 2002 (Witono *et al.* 2002). Thus, autecology study is needed. In 2013, a team of researchers from Bali Botanical Garden conducted a field survey to understand the endemic distribution and abundance patterns of *P.arinasae* as well as its microclimate preference in one of its native habitat of Mt.

Figure 42. *Pinanga arinasae* in Mt. Pengelengan with Mr. I.B.K Arinasa from Bali Botanical Garden from whom the species obtained its name. Photo credit: Sutomo

Pengelengan, Bali.

Mount Pengelengan is located in Bedugul area. The Bedugul area is divided into three parts which belong to different district, the Tabanan, Buleleng and Badung Districts. Mount Pengelengan belongs to Badung District. Geographically located at 8° 16' 30" S dan 115°11' 00" E, Mount Pengelengan is bordered by Beratan Lake to the west and the mountain stretches from north to south with an elevation varying from 1249 to 2096 m asl.

Field observation was conducted using systematic sampling. Sample plots were laid out along transect of forest path from south to north (Figure 43). Plots were made on the right and left of the transect line within a 100-m

Figure 43. Location of Mt. Pengelengan on the East side of Lake Beratan, Bedugul. Also shown in the picture are the position of sample plots along a transect of the mountain ridge.

distance from each other. Seventeen sample plots were made to sample the abundance of vascular plant especially *Pinanga arinasae* and other tree species. Environmental variables that were measured in each observation plot include soil moisture (%), soil pH (*Dementra* Soil tester), air temperature (ºC), and relative air humidity (%) (*Hanna* Termohigrometer), light intensity (*Luxmeter*), location coordinates, altitude (GPS *Garmin* 76-CSXi), and slope (*Sunto* Clinometer).

Data were analysed using ordination techniques (Clarke 1993). Non-Metric Multidimensional Scaling (NMDS) using PRIMER (Clarke and Gorley 2005)was done to analyse the data to obtain information on variation in community composition and the abundance-distribution of *P. arinasae* in the study site. Canonical correspondence analysis (CCA) (ter Braak 1986) ordination was then applied to see the influence of microclimatic factors on the abundance of *P. arinasae* and its association with other species. The CCA analysis was done using CANOCO program V.4.5 (ter Braak and Smilauer 2002).

In terms of community composition, the ordination analysis using NMDS (Figure 44) identified that there was a clear separation of the plots.There were two different major clusters consisting of plots 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, and 17 together in one cluster and plots 1, 3, 4, 5, and 6 in another cluster. This implied that plots in the same cluster have relatively similar species composition, and plots from different cluster also differed in species

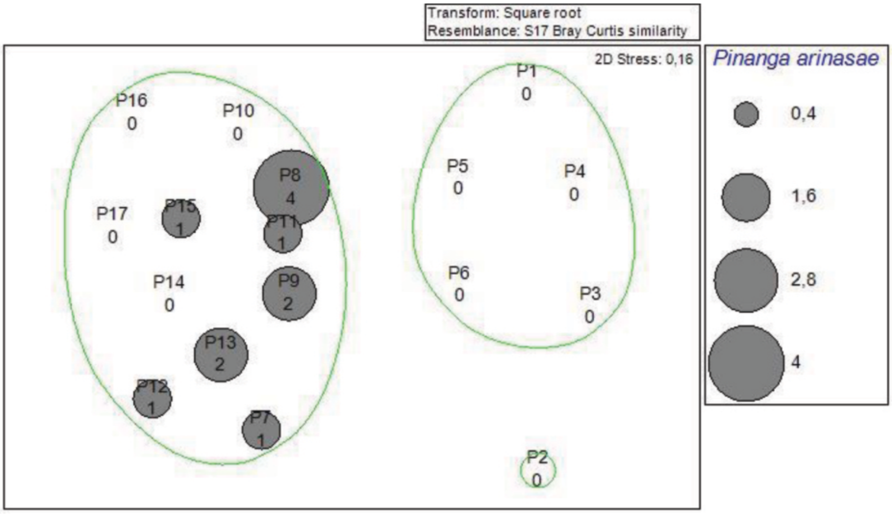

Figure 44. Configuration of NMDS ordination showing distribution and abundance of *P. arinasae* in sample plots (grey circles). Low 2D stress (0.16) indicates good ordination figure representation

composition among them. The NMDS model is reliable as can be seen from the low 2-d stress value (0.16), because if the 2-d stress value exceeds 0.25, then this means that the model is not good to predict the result (Hobbs and Mooney 1991; Hobbs *et al.* 2007). Distribution of *P. arinasae*in Mt. Pengelengan observation plots were clumped only in the left cluster. *P. arinasae* was found in seven plots (i.e., plots 7,8,9,11,12,13,15); each plot having different abundance with plot 8recording the highest number with four individuals.

The microclimate observations in Table 7 shows that the values in each plots varied. The air temperature ranged from 18 to 22°C, humidity from 78 to 100%, soil moisture from 20 to 38%, soil pH from 4 to 5, light intensity from 127 to 2570 klux, slope from 5 to 24%, and altitude from 1310 to 1506 m. In plot 8, four individuals of *P.arinasae* were found. To determine which microclimate factors most significantly affected the distribution and abundance of the species, Canonical Correspondence Analysis was performed. This approach simplifies the analysis of species-environment relationship in a way analogous to linear regression (Lepš and ˇSmilauer 2003).

Figure 45 shows the result of CCA ordination which gives a clearer view of the species distribution along some environmental gradients of *P. arinasae* in Mt. Pengelangan. The arrows refer to the measured microclimate factors (environmental gradients), the circles represent the sample plots and the

Table 7. Microclimatic factors measured at each plot in relation to distribution and abundance of *P. arinasae* in Mt Pengelangan.

Plot	Air temp (°C)	RH (%)	Soil Moist (%)	Soil pH	Light Int (Lux)	Slope (%)	altitude
P1	19.3	84.5	24	4.8	1031	10	1310
P2	21.5	78	38	5	908	15	1326
P3	21.4	81.8	25	4	379	10	1340
P4	21.8	86.7	25	4.4	657	14	1353
P5	22.1	84.6	30	4.4	832	14	1367
P6	20	85.8	30	5	127	20	1384
P7	20	92.8	38	5	199	18	1398
P8	19.7	91.6	30	5	1319	5	1398
P9	21.1	93.6	30	4.4	1718	5	1419
P10	21.2	95.5	38	4.8	839	11	1438
P11	22.5	89.4	25	4.8	2570	10	1456
P12	21.6	90.9	20	4.6	411	15	1470
P13	18.9	100	30	4.7	1617	19	1469
P14	19	100	20	4	1233	15	1480
P15	19.5	100	25	5	1730	24	1486
P16	18.3	97.3	28	4.4	1071	20	1494
P17	18.5	100	25.7	4.8	759	18	1506

triangles indicate the species names. Axes 1 accounts for 35.1% of the total variation of species distribution relative to environmental gradients with correlation value of 0.98 (Table8). Highest eigenvalues of 0.35 imply that tuneven species distribution along the available environmental gradients (Kent and Coker 1992). This may mean that there are other environmental factors that may also affect the distribution but were not measured during the study.

The length of the environmental arrows also indicates the significance. Thus, altitude, relative humidity (RH) and light intensity (Lux) play significant roles in affecting species distribution. In Figure 45, *P. arinasae* found were located very near to light intensity gradient which can imply that with light availability could be the main microclimatic factor that regulate its abundance and distribution.

In conclusion, *P. arinasae* as the endemic plant species of Bedugul in Bukit Pengelengan grows over a wide range for microclimate factor, i.e., temperature of 18-22°C, humidity of 78-100%, 20-38% soil moisture, soil pH of 4-5, Lux light intensity of 127-2570, slope of 5-24%, and altitude of 1310-1506 m altitude. Light intensity appears to be the main microclimate factor

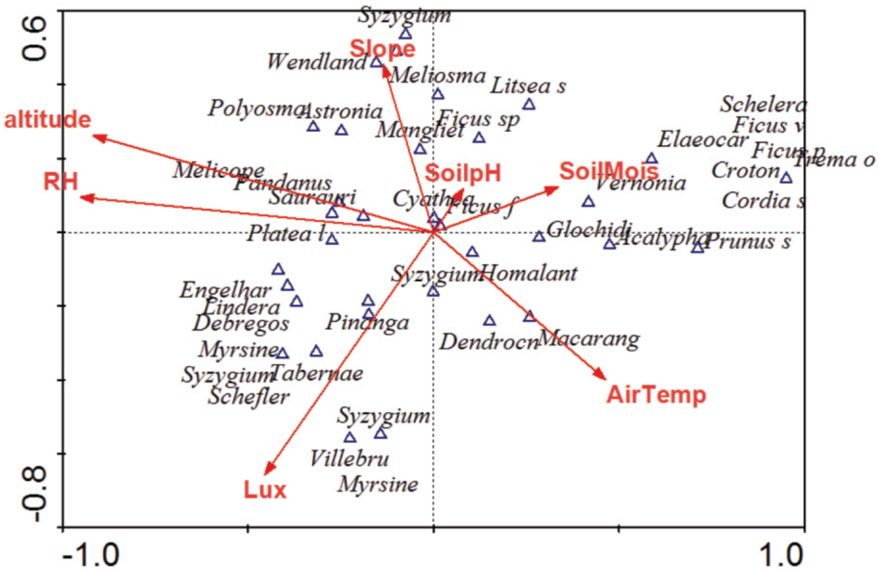

Figure 45. Ordination diagram derived from Canonical Correspondence Analysis showing distribution of *P. arinasae* species along the environmental gradients in Mt. Pengelengan, Bali.

Table 8. Eigenvalues of the Canonical Correspondence Analysis diagram for *P. arinasae* in Mt. Pengelengan, Bali.

Axes	1	2	3	4	Total inertia
Eigenvalues :	0.351	0.189	0.137	0.122	1.954
Species-environment correlations :	0.985	0.917	0.906	0.912	
Cumulative percentage variance					
of species data :	18.0	27.6	34.6	40.9	
of species-environment relation :	34.3	52.7	66.0	78.0	
Sum of all eigenvalues :					1.954
Sum of all canonical eigenvalues :					1.025

that regulates the abundance and distribution *P. arinasae*.

D. Modelling Habitat Suitability of Bali Podocarpus (*Dacrycarpus imbricatus* (Blume) de Laubenf

Fir Pandak or Bali Podocarpus (Figure 46) is one of the species that have significant value in the Batukahu Nature Reserve in Mt Pohen because they form uniform stands community at an altitude above 1400 m asl. This phenomenon is rare and almost not found anywhere else (LIPI 1992; Beatles

Figure 46. Surviving Pandak Fir tree in the 1994 burnt areas of Mt. Pohen Batukahu Nature Reserve, Bedugul. Photo credit: Sutomo

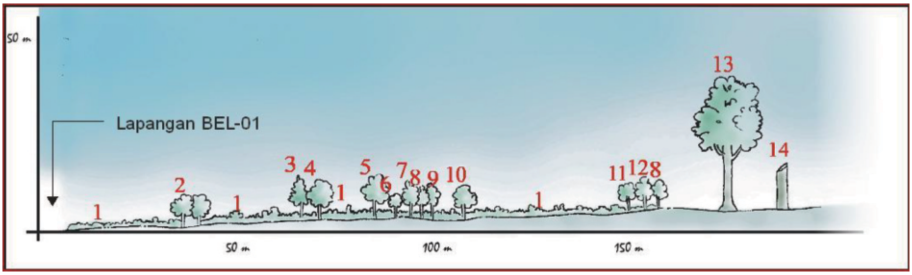

Figure 47. Forest profile diagram in the study site in Mt. Pohen (Legend: (1) Groundcover; (2,5,6,7,8,9,10,11) the surviving Fir Pandak trees from forest fire; (3) *Homalanthus gigantheus*; (4) *Vernonea arborea*); (13) mature parent tree of Fir Pandak; (14) dead trunk of Fir Pandak tree.

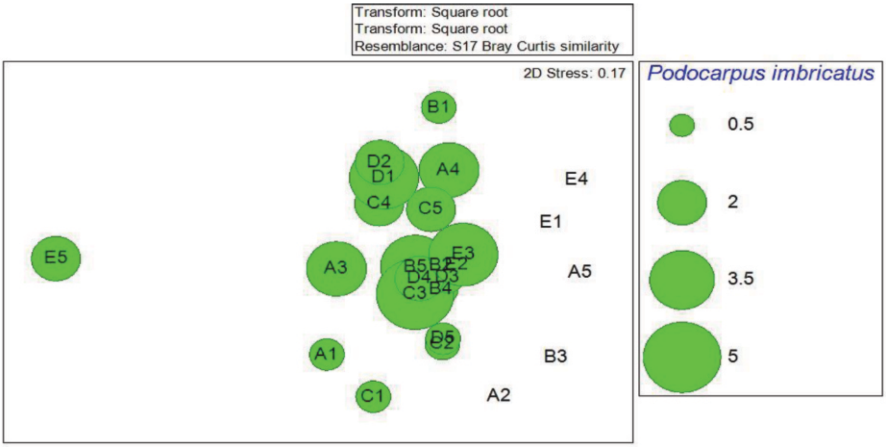

Figure 48. Results from Permanent Sample Plot (PSP) in Mt. Pohen: Abundance distribution of *Dacrycarpus imbricatus* (formerly known as Podocarpus imbricatus) in a 2d ordination space using Non-Metric Multidimensional Scalling analysis. Larger green circle indicates a higher abundance of the species in the plots.

et al., 2005).

