

# Botanical survey in thirteen montane forests of Bawean Island Nature Reserve, East Java Indonesia: Flora diversity, conservation status, and bioprospecting

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**Abstract.** Trimanto, Hapsari L. 2016. *Botanical survey in thirteen montane forests of Bawean Island Nature Reserve, East Java Indonesia: Conservation status, bioprospecting and potential tourism. Biodiversitas 17: 832-846.* Bawean Island which located between Borneo and Java islands possessed unique and distinctive abiotic and biotic resources. Botanical survey has been conducted in Bawean Island Nature Reserve. This paper reported the results of inventory study of plant bioresources in 13 montane forests of Bawean Island, discussed their conservation status, bioprospecting on some wild plant species and potential development subjected to some conservation areas. Inventory results in montane forests showed that it was registered about 432 plant species under 286 genera and 103 families; comprised of 14 growth habits in which tree plants were the most dominant with about 237 species. Conservation status evaluation showed that there are at least 33 species of plants included in IUCN list comprised of 30 species categorized as least concern and 3 species considered at higher risk of extinction *i.e.* *Podocarpus rumphii* (Near Threatened); *Pterocarpus indicus* and *Memecylon myrtilloides* (Vulnerable). Bioprospecting results showed that 10 tuberous plants prospected as food sources; 19 woody plants prospected as timber sources, and 28 plants prospected as ornamental plants. There are at least 7 invasive alien plant species identified including *Ageratum conyzoides*, *Chromolaena odorata*, *Eupatorium inulifolium*, *Lantana camara*, *Imperata cylindrica*, *Stachytarpheta jamaicensis* and *Themeda arguens*. If well managed, the development of Bawean Island as nature-based and eco-tourism may contribute both to biodiversity conservation and alleviating prosperity of the local residents.

**Keywords:** Bawean Island, bioprospecting, bioresources, conservation, montane forest, plant

## INTRODUCTION

Indonesia is the largest archipelago state in the world. It consists of more than 17,508 islands and about 70% of its territorial areas covered by oceans with more than 81,000 km of coastlines (Farhan and Lim 2010). Scientific studies revealed that impacts of climate change and the rising of sea-level on biodiversity in the island states are much greater than continental areas. Therefore, preservation of biodiversity in small islands which is under the pressure of climate change are more urgently needed than in the continent. Climate change and the rise of sea-level will cause unfavorable shifts in biotic composition and adversely affect competition among species (Nurse et al. 2001). One of the main targets of the global strategy for plant conservation is to understand and to document the diversity of plants, especially the endangered habitats in small islands (GSPC 2002). Limitations of the distribution area and the threat of the rise of sea level cause an area of small islands as vulnerable habitats and need to be prioritized in plant conservation efforts.

Bawean Island is one small island in Indonesia. Geographically, Bawean Island which is located among Borneo Island and Java Island brings about unique and distinctive of abiotic and biotic resources. Bawean island has lowland primary and secondary tropical rain forest type, with many water springs found across the island

which support bioresources richness including flora, fauna, microorganisms, etc. (Trimanto 2014). It provides wide ranges of habitat in which animals and plants with different evolutionary lineage may evolve and undergo speciation in the island. The discovery of endemic species such as Bawean deer *Axis kuhlii* (Semiadi et al. 2015), Javan warty pig *Sus verrucosus* (Blouch 1995), butterfly *Atrophaneura coon* sub. sp. *sangkapurae* (Maurizio and Salla 1992), some birds of Falconiformes and Strigiformes (Nijman 2004), etc. indicated that Bawean Island, which is rich with bioresources, can be an interesting subject of study by many biologists.

Some inventory studies and assessments on flora biodiversity in Bawean Island have been conducted sporadically in few past years. Its montane forests were characterized by dense tree species and understory with predominance of ferns, bryophytes and orchids. The dominating tree species were different for each montane forest. Most important and common trees species found in some montane forests in Bawean Island, according to scholars and researchers' report from vegetation analysis study, include *Syzigium lepidocarpa*, *Irvingia malaya*, *Garcinia* spp., *Microcos tomentosa*, *Ficus variegata*, *Myristica guatteriaefolia*, *Tetrameles nudiflora*, *Canarium hirsutum*, *Litsea firma*, *Alstonia scholaris*, *Pittosporum* sp., etc. (Mansur et al. 2004; Trimanto 2014; Danarto and Rahadianoro 2015).

Tourism has experienced rapid growth over the past 50 years and is expected to continue to develop, particularly in biodiversity 'hotspots'. Nature-based tourism is the fastest growing element of tourism *i.e.* the segment in the tourism market in which people travel with the primary purpose of visiting a natural destination (Kuenzi and McNeely 2008). According to the document long-term plan management of Bawean Island Nature Reserves and Wildlife Reserves (2012-2021), it is stated that Bawean Island will be developed into a nature-based tourism destination (Achmad 2001). In order to support the plan, some infrastructures *i.e.* road networks and airport has been built in Tambak Sub-District. However, several studies result that tourism activities which focus on the natural environment create some risks and pressures on the ecosystems, bioresources and their services. The significant alterations may include deforestation, drainage of wetlands, soil erosion, fragmentation and disruption of habitat, encroachment on protected areas, littering, air and water pollution, eutrophication, increased risk of fires, introduction of invasive alien species (weeds, pests and possibly animals), the changing behavior of wildlife and even the loss of biodiversity (Hay and Hunt 1995; Ning 1999; Kuenzi and McNeely 2008). Awareness about the impacts of tourism, the importance of biodiversity, and the need for conservation efforts have to be raised in order to prevent Bawean Island from the negative impacts of tourism

In 2014, Purwodadi Botanic Garden (Pasuruan, East Java) has conducted exploration study on the biodiversity of flora in Bawean Island and collected some plant materials to be *ex-situ* conserved. Botanical survey in small and remotes islands are necessary to reveal and study its plant diversity which may become valuable basic data of biodiversity for further development and also to evaluate the major intrinsic and extrinsic factors affecting long-term preservation (Singh et al. 2014). Furthermore, conservation and bioprospecting efforts are needed to conduct in order to keep the plant genetic resources in the island and also to utilize gene sustainability. This paper reports the results of inventory study of plant bioresources in Bawean Island, discusses their conservation status, carries out bioprospecting of some wild plant species and takes some notes on its potential tourism development.

## MATERIALS AND METHODS

### Study site

Bawean Island is a small and remote island in Indonesia and is located in Java Sea, off the North Coast of Java, about 150 km from Surabaya, the capital city of East Java. It is administered by Gresik District of East Java Province, Indonesia. The island is about 190-200 km<sup>2</sup> with mostly hilly land topography and slopes between 5-75% with altitude up to 695 m above sea level. The island was originated from a volcano and was located near its center in which igneous rocks cover about 85% of its surface with occasional limestone, sandstone and dolomite. The climate is tropical monsoonal with slightly less humid (Blouch 1995; Mansur et al. 2004). Bawean Island has function as

nature conservation area; in 1979 by Decree of Minister of Agriculture, two national nature preserves were created with areas of 3836.6 ha as wildlife sanctuary and 725 ha as Nature Reserve (Minister of Agriculture 1979; Achmad 2001). Botanical surveys were conducted in Bawean Island Nature Reserve and Wildlife Sanctuary covering 13 montane forests of the island *i.e.* Montane Forest of Langger, Pakem, Asakan, Pakotokan, Nangka, Payung-payung, Kastoba, Lumut, Gadung, Bangkuang, Pangambaan, Mandala, and Panjang (Figure 1).