Sutomo (2011) conducted a preliminary survey of surviving Pandak trees on the area affected by the 1994 forest fire in Mt. Pohen. Line transects was established to sample the vegetation and soils of the area. Forest profile diagram (Figure 47) shows that a secondary successional is taking place, with dominant species such as *Rubus* sp., *Lantana* sp., *Eupatorium odoratum* and *Melastoma malabathricum*. Three mature plant of *D. imbricatus* were found near to a remnant stem of a burnt *D.imbricatus*. Regeneration of *D. imbricatus* is considered to be slowed by the occurrence invasive dominant pioneer species. Conservation efforts both *insitu* and *exsitu* need to be initiated.

One of the main tasks of the Eka Karya Bali Botanical Garden is to carry out inventory, exploration, collection, maintenance, reintroduction, development, data collection, documentation, scientific service, conservation and introduction of dry highland plants which has value to be collected in the form of botanical gardens. The conservation of pandak firs in Bali's Botanical Garden started since the establishment of the reintroduction section in the nursery in 2000. The collection of material for propagation of pine cypress seed is mostly obtained from the exploration in Bukit Tapak which is adjacent to Bukit Pohen. At the end of 2006, pandak fir propagation activity became successful with 75% success rate. At the beginning of 2007, reintroduction and replanting and reforestation activities in the area around the Tri-danau area of Bedugul in Lake Beratan-Buyan-Tamblingan region.

Global climate change models (GCMs) predicted that by the end of the 21st century, in comparison to averages prior to the 1980s, global warming will lead to: a 3-4 °C increase in mean temperature, a 30-40% decrease in rainfall, significant changes in seasonality as well as severe weather events (IPCC 2007). At the regional scale, most species and ecological communities exist within a definable bioclimatic niche, where habitat values are largely controlled by a set of variable climatic parameters including precipitation and temperature (Molloy *et al.* 2013). When there are changes in these variables, the habitat value for that area will also change. The task of understanding how species and communities respond to changes is crucial.

Species distribution models or SDMs have the capability to assess current distribution and simulate climate-induced range shifts under different global change scenarios at the single species and community levels (Crego *et al.* 2014). SDM has enabled conservationists to predict future landscapes and has been applied in many areas of research such as for invasive species management (Webber *et al.* 2011), conservation and reintroduction of endangered species (Adhikari *et al.* 2012; Molloy *et al.* 2016), adaptive management of protected areas (Mairota *et al.* 2014), restoring landscapes connectivity (Gurrutxaga and Saura 2014)and many others.

Sutomo and Van Etten (2017) conducted species distribution modelling/habitat suitability (SDM/HSI) for invasive alien plant species, *Acacia nilotica*, in Indonesia. Thus, it is interesting to do similar analysis for the Pandak Fir (*Dacrycarpus imbricatus*) in the era of climate change in Indonesia using the Biodiversity and Climate Change Virtual Laboratory, BCCVL (http://www.bccvl.org.au/) (Hallgren *et al.* 2016). BCCVL is a unique cloud-based virtual laboratory which provides access to numerous species distribution modelling tools; a large and growing collection of biological, climate, and other environmental datasets; and a variety of experiment types to conduct research into the impact of climate change on biodiversity (Hallgren *et al.* 2016).

Global Biodiversity Information Facility, GBIF (http://www.gbif.org/) was utilized to obtain the species occurrence data for *Dacrycarpus imbricatus* (Blume) de Laubenf (GBIF 2016). The database has about 45 georeferenced occurrences of the species. This dataset was then imported to BCCVL. In this simulation, CRUclim (global), current climates (1976-2005), 30 arcmin (~50 km) were used. A statistical regression model called Generalized Linear Model (GLM) was also used to process the SDM because it accommodates regression model for data with a non-normal distribution, fitted with maximum likelihood estimation. This model produces estimates of the effect of different environmental variables on the distribution of a species. The model uses all the data available to estimate the parameters of the environmental variables, and construct a function that best describes the effect of these predictors on species occurrence. The suitability of a particular model is often defined by specific model assumptions. The prediction is visualised as the suitability of a grid cell on a scale from 0 to 1, where 0 refers to very low suitability and 1 refers to very high suitability. Further analysis was conducted to investigate the distribution of *D. imbricatus* under potential future climatic conditions. In BCCVL, this is named as the Climate Change Experiment, which obtains prediction of where *D. imbricatus*could occur in the future under a particular climate change scenario. This analysis uses the results from the SDM experiment, and projects that distribution for a certain year in the future with the climate information from one of several climate models. In this study, RCP3PD greenhouse gas emissions scenarios were selected to influence the climate model (this scenario assumes positive and effective action to reduce greenhouse case emission over the next few decades).The model was projected to year 2050.

The primary output of an SDM is a map that shows the predicted distribution of *D. Imbricatus*under the baseline conditions. It is important to note that this is not really a prediction of where the species occurs, but rather the distribution of suitable habitat as defined by the environmental variables (in this case current climate condition) included in the model. Figure 49 shows the result of the analysis showing a map of possible occurrence of *D. imbricatus* in 2050. It shows that several locations in Indonesia has high habitat suitability index/HSI (indicated by green colour). Several sites shown in the map have high HSI such as in Sumatera particularly in Aceh, Medan and Palembang, sites in Java specifically in West Java, Semarang and Situbondo, then in Bali (Bedugul), Lombok and Flores Islands, as well as several locations in Sulawesi and West Papua.

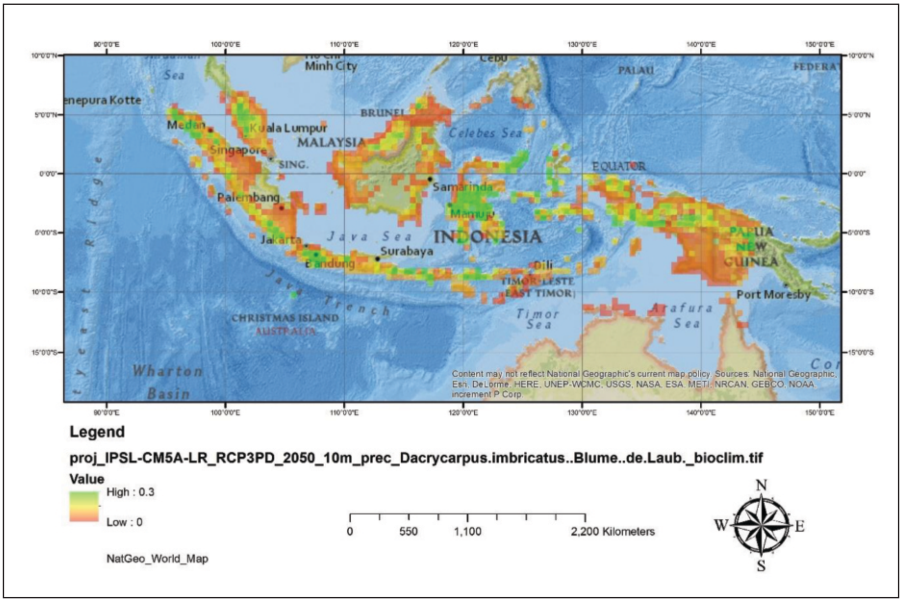

Figure 49. Map showing prediction of *Dacrycarpus imbricatus* distribution in 2050 in various regions of Indonesia.

The second SDM output is the response curve which are plots that show the relationship between the probability of occurrence for a species and each of the environmental variables.Most of the climate variables are responsive to D. Imbricatusdistribution (Figure 50). The response curves in this plot show that the probability of occurrence of the species follows an optimum curve for the specific variable. D.imbricatus occur in areas where the annual temperature ranges between 20-25°C; can grow where minimum temperature of the coldest month is around 5 or 10 to 15 or 20°C and in high rainfall places (200 – 500 mm/month).

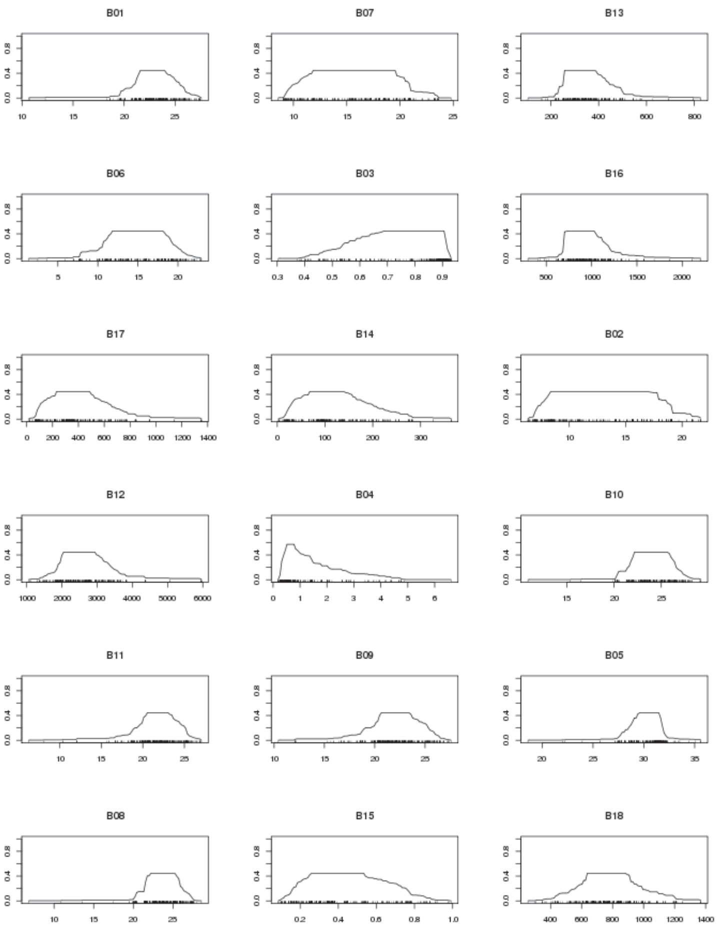

Figure 50. Response curve of *D. imbricatus* distribution to environmental variables. Notes for B01 to B19 are as follow: B01 - Annual Mean Temperature; B02 - Mean Diurnal Range (Mean of monthly (max temp - min temp); B03 - Isothermality (BIO2/BIO7); B04 - Temperature Seasonality (standard deviation); B05 - Max Temperature of Warmest Month; B06 - Min Temperature of Coldest Month; B07 - Temperature Annual Range (BIO5-BIO6); B08 - Mean Temperature of Wettest Quarter; B09 - Mean Temperature of Driest Quarter; B10 - Mean Temperature of Warmest Quarter; B11 - Mean Temperature of Coldest Quarter; B12 - Annual Precipitation; B13 - Precipitation of Wettest Month; B14 - Precipitation of Driest Month; B15 - Precipitation Seasonality (Coefficient of Variation); B16 - Precipitation of Wettest Quarter; B17 - Precipitation of Driest Quarter; B18 - Precipitation of Warmest Quarter; B19 - Precipitation of Coldest Quarter

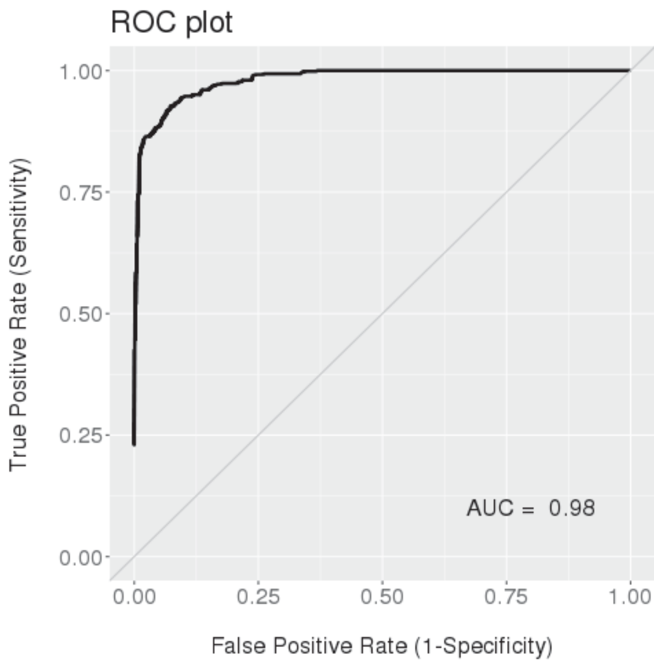

Figure 51. ROC plot which shows AUC value for *D. imbricatus* model using bioclim in BCCVL.

Model robustness was evaluated using the Area Under the Curve (AUC) of the Receiver-Operating Characteristics (ROC) curve, which is a nonparametric threshold-independent measure of accuracy commonly used to evaluate species distribution model (Bertelsmeier and Courchamp 2014). The ROC plot is a graph with the False Positive Rate (1-Specificity) on the x-axis and the True Positive Rate (Sensitivity) on the y-axis plotted across the range of threshold probability values. The closer the ROC curve follows the y-axis, the larger the area under the curve, and thus the more accurate the model. The value for ROC is the AUC, and is calculated by summing the area under the ROC curve. A value of 0.5 represents a random prediction, and thus values above 0.5 indicate predictions better than random. AUC scores were interpreted as follows: a value above 0.9 is excellent, good value is interpreted when 0.9 > AUC > 0.8, fair value is intpreted when 0.8 > AUC > 0.7, poor value is intpreted when 0.7 > AUC > 0.6 and fail value is intpreted when 0.6 > AUC > 0.5 (Crego *et al*. 2014; Sweets 1988). In general, the resulting model performance was good because the AUC values (0.82) were still in the range of 0.8 – 0.9 (Figure51).

IV. Traditional Knowledge and Culture on Plants Usage in Bedugul

Sutomo, I Dewa Putu Darma & Wawan Sujarwo
Bali Botanical Garden-Indonesian Institute of Sciences (LIPI), Candikuning Baturiti Tabanan 82191

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Sutomo. (2007) Usada Bali dalam Perspektif Konservasi Kebun Raya “Eka Karya” Bali. In: Warta Kebun Raya pp. 15-8.
Sutomo, Kurniawan A., Pendit I. M. R., Ardaka I. M. & Sudiatna I. N. (2009) Koleksi Tumbuhan Obat Usada Bali di Kebun Raya "Eka Karya" Bali. UPT Balai Konservasi Tumbuhan Kebun Raya "Eka Karya" Bali, Bali.

A. Potential usage of plants in Bedugul as traditional medicine

Up to now, many Balinese people still believe in the greater efficacy of ubad Bali (alternative medicine) than medical drugs given by doctors. Many families in Bali still entrust their physical health, let alone spiritual, in the hands of the balian (shaman). Bali's cultural wealth of indigenous medicinal knowledge is contained in Lontar Usada Bali. Usada means plants used as medicines by Balinese people, while Lontar Usada is a manuscript containing medicinal systems, medicinal materials and traditional ways of treatment in Bali. In Lontar, there are various types of usada divided according to the purpose of treatment. Each type of usada has a unique way of how to diagnose the disease, the type of plant to be used, how to dispense it and various means of support, and a series of ceremonies related to the prevention, treatment and recovery of a disease (Sutomo *et al.* 2009).

As a Balinese traditional medical treatment, the term Usada comes from a Sanskrit word '*Ausadhi*' meaning plants that are used for medicinal purposes. This usada knowledge originated from India and spread to Bali during the 5th century. Usada was written in a so called *'lontar'* made from leaves of *Borassus flabellifer* (Sutomo *et al*. 2007). Most of the lontar still remained unrevealed and they are buried by the elders and their offsprings in secret places. Only a few lontar has been revealed and now they are kept in a Lontar Museum called “Gedong Kirtya” in Singaraja, Buleleng.Tengah (1995) assumed that there are approximately more than 491 species of medicinal plants in ± 50,000 lontar usada Bali. These Balinese medicinal plants make a valuable contribution to the world's medicinal plant biodiversity. The extinction of many of these Balinese medicinal plants has become a concern of 'Eka Karya' Bali Botanic Garden (Sutomo 2007; Sutomo *et al.* 2007).

It is estimated there are ± 50,000 pieces of lontar usada in the form of Balinese and Ancient Javanese, Kawi language as well as Sanskrit. The lontar are scattered in the villages and museums in Bali. There are various types of usada known in the traditional Balinese medicine system. Generally, the name of each of these usada indicates that the usada was used in certain medications. For example, old usada which contains the procedure of treatment for the elderly. *Usada Rare* contains information about the treatments for children (*rare* = children), *Usada Buduh* about treatments for crazy people (*buduh* = mad), *Usada Upas* about the treatments for exposure to poisons or animal bites (*upas* = poison / toxic) and so forth.

Usada Bali traditional medicine is done by a person called a Balian. There are several kinds of Balian or shaman, namely: (1) Balian *Ketakson* - a Balian who gets his expertise through taksu (revelation) or magical powers that enter into him and affect his way of thinking, speaking and his behavior; (2) *Balian Usada* - a Balian who consciously learns medicine, either through other balian or self-study through lontar usada - this Balian has knowledge about medicinal plants, and they understand how plants work in the treatment.

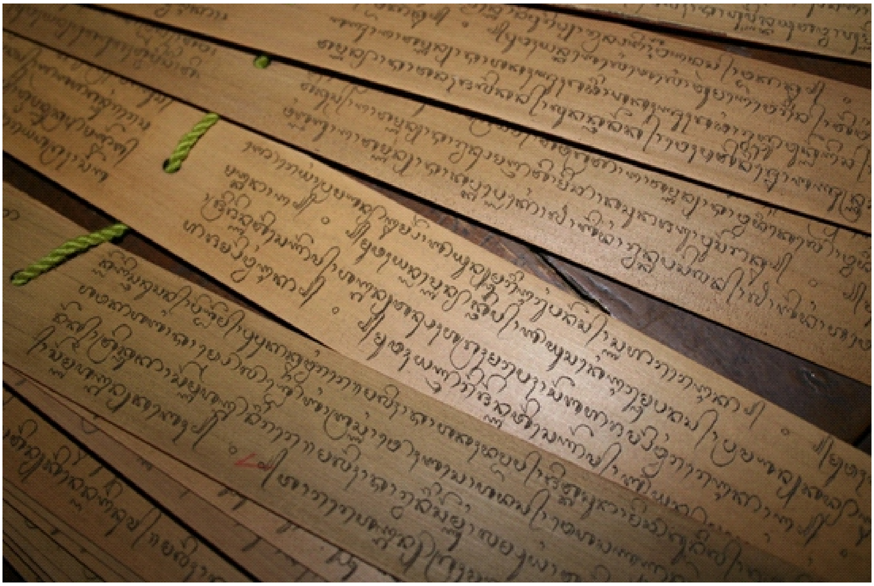

Figure 52. Balinese Lontar Usada written in dried lontar leaves. A collection of Lontar Gedong Kirtya Museum in Singaraja, Bali.Photo credit: Gede Wawan Setiadi.

Figure 53. Lontar Usada kept in Lontar 'Gedong Kirtya' Museum in Buleleng, Singaraja Bali. Photo credit: Gede Wawan Setiadi.

Figure 54. A Balian (traditional healer) showing his collection of lontar manuscripts including "Lontar Usada".Photo credit: Sutomo

Several traditional villages in Bali have experienced cultural erosion, one of which is marked by declining ethnobotany knowledge (Sujarwo *et al.*, 2014). One important factor causing cultural erosion is the influence of foreign cultures from developed countries in ecotourism areas (Sujarwo *et al*., 2014). Lake Buyan-Tamblingan is a natural tourist park frequented by both domestic and foreign tourists. In 2017, Gebby Oktavia, I Dewa Darma and Wawan Sujarwo conducted an ethnobotanical study around Lake-Buyan Tamblingan area in Bedugul (Sujarwo *et al.* 2017). Their study was aimed to determine the diversity of plants that are used as a remedy by people around Lake Buyan-Tamblingan, and to obtain information regarding the types of plants that are considered most important by these community groups. Their study was conducted for five days on 9 – 14 March 2015. Ethnobotanical data were collected through semi-structured interviews and group discussions. The respondents purposively selected were those considered to have the best knowledge of ethnobotany. A total of five respondents were interviewed. This study documented 69 species of medicinal plants belonging to 59 genera and 36 families, with the Zingiberaceae being the most widely used. The floristic region of all plant species documented included Malesiana (21.95%), India (18.90%), Indochina (16.46), and East Asia (9.15). Leaves were the part of plants most often used. Plant species that had the highest use value (UV = 1) were *Acorus calamus* L., *Cocos nucifera* L., *Curcuma longa* L. and *Zingiber officinale* Roscoe. About 37 different ailments were mentioned as being treated by these plants by communities around Buyan-Tamblingan Lake, including rheumatic, heartburn and headaches.

In another location, Sutomo *et al.* (2007) also conducted an inventory of Usada Bali medicinal plants in Buleleng which also included several sites around Lake Buyan and Tamblingan as well as a village near Gitgit waterfall. Observations and interviews were conducted using ethno-botanical tools, i.e. digital camera and audio recorder. Basic data about medicinal plants were collected through direct interviews with elders people, village leaders, religion leaders, traditional healers (*balian*) and government officers. In these interviews, the local names and uses of the plants were recorded. Some of the medicinal plants were collected for ex-situ conservation in Bali Botanical Garden. The searching of these medicinal plants was assisted by the traditional healer known as the *'Balian usada'*. Herbarium specimens were collected when there was any doubt about the scientific names of the species.

Their results revealed that there are 50 species, 30 families and 43 genus of medicinal plants found in six Villages of Buleleng. Zingiberaceae is the largest family used as medicinal plants. This family consists of 3 species in Gitgit, 2 species in Galungan and 2 species in Sekumpul. *Zingiber officinale* Rosc. is a common species in this family. In Galungan village, *Z. officinale* is

Table 9. Several species of Usada Bali which are included in the list of protected plants.

No	Vernacular names	Species name
1.	Aren	*Arenga pinnata* Merr.
2.	Asem	*Tamarindus indica* L.
3.	Bila	*Aegle marmelos* Correa
4.	Blimbing besi	*Averrhoa carambola* L.
5.	Bungli	*Oroxylum indicum* Vent.
6.	Buni	*Antidesma bunius* L
7.	Burahol	*Stelechorpus burahol* Bl.
8.	Cendana	*Santalum album* Linn.
9.	Cereme	*Phyllanthus acidus* L.
10.	Duku	*Lansium domesticum* Corr.
11.	Jeruk besar putih	*Citrus grandis* Osbeck.f
12.	Juwuk lengis	*Citrus aurantifolia* (Chris. & Panz.) Swi.
13.	Kaliasem	*Syzygium polycephallum* (Miq.) Merr.& Perry.
14.	Kembang patma	*Rafflesia padma* Bl.
15.	Kemuning	*Murraya panicullata* (L.) Jack.
16.	Kepundung	*Baccaurea racemosa* Muell. Arg.
17.	Kunci pepet	*Kaempferia angustifolia* Rosc.
18.	Lemo	*Citrus medica* L.
19.	Majegau	*Dysoxylum caulostachyum* Miq.
20.	Manggis	*Garcinia mangostana* L.
21.	Mesui	*Massoia aromatica* Becc.
22.	Mimba	*Azadirachta indica* A.Juss.
23.	Nagasari	*Mesua ferrea* L.
24.	Nangka cempedak	*Artocarpus heterophyllus* Lmk.
25.	Pakel	*Mangifera odorata* Griff.
26.	Pakis haji	*Cycas rumphii* Miq.
27.	Pinang	*Areca cathecu* L.
28.	Poh amplem	*Mangifera indica* L.
29.	Pulasari	*Alyxia stellata* Auct. Non R.& S.
30.	Pule	*Alstonia scholaris* R. Br.
31.	Rukem	*Flacourtia rukam* Zoll. & Morr.
32.	Rukem minced	*Flacourtia indica* Merr.
33.	Sentul	*Sandoricum koetjape* Merr.
34.	Sintok	*Cinnamomum sintok* Bl.
35.	Sumaga	*Citrus aurantium* L.
36.	Tingkih	*Aleurites moluccana* Willd

*Sources : Mogea *et al.*(2001);Sarna *et al.*(1993)

used to expel evil spirit (magical uses) whereas in Sekumpul villages it is used to treat cough and as an aphrodisiac. Most of Zingiberaceae are commonly used together with some other medicinal plants for better result. The second largest family is Euphorbiaceae. The highest numbers of medicinal plants are found in Gitgit Village consisting of 12 families and 13 species.

These medicinal plants were found in various locations such as in the edge or border between forest and village, people backyard, garden, and also near the river (i.e. *Acorus calamus* Linn.). Determination and plant identification has to be done carefully due to the various local names for one species or in Bali they called it to has a *'Dasa nama'* (ten names) for each species.