### Botanical survey method

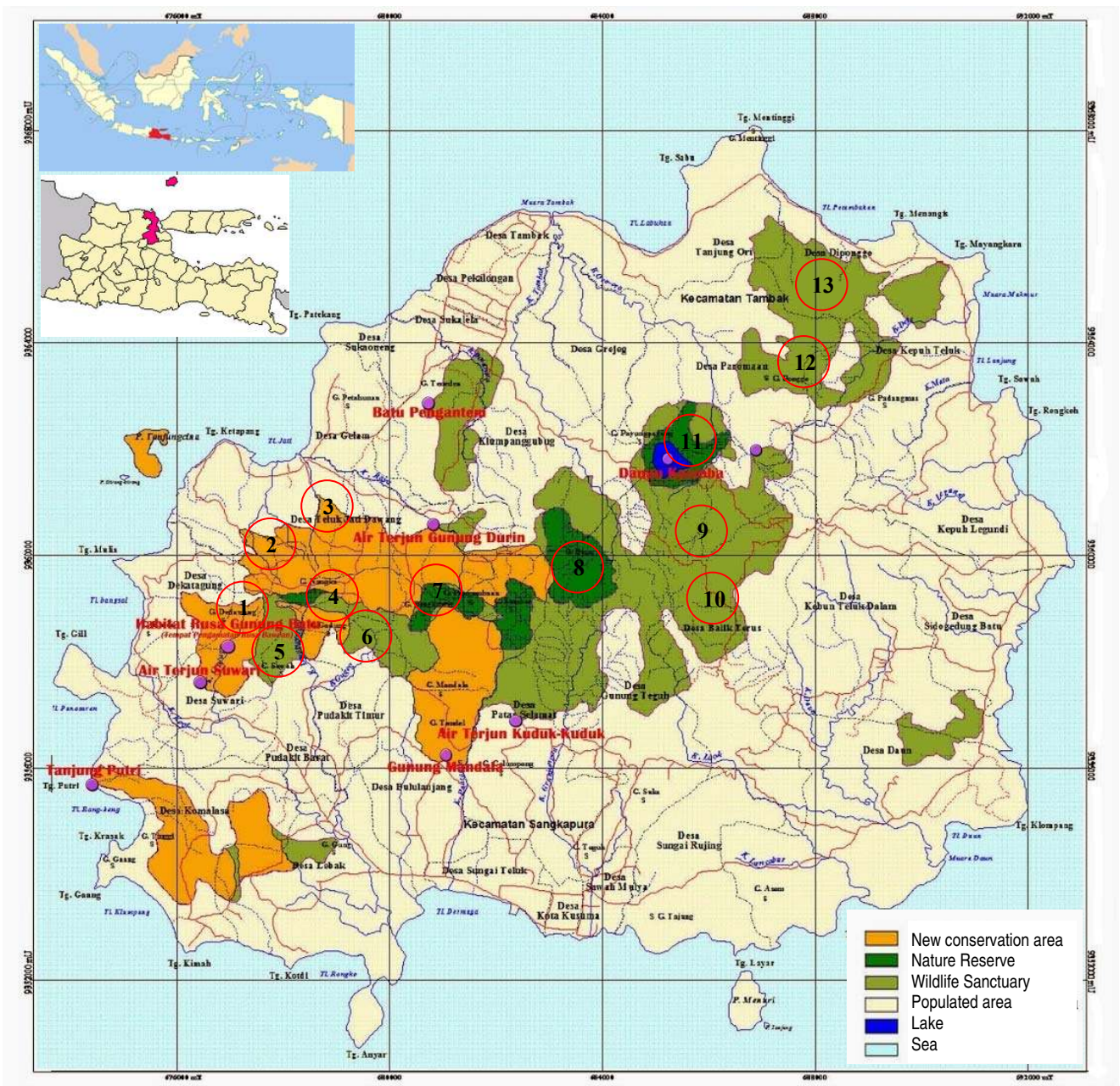
Plant exploration was conducted using survey method to inventory and gather plant materials in forms of seedlings, seeds, cuttings, tubers, corms, etc. for *ex-situ* conservation purpose in Purwodadi Botanic Garden. Plants inventoried including Angiosperms, Gymnosperms and Pteridophytes (Bryophytes, Lichens and Algae were excluded). Direct identification were made for each plant in the field using main and specific morphological characters such as habit, stem or branch, petiole or rachis, stipules, leaf, inflorescence, flower, fruit and seed forms, also exudate, smell and glands. Supporting data was recorded and documented, *i.e.* coordinate and climatic factors (air temperature, relative humidity, soil pH and soil humidity). For those unidentified and particular suspect, more detailed identification were conducted by collecting voucher specimens (Damery et al. 2011) to be identified in Herbarium Bogoriense (BO) of the Research Center for Biology, Indonesian Institute of Sciences, Cibinong-Bogor, West Java, Indonesia.

### Classification by plant habit

We classified diversity of plant based on its plant habit. Plant habit refers to the overall shape of a plant. It refers to the genetic tendency of a plant to grow in a certain shape and to attain a certain mature height and spread. The classification of plant habit includes trees, shrubs, vines, climber, woody climber, herbaceous (annual and perennial), epiphytic (fern and orchid), terrestrial (fern and orchid), tuber and rhizome (Jud et al. 2007).