Some of these medicinal plants are considered as protected plants by government decree and IUCN. For example, just to name a few is Pule (*Alstonia scholaris* (L.) R.Br.) is not only a plant species that is protected and considered as vulnerable but also it is a sacred plant for Balinese. Pule's bark is used to treat fever. Pule usually grows wild in some sacred place or 'keramat' like the cemetery or the temple. There is also Buwah or *Areca cathecu* L. which is also protected by government decree. The fruits of this plant are consumed to increase men's stamina (aphrodisiac effect). Each species of medicinal plants has specific part for remedies treatment. It could be only a little part and a mixture with parts of other plants or some parts of the same plant used together in the same treatment. Leaf is the main part of plant used in traditional remedies in all villages. The next most commonly used are fruit, whole plants, roots, rhizomes and bark. The treatment of these medicinal plants can be divided into three categories; internal disease, external disease and magical disease. (Figure 55).

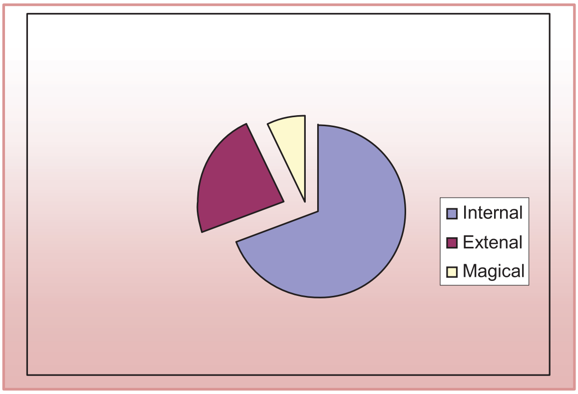

Figure 55. Percentage of type of usage for the Usada Bali medicinal plants found in the study.

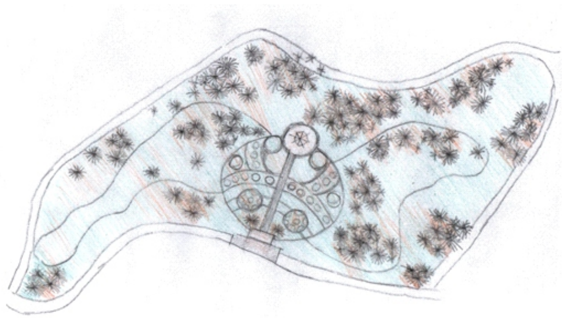

Figure 56. Design of "Taman Usada". A thematic plant collection in Bali Botanical Garden to conserve traditional medicinal plant as part of Balinese indigenous knowledge "Usada Bali". Design and sketch by I Dewa Putu Darma.

Collection of medicinal plants in the Bali Botanical Garden is arranged in a theme park named Taman Usada. This garden design usada brings the concept of a circle that reflects the circle of life. Usada Park occupies an area of 1.6 ha. It has supporting elements such as *angkul-angkul*, footpaths that are also be used for foot massage, benches and tables, and wooden bridges were used to create a landscape of artistic and beautiful garden (Sutomo *et al.* 2009). Up to date as per February 2018, Bali Botanical Garden has been collecting 213 species of Usada Bali which consist of 62 families, and 139 genera.

Figure 57. Angkul-angkul as the gate to enter the "Taman Usada", thematic park to conserve Usada Bali medicinal plants in Bali Botanical Garden. Photo credit: Sutomo

B. Plants and traditional Balinese ceremonies

In Usada Bali, often in the process of medication or healing, one or two ceremonies are needed. In this part of the chapter, we will discuss the usage of plants in Balinese ceremonies. The world's environmental movement has also received strong support from philosophers and clerics. They want the application of a new ecological philosophy that uses an ecological, philosophical and spiritual approach.The majority of people in Bali are Hindu, the basic concept of Hinduism is to humanize nature and environment. The implementation is done through ceremonial activities.The ceremony is part of the three basic frameworks of Hinduism aimed at achieving perfection, happiness and prosperity (based on the concept of *tri hita karana*). In the implementation of the ceremony using plants as an offering. It is estimated that approximately 462 species of plants used in Hindu religious ceremonies in Bali, as many as 65 species (14.1%) are included in rare or protected categories. Ceremony contains meaning or message to people about submission and purity to the God Almighty. Utilization of plant species in the ceremony indicate a mandate or message of responsibility for its preservation (and conservation), so that the implementation of the ceremony continue to be sustainable.The ceremony in its daily life is as follows: A) the relationship between man and God is manifested by *Dewa Yadnya*; B) the relationship between man and his fellow manifested with *PitraYadnya*, *Resi Yadnya*and *Manusia Yadnya*; C) Human relationship with the natural environment manifested by *BuhtaYadnya.*

Hindu religious ceremony in Bali cannot be separated from plants, which is used as a means of upakara (banten). Bedugul forest area is an upstream area that has many temples and three lakes: Beratan, Buyan and Tamblingan. Ceremonies related to conservation are the ceremonies of *Mekelem* and *Danu Kertih*. Bhagavad Gita, chapter IX No: 26 mentions: “patram puspam phalam toyamyo me bhaktya prayacehatitad aham bhaktyu pahrtamasnami prayatatmanah”. To the meaning “Whoever with the embodiment offered to me a leaf, flowers, fruits, or water which is based on love and out of a pure heart, I accept”. Plants in Hindu religious ceremonies in Bali have significance as a symbol of God. For example: In the formation of betel leaf juice, it symbolizes Lord Vishnu, lime symbolizes Lord Shiva and betel fruit symbolizes Dewa Brahma. The use of plants in*upakara* is grouped into two namely: 1) *rerampen* (*jejahitan ron busung*) that is *upakara* derived from coconut leaves and *enau* sewn; and 2) *etheh-eteh banten* is a means of *upakara* derived from plants for filler in *banten* (praying offering set), making tirta and praying (pemuspan). The use of plants such as pandan arum and other fragrants plants species are intended to act as stimulants to focus the mind toward holiness.

Figure 58. Example of a Balinese Hindu religious ceremony. Offerings brought to Temples. Photo credit: I Dewa Putu Darma

There are many reasons for the protection of nature such as : 1) reasons for protection due to human interest; 2) reasons for the protection of nature through the examination of nature as itself; and 3)reasons for the ecological effort from the religious point of view. This means that the conservation principle must refer to the management of biological resources in such a way that it can meet the needs of human life today and the future optimally. In conservation efforts, communities should be made aware of the importance of conserving local plant heritage, working actively in its preservation, and being made to feel the benefits of conservation over time. From the above description of the utilization of plants in Hindu religious ceremonies in Bali contains a message to be responsible for its preservation which is a form of submission to God.

Botanical Gardens as plant conservation institutions have a very strategic role in the efforts to save and protect the diversity of Indonesian plant species. Some of the Bali Botanical Gardens have a close relationship with the culture of the Balinese Hindu community. The collection is planted in a park named as "Taman Panca Yadnya" (Figure 59). Taman Panca Yadnya is one of the thematic plant collection in Bali Botanical Garden with its concept of conservation and culture in harmony. Up to date, the garden has collected as many as 213 species which belongs to 62 families and 139 genus.

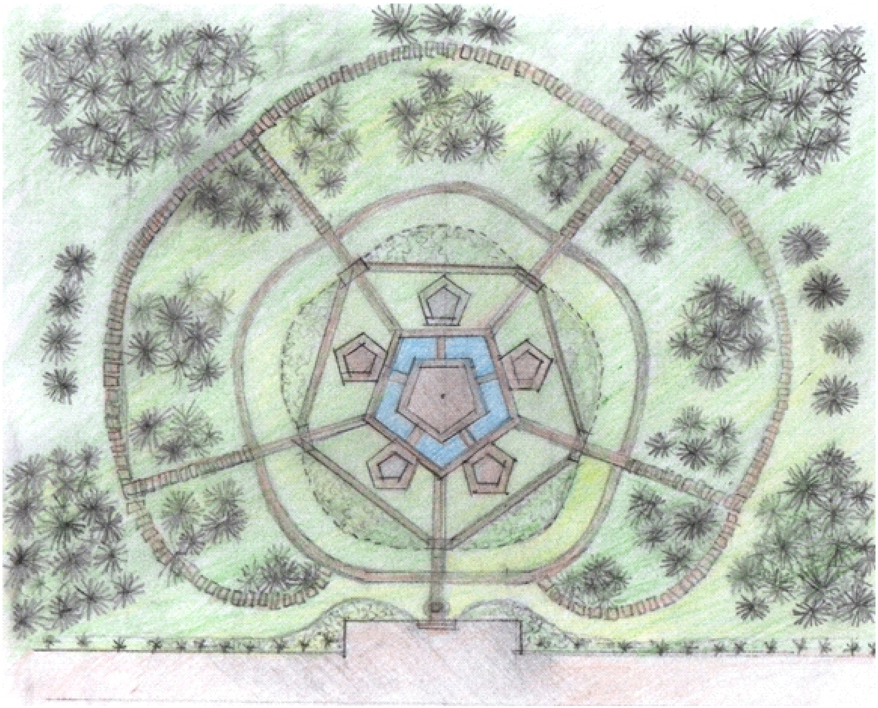

Figure 59. Design of "Taman Panca Yadnya" a thematic plant collection in Bali Botanical Garden which conserves plant species that are utilized in Balinese Hindu culture and ceremonies. Sketch by: I Dewa Putu Darma.

V. Carbon stocks and aspects of Plant Conservation

Sutomo, Arief Priyadi&I Dewa Putu Darma
Bali Botanical Garden-Indonesian Institute of Sciences (LIPI), Candikuning Baturiti Tabanan 82191

Part of this chapter has been published as follow:
Priyadi A., Sutomo S., Darma I. & Arinasa I. B. K. (2014) Selecting Tree Species with High Carbon Stock Potency from Tropical Upland Forest of Bedugul-Bali, Indonesia. Journal of Tropical Life Science4, 201-5.

A. Carbon stock of plants in Bedugul highland

Large areas of lowland forest in Sumatera, Borneo and Java has been cleared for mainly anthropogenic reasons (Lavigne and Gunnell 2006). Consequently highland or upland forests are the last resort for biodiversity and ecosystem services (Fardilla and Sutomo 2013).Upland forests are important component of ecosystems since they serve as protector of watershed systems and since there have been continuous destruction of lowland forests, they are also maintaining species diversity (Goltenboth *et al.* 2006). Additionally, in the context of climate change, forests can act as carbon sink.

There have been a variety of studies related to carbon stock of various types of forest ecosystems in Indonesia, especially for upland forest. The most prominent one is studies which have been carried out in Cibodas biosphere reserve or also known as Mt. Gede-Pangrango National Park (Astutik 2011). Similar research hence also neede for Bedugul area in Bali which is also suitable to be proposed as the next biosphere reserve. Therefore in 2013, a group or researchers from Bali Botanical Garden conducted ecological survey in three upland forest areas of Bedugul, namely Mt. Mangu (east of Beratan Lake), forest area west of Buyan Lake, and forest area south of Tamblingan lake. Plots of 20 m x 20 m were laid across transects with distance between plots 50 m – 100 m. There were 17 plots on Mt. Mangu (1,305 – 1,506 m asl) and 10 plots each in Buyan (1,219 – 1,298 m asl) and Tamblingan (1,226 –1,243 m asl). On each plot, all trees with diameter at breast height (dbh) of at least 10 cm were recorded. Coordinate points of each plot and the altitude were determined with a Garmin 76CSXi GPS. Data of dbh for each treespecies then converted to above ground biomass by allometric equations namely: Brown (Br), Ketterings (Kt), Chave (Cv) and Basuki (Bs). Data of wood density (g.cm-3) to predict carbon stock using Kt and Cv equations were obtained from wood density database (Rahayu 2009). The data from those 3 locations and 4 different methods then subjected to Analysis of Variance (ANOVA) and Duncan's test (α=0.05) in order to achieve comparisons.

Their results was published as a paper in the Journal of Tropical Life Sciences (Priyadi *et al.* 2014). Despite being the richest site in term of species, the carbon stock at Mt. Mangu is the lowest compared to Buyan and Tamblingan. Since there was no significant difference in tree density, higher average tree dbh is the primary reason which explains the higher of carbon stock in Buyan and Tamblingan.

Table 10. Duncan's test of carbon stock and its components.

Site	Average of tree dbh (cm)	tree density (individuals.ha^{-1})	% tree density from [8]	carbon stock (tonnes.ha^{-1})	% C stock average from [8]
Mt. Mangu	30.74 b	550 a	180.3	214.2 b	60.4
Buyan	38.97 ab	446 a	146.2	693.0 a	195.4
Tamblingan	41.75 a	443 a	145.2	749.1 a	211.1

Remark: On the same column, values with same letter are not significantly different (duncan's test α=0.05)

If these results are compared to published data, for example Astutik (2011) in Mt. Gede-Pangrango West Java reported that tree density of 305 individuals ha^{-1} and average C stock was 354.65 t.ha^{-1}, it will be found thatC stock in Mt. Mangu was lower. Nevertheless, C stockin Buyan and Tamblingan is roughly twice as high. Additionally, carbon content of 152.3 t.ha^{-1}with number of individuals 337 trees.ha^{-1} was reportedby Hidayati *et al*. (2012) from highland forest of Mt. Halimun-SalakWest Java. From these two comparisons, it can be shown that carbon stock of upland forest in Bedugul areas is relatively high, especially in Buyan and Tamblingan.

For species assemblage varied across sites, information about individual species characteristics related to its carbon content is shown in Table 11. For convenience, the list in that table was sorted by carbon average for each tree.

List of species with highest SDR in Table 11 were very dissimilar from those reported by Astutik (2011) and Hidayati *et al.* (2012). There was only one species which was also mentioned by Astutik (2011),i.e. *Platea latifolia,* and also onespecies by Hidayati *et al.* (2012) i.e. *Vernonia arborea*. The values of carbon content per tree range from 40.35 kg.tree^{-1} for *Tabernaemontana macrocarpa* to 12.8 t.tree^{-1} for *Planchonella* sp. Although the first has much lower carbon content than the second species, its SDR value is higher.

This data indicated that individual carbon stock capacity can not be solely functioned as an indicator to select tree species with high potency to stock carbon. It can be inferred from the frequency component in SDR calculation (not shown), species with low carbon stock individually such as *Tabernaemontana macrocarpa* occurred very frequently in almost every plot. On the other hand, huge trees like *Planchonella* sp., *Ficus drupacea* and some

Table 11. Summed Dominance Ratio (SDR), diameter at breast height (dbh) and average of carbon stock (kg.tree -1) in Mt. Mangu, Buyan & Tamblingan.

No	Species	Family	SDR (%)			dbh (cm)	Wood Density ($g.cm^{-3}$)	Average of Carbon ($kg.tree^{-1}$)
			Mt. Mangu	Buyan	Tamblingan			
1	*Planchonella sp.*	Sapotaceae	-	16.01	-	15->150	0.56	12,876.26
2	*Ficus* drupacea	Moraceae	5.65	-	11.52	30 - >150	0.44	11,524.47
3	*Dendrocnide peltata*	Urticaceae	-	12.37	15.75	10 - >150	0.20	2,232.57
4	*Vernonia arborea*	Asteraceae	4.41	-	-	20 - >150	0.38	790.48
5	*Macaranga tanarius*	Euphorbiaceae	4.02	-	-	25-65	0.50	635.79
6	*Platea latifolia*	Icacinaceae	24.57	-	-	15 - 85	0.43	493.25
7	*Dendrocnide stimulans*	Urticaceae	5.37	-	-	10 - >150	0.38	393.4
8	*Polyosma integrifolia*	Escalloniaceae	-	8.17	-	15 - 50	0.61	393.33
9	*Homalanthus giganteus*	Euphorbiaceae	7.56	-	-	15 - 45	0.36	108.09
10	*Tabernaemontana macrocarpa*	Apocynaceae	-	13.21	24.66	10 - 40	0.30	40.35
	Total		**51.58**	**49.77**	**51.93**			

others with dbh over 150 cm can only be found occasionally in a small portion of the plots. These information were in accordance with previous study, as (Yamada 1975) pointed out that for tropical forests of Southeast Asia, tree numbers for each species are typically small and there is usually no dominant species (Priyadi *et al.* 2014).

B. Plant conservation: key-species selection and propagation of rare plants

Bali Island, which lies west of Wallacea lines, is believed to have a specific type of flora. Bedugul, which is situated at the center of the island, comprises many different areas with different land uses. One of the most prominent is the natural forests with their status as the Batukahu Nature Reserve. This place is home for a variety of native plants. On the other hand, there have been some parts of the forest which are man-made, as a result of reforestation programs in the past. Mostly, these forests are homogenous in which *Altingiaexcelsa*as the main component. Additionally, *Bischofiajavanica*, *Micheliachampaca*, and *Manglietiaglauca* were also planted in the area.

In term of native species, present plant diversity is a result of evolutionary process, which takes place over the last few million years. Nowadays, a variety of threats are believed to threaten this diversity whether it is natural such as climate change, natural disasters or anthropogenic such as land conversion from forests to agricultural fields, settlements, roads, mining, etc. On the other hand, humankind relies on plants for a number of purposes: timber, foods, medicines, and so on. In order to sustain the availability of plants, people started to think and to practice plant conservation efforts, which basically can be grouped as *insitu* and *exsitu*. Because of the importance of plants to human necessities, people also understand the need for plant conservation. In term of the two methods of plant conservation, i.e. *in situ* and *ex situ,* the first is often preferred although the second is also important. It is a matter of fact that in Bedugul both practices are available.

The in-situ conservation actions within this area are under the authority of Balai Konservasi Sumber Daya Alam Bali (Bali Natural Resources Conservation Bureau). Bedugul with its natural montane forests is a sanctuary for remnant mountain flora. The unit of *in situ* conservation area in Bedugul is called Kesatuan Pengelolaan Hutan Konservasi – KPHK that consists of Batukahu Natural Reserve (Cagar Alam) I, II, and III as well as Natural Tourism Park (Taman Wisata Alam) Buyan – Tamblingan (www.ksda-bali.go.id). According to official site of BKSDA Bali, the history of *in situ* conservation of Batukahu forest groups dates back to the era of Dutch East Indies in 1927 in which 15,153 ha of the area stated as conservation sites with hydro-orological services. At present, total conservation area is reduced to a total of only 1,762.8 ha. Batukahu Natural Reserve I (Mt. Tapak) covers area of 810.40 ha, Batukahu Natural Reserve II (Mt. Pohen) covers area of 388.20 ha, and Batukahu Natural Reserve III (Mt. Lesong) covers area of 564.20 ha.

Bali Botanical Garden under the authority of Indonesian Institute of Sciences serves as the main *ex situ* plant conservation site in the area. It covers area of 157.5 ha, lies at altitude of 1,250 – 1,450 with main role as ex situ conservation of mountain flora especially from mountainous region in eastern Indonesia (www.kebunrayabali.com). Numerous botanical explorations have been carried out to collect plant propagules from the wild to be collected in the garden. As a result, at present this garden collects more than 2,100 plant species. Apart from its main function in *exsitu* plant conservation, this institute also conducts plant research and educational services. Some research is carried out in the garden, whereas some others can only be conducted in the wild. Within the period of the last 10 years, staffs of Bali Botanic Garden have conducted multifaceted research in plant ecology within Batukahu Nature Reserve, Bedugul, Bali. One is aimed at the identification of indicator species in the area.

Among many available plant species in a given area, it is believed that their role in the plant community varies. This also applies to conservation efforts, in which a number of terminology arises, i.e. (1) ecological indicators, (2) keystones, (3) umbrellas, (4) flagships, and (5) vulnerables (Noss, 1990). The first category applies to some components that show disturbance. The second category responsible to the existence of bigger part of the community. The third is defined as species, which requires large area therefore able to protect another species. The fourth one symbolizes the most important component for conservation. The last one applies to species with high risk of extinction. Monitoring of plant species assemblage therefore is a pivotal step to identify a component into a category.

Because Bedugul is a home for a number of different plant species, setting of priorities is necessary to deal with plant conservation. Forest inventories of plant in Bedugul conducted by Bali Botanic Garden resulted in more than 40 species (Priyadi *et al*., 2014), or exactly 46 species (Table 12). Among those, trees are easy to spot and therefore need to be prioritized. A vegetation analysis conducted in 2014 by Bali Botanic garden in Tapak, Pengelengan and Lesung Hill by applying point centered quarter methods resulted a data set that can be summarized in Table 12. This result is based on indicator species analysis described by (Noss, 1990; De Caceres *et al*., 2010; Caceres, 2013). Briefly, a vegetation inventory was implemented using point-centered quarter method (PCQM) (Mitchell, 2010), in which geographical coordinates of each sample was recorded with a hand-held GPS. Altitudinal information was used as an input along with corresponding species matrix for indicspecies package (De Caceres, 2013). This result suggests that indicator species vary among altitudes as well as among sites.

Table 12. Indicator species by altitude in 3 different sites of Bedugul.

	Gn. Mangu	Gn. Tapak	Gn. Lesung
Upper(1.697–2.002 m)	*Platea latifolia* *Adinandra* sp. *Astronia spectabile* *Lindera*sp. *Polyosma integrifolia*	*Dacrycarpus imbricatus* *Adinandra* sp. *Astronia spectabile*	*Lophopetalum javanicum* *Syzygium racemosum* *Dacrycarpus imbricatus* *Casuarina junghuhniana*
Medium(1.396 – 1.624 m)	*Platea latifolia* *Acronychia trifoliata* *Pinanga arinasae*	*Dacrycarpus imbricatus*	*Lophopetalum javanicum* *Dysoxylum sp.* *Syzygium racemosum* *Dacrycarpus imbricatus*
Lower(1.116–1.332 m)	*Acronychia trifoliata* *Ficus* sp.	-	*Dysoxylum sp.* *Syzygium racemosum*

The same datasets were also further analyzed with two additional information from PCQM observations, i.e. basal area and distance from each central point. This data analysis was performed in an R script (Mitchell, 2010). The result in Table 2, shows components of classical vegetation analysis, i.e. density, coverage, frequency and important values. It is important to note that the first 12 species in this list composes almost 60% of the relative importance values.

Table 13. A vegetation analysis based on PCQM method, covers all 3 areas shown in indicator species analysis.

No	Species	Relative Density	Relative Coverage	Relative Frequency	Relative Importance
1	***Dacrycarpusimbricatus***	4.73	13.28	5.04	7.68
2	***Acronychiatrifoliata***	6.76	3.83	6.72	5.77
3	*Homalanthusgiganteus*	7.43	2.16	6.72	5.44
4	***Casuarina junghuhniana***	1.35	12.65	1.68	5.23
5	***Lophopetalumjavanicum***	4.73	6.28	4.2	5.07
6	***Syzygiumracemosum***	6.76	1.17	5.88	4.6
7	*Polyosmaintegrifolia*	5.41	1.78	5.88	4.36
8	*Engelhardtiaspicata*	2.7	6.09	3.36	4.05
9	*Syzygium sp.*	4.73	3.54	2.52	3.6
10	*Dendrocnidepeltata*	2.7	5.66	1.68	3.35
11	***Astroniaspectabilis***	4.05	2.44	3.36	3.28
12	***Dysoxylum sp.***	3.38	3.07	3.36	3.27
13	***Platea latifolia***	4.73	1.27	3.36	3.12
14	*Ficussp (bunut)*	0.68	6.13	0.84	2.55
15	*Tremaorientalis*	1.35	4.59	1.68	2.54
16	*Cyathealatebrosa*	2.7	1.17	3.36	2.41
17	*Ficusbenjamina*	1.35	4.17	1.68	2.4
18	***Lindera sp.***	2.7	0.81	3.36	2.29
19	***Ficus sp.***	1.35	3.38	1.68	2.14
20	***Adinandra sp.***	2.03	1.8	2.52	2.12
21	*Ehretiajavanica*	2.03	1.18	2.52	1.91
22	*Myrsine sp.*	2.03	0.37	2.52	1.64
23	*Erythrina sp.*	2.03	1.08	1.68	1.6
24	*Saurauia sp.*	1.35	1.58	1.68	1.54
25	*Albisia sp.*	1.35	1.81	0.84	1.33
26	*Macaranga sp.*	1.35	1.49	0.84	1.23
27	*Ficuspadana*	1.35	0.64	1.68	1.22
28	*Omalanthusgiganteus*	1.35	0.37	1.68	1.13
29	*Dendrocnidestimulans*	1.35	0.35	1.68	1.13
30	*Elaeocarpussphaericus*	0.68	1.83	0.84	1.12
31	***Pinangaarinasae***	1.35	0.16	1.68	1.06
32	*Syzygiumsp*	1.35	0.15	1.68	1.06
33	*Weinmannia sp.*	1.35	0.53	0.84	0.91

Table 13. Continued

No	Species	Relative Density	Relative Coverage	Relative Frequency	Relative Importance
34	*Glochidion sp1*	1.35	0.21	0.84	0.8
35	*Camelia sp.*	0.68	0.46	0.84	0.66
36	*Bischofiajavanica*	0.68	0.44	0.84	0.65
37	*Engelhardiaspicata*	0.68	0.37	0.84	0.63
38	*Ilex sp.*	0.68	0.33	0.84	0.62
39	*Ficusfistulosa*	0.68	0.3	0.84	0.61
40	*Polyosma sp.*	0.68	0.23	0.84	0.58
41	*Tabernaemontanamacrocarpa*	0.68	0.2	0.84	0.57
42	*Hypobatrum sp.*	0.68	0.18	0.84	0.57
43	*Glochidion sp.*	0.68	0.16	0.84	0.56
44	*Macarangatanarius*	0.68	0.15	0.84	0.56
45	*Syzygium sp6*	0.68	0.15	0.84	0.56
46	*Platea sp.*	0.68	0.03	0.84	0.52
	Total	100.05	100.02	99.96	100.04

Remark: bold type font indicates that these species listed on Table 1.