### Conservation status: evaluation, bioprospecting and plant invasiveness determination

The conservation status of plant species were evaluated using application of International Union for Conservation of Nature: Conservation Categories and Criteria (IUCN 2011) on its official website, *i.e.* <http://www.iucnredlist.org/search>. Whilst, interviews to local residents were conducted to gather bioprospecting information of the plants focusing on its uses as food sources, timber and ornaments. Prior informed consent (PIC) was obtained verbally before commencing each interview (Ellena et al. 2012). The plant invasiveness were determined by looking out from literature list of invasive plant species in Indonesia (Tjitrosoedirdjo 2005), from invasive alien plant species database of SEAMEO Biotrop and the State Ministry of the Environment (<http://www.biotrop.org/database.php?act=dbias>) and also from some world's invasive alien plant species databases.



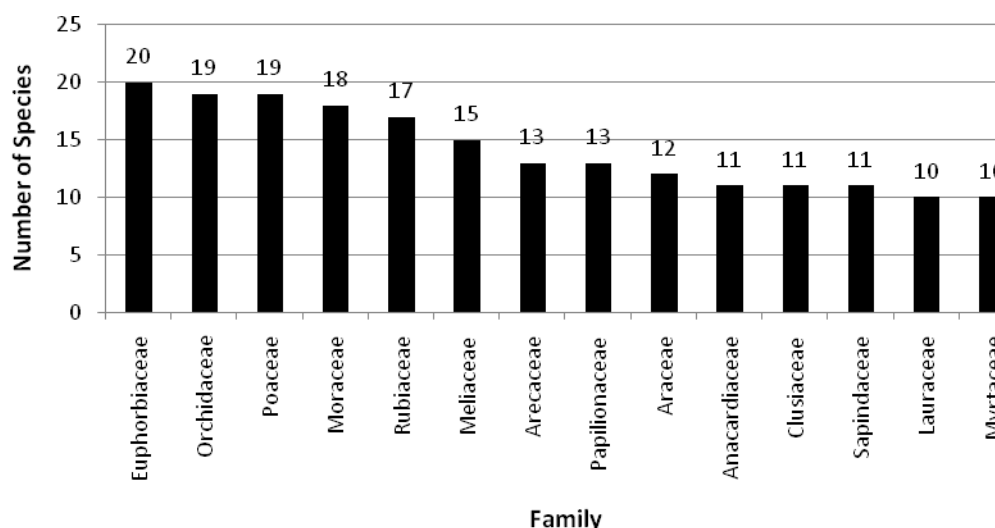
**Figure 1.** Maps of Bawean Island: botanical surveys covering 13 montane forests: 1. Langger, 2. Pakem, 3. Pakotokan, 4. Nangka, 5. Panjang, 6. Mandala, 7. Bangkuang, 8. Lumut, 9. Asakan, 10. Gadung, 11. Kastoba, 12. Pangambaan, 13. Payung-payung

**RESULTS AND DISCUSSION**

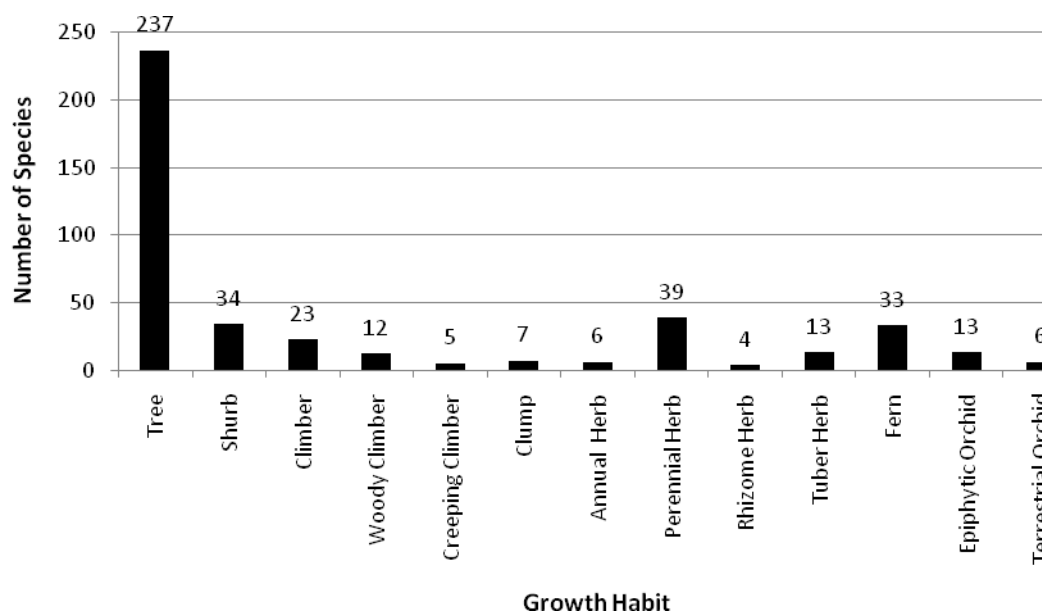
**Plant inventory in 13 montane forests of Bawean Island**