By completing those two analyses, we determined 12 tree species from Bedugul for priority for in-house research at Bali Botanical Garden, i.e. *D. imbricatus*, *A. trifoliata*, *C. junghuhniana*, *L. javanicum*, *S. racemosum*, *A. spectabilis*, *Dysoxylum* sp., *P. latifolia*, *Lindera* sp., *Ficus* sp., *Adinandra* sp., and *P. arinasae*. The first topic to be selected was their propagation, especially by seeds. Among those, seeds of 6 species i.e. *D. imbricatus*, *C. jughuhniana*, *S. racemosum*, *Dysoxylum* sp., *P. latifolia*, and *P. arinasae* have been collected and successfully germinated.

This is a main activity of Reintroduction Unit of Bali Botanic Garden, in which many tree species are propagated and later on distributed for a variety of purposes. In the case of native species from Begudul area, some are already familiar but some other is still enigmatic. For example, seedlings of *Dacrycarpusimbricatus* and *C. junghuhniana* are usually spotted in the field, pulled out, transported and replanted on raised soil beds. However, it is not easy to propagate these two species directly from seeds. The first species is a dioecious gymnosperm in which their pollination is facilitated by wind. As consequences, many factors affect the success of viable seed development on female trees. Different case exists for the second species because of its light and tiny seeds. For a natural process, as the pods mature large numbers of seeds are dispersed by wind. We observed that these seeds are able to germinate only if they come to contact with moist mossy surface. Otherwise, they will soon lose their viability. *Syzygiumracemosum*, *Dysoxylum* sp. and

P. latifolia produce recalcitrant seeds. Measurement of moisture content from fresh seeds of *S. racemosum* and *P. latifolia* resulted in 117% and 132%, respectively. Based on our experience, it is not difficult to germinate these seeds provided that they are germinated as soon as possible from collection date. Seeds of *P. arinasae* are also easy to germinate provided that they are already mature and shown as soon as possible.

At present we are still trying to get more information on how to propagate *A. trifoliata*, *L. javanicum*, *A. spectabilis*, *Lindera sp.*, *Ficus sp.*, and *Adinandra sp*. Propagation by seeds are still preferred due to its simplicity, speed, uniformity, and mass products. However, within periods of our observations, it is difficult to get seed of these species. A number of reasons may apply, e.g. the available mother plants may not be mature enough (for *A. trifoliata*, *L. javanicum*, *Adinandra* sp., *Lindera* sp., *A. spectabilis*), and a complex symbiosis within the genus *Ficus* with certain types of wasps is required to facilitate their pollination.

In summary, *in situ* and *ex situ* plant conservation are practiced in Bedugul. These could indicate the importance of Bedugul area as a leading conservation area. Among the large number of plant species available, efforts should be prioritized on particular species. We determined 12 indicator species in which a half of those numbers have been successfully propagated by seeds and the other half is still enigmatic.

C. The concept of sacred sites traditional culture and their link with plant conservation

Bedugul forest area with its three lakes (Beratan, Buyan and Tamblingan) is a sacred upstream area. Sacredness is easier to recognize than define. Sacred relates to a mystery that is amazing, scary, but considered sacred. In a broader sense sacred is something that has a protective understanding of abuses, confusion, and pollution, which needs to be respected. The forest area of Buyan and Tamblingan lakes including upstream of Catur Angga Batukaru determines the sustainability of Subak Jati Luwih as a World Heritage Heritage Site.

Currently there is a new ecological philosophy that uses ecological, philosophical and spiritual approaches. The reasons for the protection of nature can be in the form of ecological effort from the religious point of view. Therefore the concept of sacred or holy is a strategic concept in the protection of plants or conservation.

Observations in the area Bedugul found several species of trees in the sacral category. Noted there are five types of banyan tree (*Ficus bejamina*), keroya (*Ficus lacor*), keresek (*Ficus* sp.), Kepuh (*Bombac ceiba*) and pule

Figure 60. Twin Dragons statue, as a guardian, which symbolize the sacred meaning of the Beratan Lake in Bedugul area, Bali. Sketch by I Dewa Pt. Darma

(*Alstonia scolaris*). Sacred or holy by the community is manifested by giving cloth poleng (black and white) or white yellow and give offerings on the tree. Types of sacred trees generally have large tree shapes. This seems to be related to seed and tree-producing trees as epiphytic host hosts. The concept of sacred or holy is a form of protection of the community toward plants. The people of Bali are generally bound by an awareness of cultural unity strengthened by the unity of language and unity of religion.

From those five tree species, Pule or *Alstonia scholaris* is of interest to discuss in this section due to its spiritual and traditional usage as well as its conservation status. *Alstonia scholaris* (L.) R. Br. has a synonym of *Echites scholaris* L., Echites of Pala Ham., and *Tabernaemontana alternifolia* Burm. In Java known as the pule, the Sundanese call it lame, rite in Ambon while in general *A. scholaris* (L.) R. Br in Indonesia is known by the name of pulai. (Valkenberg, 2002).The distribution of this plant is quite extensive, among others in Asia Pacific from India and Sri Lanka to mainland Southeast Asia and South China, almost throughout Malaysia to North Australia and Solomon

Islands. In North America this plant is used as an ornamental plant (Doran, JC & Turnbull, JW. 1997). According to Valkenberg (2002) *A. scholaris* (L.) R. Br. spread across Sri Lanka, Indo-China, Malesia Region, Australia to the Pacific Islands. *A. scholaris* (L.) R. Br. is a protected species. It is protected by: 1. PP no.7 th.1999,2. Minister of Agriculture no. 54 / kpts / um / 2/1972,3. Kepmen Kehutanan no. 261 / kpts-IV / 1990 and4. Included in the IUCN red-list for vulnerable categories.

Figure 61. Pule (*Alstonia scholaris*) planted in Bali Botanical Garden. Photo credit: Sutomo

In Bali, Pule plays an important role in the life of the community. Pule is used in many ceremonies Pitra Yadnya as one component bebanten or offerings. The pule tree is considered a sacred tree and usually grows wild around temples or cemeteries. Because of its sacred aura, usually masksused for ceremonial activities made of pulewood are considered to have a certain magical value. In addition pule also included one of 491 species of lontar usada medicinal plants that have been identified by Nala.

Beside being a tool for protecting plants, the sacred concept also involves conserving and preserving water. In Bedugul area, the diverse forest landscape such as those found on Mt. Tapak are a valuable sources of clean water. Several water springs can be found around Bedugul. One of the important spring is the one that names as "Tirta Madurgama" which is located inside a forest on Mt. Tapak, the location is approximately 45 minutes hiking start from the top of Bali Botanical Garden area. Tirta Madurgama has significant value for people surrounding Kembangmertha Village. Based on our observation, the forest are still intact and several points near the springs are designated for offerings and also several statues that symbolize its sacred meaning (Figure 62).

Figure 62. "Tirta Madurgama" water springs found inside forest on Mt. Tapak Bedugul. Several statues symbolize its sacred and holly. Notice there is always Dragon statue in places where water is the important component (such as seen near Beratan Lake, figure). Photo: Sutomo

VI A Synthesis : The potential application of the Biosphere Reserve concept for Bedugul

Sutomo, Arief Priyadi & I Dewa Putu Darma Bali Botanical Garden-Indonesian Institute of Sciences (LIPI), Candikuning Baturiti Tabanan 82191

Biosphere reserves are not widely known by the general public in Indonesia even though the word biosphere reserve has been listed in law number 5 (of 1990) on the conservation of biological natural resources and their ecosystems. A biosphere reserve is defined as a conservation area of terrestrial and coastal/marine ecosystems or a combination of more than one ecosystem type, internationally recognized as a part of the MAB-UNESCO program to promote a balance of relationships between people and nature.Biosphere reserves are a blend of conservation of landscape diversity, ecosystems, biodiversity and genetics without forgetting the economic development of the society whilst also maintaining local cultural wisdom. Biosphere reserves have a function to support research, monitoring and pilot projects, as well as education and training. Thus, biosphere reserves are not just for conservation, but essentially efforts to implement sustainable development (Darnaedi *et al*. 2005).

The endorheic drainage basin of Bedugul, on the border of Tabanan and Buleleng regencies of Bali Province, is an important landscape for conservation, residents, agriculture, tourism, religion and culture. The rapidly expanding human activity in the region raises concerns especially in the buffer zones which are ecologically inseparable from the existence of the three lakes (Beratan, Buyan and Tamblingan). The occurrence of land use change in the Bedugul area, including the uncontrollable tri-lake area, and without applying proper soil and water conservation techniques, can lead to erosion, declining water quality and sedimentation and may damage the function of the lake area as water catchment areas.

Therefore, we need to formulate a development policy for Bedugul area which can not be separated from Balinese regional development policy in the field of resources and environment. With reference to the policy and the results of the studies on the Bedugul area, which demonstrate important components of various ecological services, it is necessary to propose a model for the management using the Biosphere Reserve concept. This concept is a blend of conservation of the diversity of the landscape, including its ecosystems and their biological and genetic resources, without forgetting the economic development of society whilst also maintaining local cultural wisdom.

Development of Bedugul area is required to be in harmony with its conservation function. For that reason, in 2005 Eka Karya Bali Botanical Garden (KREK) in cooperation with BAPEDALDA Bali Province held a symposium entitled "Analysis of Carrying Capacity and Resource Capacity in Beratan Tri-Lake Area, Buyan and Tamblingan". In the symposium, the proposed management of the appropriate Bedugul endorheic basin area was recommended to bein the form of a Biosphere Reserve/Cagar Biosfer (CB). According to the Biosphere Reserve (Soedjito, 2004), the Biosphere Reserve is 'the site designated by various countries through the cooperation of the UNESCO-MAB program to promote the conservation of biodiversity and sustainable development, based on the efforts of local communities and reliable science'. The concept is a combination of preserving the diversity of landscapes, ecosystems, biodiversity and genetics in harmony with economic development and local cultural wisdom (Darnaedi *et al*., 2005).

With regard to biodiversity in Bedugul, at a symposium at the Bali Botanical Garden in 2005 on tri-lakes, it has been recommended that some native plant species in the area can be reintroduced to restore the function of the lake buffer. Some species that are found naturally include Cemara Pandak (*Dacrycarpus imbricatus*) and Cemara Geseng (*Casuarina junghuhniana*). In addition, several types of bamboo such as Scizostachyum brachycladum, Dendrocalamus asper and Gigantochloa apus, because these plants can maintain the water system. Several species are rare and endemic species found only in Bukit Pohen Bedugul areas such as Pinanga arinasae and Dicksonia blumei.

In one of the research activities by the Bali botanical garden in 2010, on the hill of Pohen (one of the forest fragments in the Bedugul area) a permanent plot of 1 ha was constructed, to study the diversity of flora and the potential of carbon sinks at the site. The results of this study reveal that the Bedugul endorheic basin area is very rich in biodiversity, including some rare species of flora that must be protected. Thus, the unique and rich biodiversity of the endorheic basin region of Bedugul is highly suitable to become the next Biosphere Reserve.

References

Abdulhadi R. (2005). Analisis Kawasan Penyangga Tri-Danau Beratan-Buyan dan Tamblingan. In: Simposium Analisis Daya Dukung dan Daya Tampung Sumber Daya Air di Kawasan Tri-Danau Beratan, Buyan dan Tamblingan Provinsi Bali (eds P. E. Hehanusa, R. Abdulhadi and M. Siregar) pp. 23-30. UPT BKT Kebun Raya Bali LIPI, Bali.

Adhikari D, Barik SK, Upadhaya K. (2012). Habitat distribution modelling for reintroduction of Ilex khasiana Purk., a critically endangered tree species of north-eastern India. Ecological Engineering 40, 37-43.

Anderson LG, Rocliffe S, Haddaway NR, Dunn AM. (2015). The Role of Tourism and Recreation in the Spread of Non-Native Species: A Systematic Review and Meta-Analysis. PLoS ONE 10(10): e0140833. https://doi.org/10.1371/journal.pone.0140833.

Ardika W. (2005). Peran Budaya dalam Pelestarian Sumber Daya Air. In: Simposium Analisis Daya Dukung dan Daya Tampung Sumber Daya Air di Kawasan Tri-Danau Beratan, Buyan dan Tamblingan Provinsi Bali (eds M. Siregar, R. Abdulhadi and P. E. Hehanusa) pp. 43-7. UPT BKT Kebun Raya Bali LIPI, Bali.

Arinasa IBK. (2013). Morphology of *Pinanga arinasae*. Kebun Raya Eka Karya Bali LIPI, Tabanan.

Arinasa IBK. (2009). Reintroduksi Palem Nyabah (*Pinanga arinasae* J.R. Witono) Jenis Endemik Di Bali. Prosiding Seminar "Peranan Konservasi Flora Indonesia Dalam Mengatasi Dampak Pemanasan Global", 2009, hlm. 276-279. SSN / ISBN / IBSN: ISBN 978-979-799-447-1SSN / ISBN / IBSN: ISBN 978-979-799-447-1.

Astutik S. (2011). Carbon stock linkage to plant diversity on Mount Gede Pangrango National Park as the core zone of Cibodas Biosphere Reserve. MAB-Division of Ecological Sciences-UNESCO, Miollis.

Aubert M, Alard D, Bureau F. (2003). Diversity of plant assemblages in managed temperate forests: a case study in Mormandy (France). Forest Ecology Management 175, 321–37.

Augusta TS. (2015). Identifikasi jenis dan analisa vegetasi tumbuhan air di Danau Lutan Palangkaraya. Jurnal Ilmu Hewani Tropika 4, 1-5.

Austin MP, Pausas JG. (2001). Patterns of Plant Species Richness in Relation to Different Environments: An Appraisal. Journal of Vegetation Science 12, 153-66.

Backer CA, van den Brink RCB. (1963). Flora of Java. The Rijksherbarium, Leiden.

Bao MC, Shao LP, Guang YN. (2009). Effects of the invasive plant *Mikania micrantha* H.B.K. on soil nitrogen availability through allelopathy in South China. Biology Invasions 11, 1291–9.

Barata UW. (2000). Biomasa, komposisi dan klasifikasi komunitas tumbuhan bawah pada tegakan *Acacia nilotica* di Taman Nasional Baluran, Jawa Timur. In: Fakultas Kehutanan. Universitas Gadjah Mada, Yogyakarta.

Barbour MG, Burk JH, Pitts WD. (1980). Terrestrial plant ecology. The Benjamin Cummings Publishing Company Inc., California.

Biswas SR, Choudhury JK, Nishat A, Rahman MM. (2007). Do invasive plants threaten the Sundarbans mangrove forest of Bangladesh? Forest Ecology and Management245, 1-9.

Chen J, Franklin JF, Spies TA. (1995). Growing-season microclimatic gradients from clearcut edges into old-growth Douglas-fir forests. Ecology Application. 5: 74-86.

Clarke KR. (1993). Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology 18, 117-43.

Clarke KR, Gorley RN. (2005). PRIMER: Plymouth Routines in Multivariate Ecological Research. PRIMER-E Ltd., Plymouth.

Clearly DFR, Priadjati A, Suryokusumo BK, Steph BJM. (2006). Butterfly, seedling, sapling and tree diversity and composition on a fire-affected Bornean rainforest. Australian Ecology 31, 46-57.

Condit R, Hubbell SP, Lafrankie JV, Sukumar R, Manokaran N, Foster RB, Ashton PS. (1996). Species-area and species individual relationships for tropical trees: a comparison of three 50-ha plots. Journal of Ecology 84, 549-62.

Crego RD, Nielsen CK, Didier KA. (2014). Climate change and conservation implications for wet meadows in dry Patagonia. Environmental Conservation 41, 122-31.

Darma IDP, Prihadi A, Sujarwo W. (2017). Analisis Vegetasi Tumbuhan Air Di Kawasan Tri Danau (Beratan, Buyan, Tamblingan) Bali. LIMNOTEK-Perairan Darat Tropis di Indonesia 24.

Darnaedi D, Siregar M, Soedjito H, Sukara E. (2005a). Konsep Cagar Biosfer: Alternatif pengelolaan kawasan tri-danau Beratan, Buyan dan Tamblingan Provinsi Bali. In: Simposium Analisis Daya Dukung dan Daya Tampung Sumber Daya Air di Kawasan Tri-danau Beratan, Buyan dan Tamblingan (eds P. E. Hehanusa, R. Abdulhadi and M. Siregar) pp. 31-42. UPT Balai Konservasi Tumbuhan Kebun Raya "Eka Karya" Bali - LIPI, Bali.

Davidar P, Mohandass D, Vijayan L. (2007). Floristic inventory of woody plants in a tropical montane (shola) forest in the Palni hills of the Western Ghats, India. Tropical Ecology 48, 15-25.

Davies-Colley RJ, Payne GW, van Elswijk M. (2000). Microclimate gradients across a forest edge. New Zealand Journal of Ecology 24(2): 111-121.

Fardilla D, Sutomo. (2011) Efek Tepi Koridor Jalan di Hutan Bukit Pohen Cagar Alam Batukahu Bali. Berkala Penelitian Hayati Journal of Biological Researchers 17, 9-13.

Fardilla D, Sutomo. (2013) Ecological Studies in Tropical Forest of Mt. Pohen Bali Indonesia. Lambert Academic Publishing, Germany.

Fierke MK, Kauffman JB. (2006) Invasive species influence riparian plant diversity along a successional gradient, Willamette River, Oregon. Natural Areas Journal 26, 376-82.

Forman RTT. (1995). Land Mosaics: The Ecology of Landscapes and Regions. Cambridge University Press, Cambridge. 87-90.

GBIF. (2016) *Acacia nilotica* (L.) Willd. ex Delile. GBIF Secretariat: GBIF Backbone Taxonomy.

Gehlhausen SM, Schwartz MW, Augspurger CK. (2000). Vegetation and microclimatic edge effects in two mixed-mesophytic forest fragments. Plant Ecology 147: 21-35.

Goltenboth F, Langenberger G, Widmann P. (2006) Mountain Forests. In: Ecology of Insular Southeast Asia: The Indonesian Archipelago. (ed F. Goltenboth). Elsevier, Singapore.

Gomez-Pompa A, Vazquez-Yanes C. (1981) Successional Studies of a Rain Forest in Mexico. In: Forest Succession: Concepts and Application (eds D. C. West, H. H. Shugart and D. B. Botkin) pp. 246-66. Springer-Verlag, New York.

Gurrutxaga M, Saura S. (2014) Prioritizing highway defragmentation locations for restoring landscape connectivity. Environmental Conservation 41, 157-64.

Hakim L, Miyakawa H. (2015) Exotic plant species in the restoration project area in Ranupani recreation forest Bromo Tengger Semeru National Park. Biodiversity Journal 6, 831-6.

Hallgren W, Beaumont L, Bowness A, Chambers L, Graham E, Holewa H, Laffan S, Mackey B, Nix H, Price J. (2016) The Biodiversity and Climate Change Virtual Laboratory: Where ecology meets big data. Environmental Modelling & Software 76, 182-6.

Hanum SF, Darma DP. (2005) Rencana Pengelolaan Lansekap Kawasan Tri-Danau Beratan-Buyan-Tamblingan. In: Simposium Analisis Daya Dukung dan Daya Tampung Sumber Daya Air di Kawasan Tri-danau Beratan, Buyan dan Tamblingan (eds P. E. Hehanusa, R. Abdulhadi and M. Siregar) pp. 109-20. UPT Balai Konservasi Tumbuhan Kebun Raya "Eka Karya" Bali - LIPI, Kebun Raya Bali.

Harper KA, Macdonald SE, Burton PJ, Chen J, Brosofske KD, Saunders SC, Euskirchen ES, Roberts D, Jaiteh MS, Esseen PA. (2005). Edge Influence on Forest Structure and Composition in Fragmented Landscapes. Conservation Biology 19: 768-782.

Hidayati N, Mansur M, Juhaeti T. (2012) Physiological characteristics related to carbon sequestration of tree species in highland forest ecosystem of Mount Halimun-Salak National Park. Indonesian Journal of Forestry Research 9, 49-61.

Hobbs RJ, Mooney HA. (1991) Effects of Rainfall Variability and Gopher Disturbance on Serpentine Annual Grassland Dynamics. Ecology 72, 59-68.

Hobbs RJ, Yates S, Mooney HA. (2007) Long-term data reveal complex dynamics in grassland in relation to climate and disturbance. Ecological Monographs 77, 545-68.

IPCC. (2007) Summary of Policy Makers. In: Climate Change 2007: the Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (eds S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H. L. Miller). Cambridge University Press, Cambridge.

Jongman RHG, ter Braak CJF, van Tongeren OFR. (1987). Data Analysis in Community and Landscape Ecology. Centre for Agricultural Publishing and Documentation, Wageningen.

Kartawinata K, Priyadi H, Sheil D, Riswan S, Sist P, Machfudh. (2006). A field guide to the permanent sample plots in the conventional logging blocks 28 & 29 at CIFOR Malinau research forest East Kalimantan. CIFOR, Bogor.

Keeley JE, Baer-Keeley M, Fotheringham CJ. (2005). Alien plant dynamics following fire in Mediterranean-climate California shrublands. Ecological Applications 15, 2109-25.

Kent M, Coker P. (1992). Vegetation Description and Analysis, A practical Approach. John Wiley & Sons, New York.

KSDA. (2005) Informasi Potensi Kawasan Konservasi Propinsi Bali. KSDA, Denpasar.

Kunwar RM. (2003). Invasive alien plants and Eupatorium: Biodiversity and livelihood. Himalayan Journalof Science1, 129-33.

Lavigne F, Gunnell Y. (2006) Land cover change and abrupt environmental impacts on Javan volcanoes, Indonesia: a long-term perspective on recent events. Regional Environmental Change6, 86-100.

Lepš J, ˇSmilauer P. (2003) Multivariate Analysis of Ecological Data using CANOCO. Cambridge University Press, Cambridge.

LIPI PBG. (1992) Studi Daya Dukung Habitat Flora dan Fauna Endemik Serta Hidrologi Untuk Rencana Pengusahaan Panas Bumi di Batukahu Bali. p. 157. Puslitbang Biologi dan Geoteknologi LIPI, Bogor.

LoweS, Browne M, Boudjelas S, De Potter M. (2000). 100 of The World's Worst Invasive Alien Species A Selection from the Global Invasive Species Database. Published by The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN). 12pp. First Published as special lift-out in

Alien 12 December 2000. Updated and reprinted version: November 2004.

Luken JO. (1990). Directing ecological succession. Chapman and Hall, London.

Mairota P, Leronni V, Xi W, Mladenoff DJ, Nagendra H. (2014). Using spatial simulations of habitat modification for adaptive management of protected areas: Mediterranean grassland modification by woody plant encroachment. Environmental Conservation 41, 144-56.

Matlack GR. (1993). Microenvironment variation within and among forest edge sites in the eastern United States. Biol. Cons. 66: 185-194.

Mogea JP, Gandawidjaja D, Wiriadinata H, Nasution RE, Irawati. (2001). Tumbuhan Langka Indonesia. Puslitbio-LIPI, Bogor.

Molloy SW, Davis RA, van Etten EJB. (2013). Species distribution modelling using bioclimatic variables to determine the impacts of a changing climate on the western ringtail possum (*Pseudocheirus occidentals*; Pseudocheiridae). Environmental Conservation 41, 176–86.

Molloy SW, Davis RA, van Etten EJB. (2016). Incorporating Field Studies into Species Distribution and Climate Change Modelling: A Case Study of the Koomal *Trichosurus vulpecula hypoleucus* (Phalangeridae). PloS ONE 11, 1-18.

Owen CS, Smart RM, Honnel DR, Dick GO. (2005). Effect of pH on Growth of *Salvinia molesta*. Journal Aquatic Plant Management 43, 34-8.

Pena CM. (2003). Changes in forest structure and species composition during secondary forest succession in the Bolivian Amazon. Biotropica 35, 450-61.

Priyadi A, Sutomo S, Darma I, Arinasa IBK. (2014). Selecting Tree Species with High Carbon Stock Potency from Tropical Upland Forest of Bedugul-Bali, Indonesia. Journal of Tropical Life Science 4, 201-5.

Rahayu S. (2009). Wood Density Database. World Agroforestry Centre.

Sarna K, Rideng IM, Sumardika N. (1993). Laporan Penelitian, Inventarisasi dan Pelestarian Tanaman Langka di Bali dalam Usaha Menunjang Obyek Wisata dan Studi. Fakultas Keguruan dan Ilmu Pendidikan Universitas Udayana Denpasar.

Satyanti A, Siregar HM. (2012). Microclimate Preference and Habitat of Begoniain Bedugul, Bali. Biotropia 19, 80-91.

Setiadi IGW, Siringoringo RL. (2017). Ethnobotanical tourism potential in Bali Botanical Garden. Jumpa 3 [2] : 387 - 396. ISSN 2406 9116.

Setyawati T, Narulita S, Bahri IP, Raharjo GT. (2015). A Guide Book to Invasive Plant Species in Indonesia. Research, Development and Innovation Agency. Ministry of Environment and Forestry, Bogor-Indonesia. pp: 16, 56, 74, 141, 210, 213, 225, 358, 367.

Smiet AC. (1992). Forest Ecology on Java: Human Impact and Vegetation of Montane Forest Journal of Tropical Ecology 8, 129-52.

Soerianegara I, Indrawan A. (1982). Ekologi Hutan Indonesia. Fakultas Kehutanan Institut Pertanian Bogor, Bogor.

Soerjani M, Kostermans AJGH, Tjitrosoepomo G. (1987). Weeds of Rice in Indonesia. Balai Pustaka, Jakarta.

Soedjito H. (2004). Pedoman pengelolaan cagar biosfer di Indonesia. Panitia Nasional Mab Indonesia, Lembaga Ilmu Pengetahuan Indonesia.

Stevens J. (1992). Applied Multivariate Statistics for the Social Sciences. 2nd ed. Lawrence Erlbaum Associates Publishers, New Jersey.

Sujarwo W, Arinasa IBK, Salomone F, Caneva G, Fattorini S. (2014). Cultural erosion of Balinese indigenous knowledge of food and nutraceutical plants. Economic Botany, 68 (4), 426-437.

Sujarwo W, Darma DP, Oktavia GAE. (2017). Studi Etnobotani Tumbuhan Obat di Kawasan Sekitar Danau Buyan-tamblingan, Bali. Buletin Kebun Raya.

Sukarman, Dariah A. (2014). Tanah Andosol Di Indonesia: Karakteristik, Potensi, Kendala, Dan Pengelolaannya Untuk Pertanian.

Sunarta IN,Susila KD, Kariasa IN. (2018). Landslide Hazard Analysis and Damage Assessment for Tourism Destination at Candikuning Village , Tabanan Regency , Bali , Indonesia.IOP Conference Series: Earth and Environmental Science 123:1–10. doi :10.1088/1755-1315/123/1/012006.

Sutomo. (2007). Usada Bali dalam Perspektif Konservasi Kebun Raya "Eka Karya" Bali. In: Warta Kebun Raya pp. 15-8.

Sutomo, Mukaromah L, Sandi IK. (2007). The "Usada Bali" Medicinal Plants in Some Areas of Buleleng, Bali. In: Seminar Konservasi Tumbuhan Usada Bali dan Peranannya dalam Mendukung Ekowisata (eds M. Siregar, H. M. Siregar, I. B. K. Arinasa and W. S. Lestari) pp. 92-7. UPT Balai Konservasi Tumbuhan Kebun Raya "Eka Karya" Bali Lembaga Ilmu Pengetahuan Indonesia, Kebun Raya Bali.

Sutomo, Kurniawan A, Pendit IMR, Ardaka IM, Sudiatna IN. (2009). Koleksi Tumbuhan Obat Usada Bali di Kebun Raya "Eka Karya" Bali. UPT Balai Konservasi Tumbuhan Kebun Raya "Eka Karya" Bali, Bali.

Sutomo. (2011). Cemara Pandak di Kawasan Bekas Kebakaran Hutan Bukit Pohen Cagar Alam Batukahu Bali. Al-Kauniyah Jurnal Biologi Lingkungan 5, 20-5.

Sutomo, Darma IDP. (2011). Canonical Corespondence Analysis of Plant Community at Buyan-Tamblingan Lake Forest Areas Bali. In: Konservasi Tumbuhan Tropika: Kondisi Terkini dan Tantangan ke depan (eds D. Widyatmoko, D. M. Puspitaningtyas, R. Hendrian, I. Fijridiyanto, A., J. R. Witono, R. Rosniati, S. R. Ariati, S. Rahayu and T. N. Praptosuwiryo) p. 429. UPT BKT Kebun Raya Cibodas-LIPI, Cibodas, Jawa Barat.

Sutomo, Undaharta NKE, Bangun TM, Lugrayasa IN. (2012). Studi Komposisi dan Dinamika Vegetasi Pohon Hutan dengan Pembuatan Plot Permanen 1 Ha di Gunung Pohen Cagar Alam Batukahu Bali. Bumi Lestari 12, 366-81.

Sutomo. (2014). Komposisi Komunitas Tumbuhan Bawah di Dalam Plot Permanen 1 Ha Gunung Pohen Cagar Alam Batukahu Bali In: Seminar Nasional Biodiversitas (ed Sugyarto). FMIPA UNS, Solo.

Sutomo, van Etten E. (2017). Species distribution model of invasive alien species *Acacia nilotica* for Central-Eastern Indonesia using Biodiversity Climate Change Virtual Laboratory (BCCVL). Tropical Drylands1, 36-42.

Sutyarto R. (2002). Kajian longsor lahan: Studi kasus di kawasan Bedugul, Bali. Jurnal Lingkungan Hidup Bumi Lestari 2, 8-13.

Suzuki E, Masaaki Y, Simbolon H, Muhidin A, Wakiyama S. (1997) Establishment of two 1 ha permanent plots in Gunung Halimun National Park for study of vegetation structure and forest dynamics. In: Research and Conservation of Biodiversity in Indonesia (eds Y. Masaaki,

H. Simbolon and J. Sugardjito) p. 36. LIPI, the research centre for biology, Indonesian Institute of Sciences, Bogor.

Tengah IGP, Arka IW, Sritamin NM, Gotama IBK, Sihombing H. (1995). Studi tentang inventarisasi, determinasi dan cara penggunaan tanaman obat pada "*Lontar Usada*" di Bali. Puslitbang Farmasi Balitbang Kesehatan Departemen Kesehatan Republik Indonesia, Jakarta.

ter Braak C. (1986). Canonical correspondence analysis: A new eigenvector technique for multivariate direct gradient analysis. Ecology 67, 1167–79.

ter Braak C, Smilauer P. (2002). CANOCO for Windows version 4.5. Biometrics Plant Research International, Wageningen The Netherland.

The Plant List. (2013). The Plant List A Working List of All Plant Species. http://www.theplantlist.org/. accessed at 22th February 2018.

Tjitrosoedirdjo SS.(2005). Inventory of The Invasive Alien Plant Species in Indonesia. BIOTROPIA. 25: 60 – 73. DOI: http://dx.doi.org/10.11598/btb.2005.0.25.209.

Tjitrosoedirdjo SS, Mawardi I, Tjitrosoedirdjo S. (2016). 75 Important Invasive Plant Species in Indonesia. SEAMEO BIOTROP Southeast Asian Regional Centre for Tropical Biology. Bogor-Indonesia. ISBN: 978-979-8275-49-4. pp: 4, 13, 19, 26, 32, 34, 37, 54, 64, 56.

Uhl NW, Dransfield J. (1987). Genera palmarum, a classification of palms based on the work of Harold E. Moore,Jr. Allen Press and The Bailey Hortorium and The International Palm Society, Kansas.

Van Steenis CGGJ. (1972). The Mountain Flora of Java. E.J Brill, Leiden.

Van Valkenberg JLCH. (2002). Plant Resources of South-East Asia: Medicinal and Poisonous Plants 2. Prosea Foundation.

Walker LR, Del Moral R. (2008). Lessons from primary succession for restoration of severely damaged habitats. Applied Vegetation Science 12, 55–67.

Wahyuni S, Hanum SF, Kuswantoro F, Pendit IMR, Slamet, Haerudin E. (2017). Eksplorasi Flora Pengkayaan Koleksi Kebun Raya Gianyar-Bali. Pusat Konservasi Tumbuhan Kebun Raya-LIPI. Bogor-Indonesia.

Ward JE, MacDonald LBA, Thompson RJ. (1993). Mechanism of suspension feeding in bivalves: Resolution of current controversies by means of endoscopy. Limnology Oceanography 38, 265-72.

Webber BL, Yates CJ, Le Maitre DC, Scott JK, Kriticos DJ, Ota N, McNeill A, Le Roux JJ, Midgley GF. (2011). Modelling horses for novel climate courses: insights from projecting potential distributions of native and alien Australian acacias with correlative and mechanistic models. Diversity and Distributions 17, 978–1000.

Whitten T, Soeriaatmadja RE, Afiff SA. (1996). The ecology of Indonesia series volume II: The ecology of Java and Bali. Periplus, Hongkong.

Witono JR. (2003). Phenetic study on clustered Pinanga of Java and Bali. BIODIVERSITAS 4, 38-42.

Witono JR, Mogea JP, Somadikarta S. (2002). Pinanga in Java and Bali. Palms 46, 193-201.

Yamada I. (1975). Forest ecological studies of the montane forest of Mt. Pangrango, West Java: I. Stratification and floristic composition of the montane rain forest near Cibodas.

Young A, Mitchell N. (1994). Microclimate and vegetation edge effects in a fragmented podocarp-broadleaf forest in New Zealand. Biological Conservation 67: 63-72.

About the authors:

Dr. Sutomo completed his PhD study at Edith Cowan University Australia. He is now working with Indonesian Institute of Sciences (LIPI) as a researcher in plant ecology at the Botanical Garden of Indonesia in Bali. He is the head of plant conservation research group (KELTI KONSERVASI) in Bali Botanical Garden as well as affiliate scientist at SEAMEO-BIOTROP since March 2018. His consistent interest in ecology and research in Bedugul area initiated this book.

Ir. I Dewa Putu Darma has B.Sc., in Agriculture from Tabanan University in Bali. He is now a senior researcher at Bali Botanical Garden. His main field of interest has always been ethnobotany and garden landscaping as well as design. He is also assisting other newly emerging botanical gardens in Indonesia such as Lombok Botanical Garden, and Jembrana Botanical Garden as an expert in thematic garden design for plant conservation. He also the designer for almost all thematic garden collection in Bali Botanical Garden.

Dr. Wawan Sujarwo is an ethnobotanist at the Indonesian Institute of Sciences (LIPI), and head of scientific information and services to the Bali Botanic Garden. Dr. Sujarwo's primary area of research has focused on the relationships between plants and people, especially in the traditional Balinese communities. He has widely documented Balinese ethnobotanical knowledge in many renowned international journals with highly impact factor. He received a PhD in ethnobotanical sciences from Università degli studi Roma Tre, Italy.

Farid Kuswantoro, S.Si., completed his B.Sc. in Biology from Gadjah Mada University in 2012. In 2013-2014 he works in Bogor Botanic Gardens as Regional Botanic Gardens Development Assistant and assigned to help the development of Wamena "Biology" Botanic Gardens and Balikpapan Botanic Gardens. Started at 2015 he works for Bali Botanic Gardens as researcher candidate, and then holds the position as a researcher in Botany started in December 2017 until now.

Rajif Iryadi, S.Si., completed his B.Sc. in the Cartography & Remote Sensingof Geography Faculty from Gadjah Mada University in 2011. In 2011-2014 he works in Consultant Mapping as Remote Sensing and Geographic Information System (GIS) staff and Team of mining exploration in Papua, Bengkulu, and West Java. Started at 2014 he works for Bali Botanic Gardens – Indonesian Institute of Sciences (LIPI) as researcher and GIS.

Arief Priyadi, S.Si., M.P. graduated from undergraduate study program of Agronomy Faculty of Agriculture Gadjah Mada University (UGM) Yogyakarta in 2004 and also graduate program of the same institution in 2007. Hewas formerly a lecture assistant of weed science, statistics & experimental design and also crop production % management in the Faculty of Agriculture in UGM. From 2011 – present he is a researcher of botany at Bali Botanical garden Indonesian Institute of Sciences (LIPI). He is now undertaking his PhD study in China.

Ecology

Of Bedugul Basin Bali

Forest areas in the Bedugul Basin are among the remaining tropical mountain rainforests in Bali and they play significant roles in maintaining the ecosystem, preventing erosion, preserving biodiversity, and functioning as a water source and buffer zone for the surrounding areas including the lower areas of Bali.

However, forest areas in the Bedugul Basin, especially in forest areas near Beratan and Buyan Lakes, and also Mt. Pohen, are becoming more and more threatened as its extent and vegetation cover have declined due to the increased human activities, climate change and natural disasters. Hence, ecological research in these areas of Bedugul Basin is needed to assess and also anticipate any potential changes so that its natural resources could be protected and sustained in the era of changing climate.

This book is a compilation of relevant research works that were conducted in Bedugul Basin from 2005 up to 2017. The relatively new study of species distribution modelling (SDM) using Biodiversity and Climate Change Virtual Laboratory (BCCVL) for Dacrycarpus imbricatus is also introduced in this book. Another important and recent research output included in this book is the exploration of the autecology of an important endemic species, Pinanga arinasae, which is only found on Mt. Tapak, Bedugul.

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