Plant inventory results showed that it registers about 432 plant species under 287 genera and 103 families in 13 montane forests of Bawean Island within altitudes 8 to 572 m above sea level. Plant species under Euphorbiaceae Family were the most commonly found; followed by Orchidaceae, Poaceae, Moraceae, Rubiaceae, and so on (Figure 2.A). The complete list of plant species is showed in Table S1. The abundance of Euphorbiaceae indicated

that montane forests in Bawean Island has carried out succession process. Member of Euphorbiaceae i.e. *Homalanthus populneus* and *Macaranga tanarius* were categorized as pioneer plant species in early stages of secondary succession in montane forests (van Valkenburg and Ketner 1994). In addition there were about 13 species of *Ficus* spp. (Moraceae). *Ficus* is known as key species in tropical rain forests in which some of them are pioneer in dry habitats (Lee et al. 2013); like in limestone soil of Bawean Island.



**Figure 2.** Inventory results of plant families with 10 and above species member in 13 montane forests of Bawean Island Nature Reserve, Indonesia



**Figure 3.** Growth habit diversity of plants inventoried in 13 montane forests of Bawean Island Nature Reserve, Indonesia

Based on its growth habit, it was grouped into 14 habits in which tree plants were found dominant with about 237 species and then followed by ferns, shrubs, perennial herbs and climbers which were found in moderate amount, and so on (Figure 3). Plant habit provides important information about its ecology (Jud et al. 2007). The high diversity of plant habits in 13 montane forests in Bawean Island indicates the diversity of macro and micro climates of the forests. This study showed that the soil temperature ranged 26,4 °C to 39,1 °C, relative humidity was 77 % to 95 %, pH was 5,1 to 6,8 and light intensity was 1760 to 93500 lux.

#### Trees

Tree plants are found dominant in 13 Montane Forests of Bawean Island. It was recorded about 237 species

(Figure 3) under 144 genera and 51 families. High diversity and density of tree plants were supported by high relative humidity of the forest (79% to 99%). Tree plants provide shades as habitat for annual/perennial herbaceous plants and ferns. Tree plants also has important roles as host tree (phorophytes) and habitat of epiphytic plants and climber plants.

*Irvingia malayana* (Simaroubaceae) (Figure 4.A) and *Ficus variegata* (Moraceae) (Figure 4.C) were known as the dominant trees in Bawean Island. It was distributed in primary or secondary forests of the island. Furthermore, the high important value of tree plants in 7 montane forests of Bawean Island were *Myristica guatteriaefolia* (Myristicaceae), *Canarium asperum* (Burseraceae), *Syzygium garciniifolium* (Myrtaceae), *Pittosporum moluccanum* (Pittosporaceae),

*Calophyllum soulattri* (Clusiaceae), *Dysoxylum densiflorum* (Meliaceae), *Garcinia dioica* (Clusiaceae), and *Garcinia celebica* (Clusiaceae) (Trimanto 2014).

Tree plant species in Bawean Island were more similar to Java Island than to Borneo Island. *Podocarpus brateatus* (Podocarpaceae), *Aglaia lawii* (Meliaceae), *Canarium asperum* (Burseraceae), *Pongamia pinnata* (Papilionaceae), *Lepisanthes rubiginensis* (Sapindaceae), *Poliscias nodosa* (Araliaceae), *Caryota mitis* (Arecaceae) and *Suregeda glomerulata* (Euphorbiaceae) were commonly distributed at disjunctive locations in Sumatra, Sulawesi, Java, Flores Island and Papua. However, those species were not recorded to be available in Borneo (Lemmens et al. 1995; World Conservation Monitoring Centre 1998a; Farjon 2013).

#### Shrubs

It was recorded about 34 shrub species (Figure 3) under 27 genera and 16 families. They were mostly from Rubiaceae Family comprised of 8 species, followed by Verbenaceae, Acanthaceae, Annonaceae, Euphorbiaceae, Malvaceae, etc. Some other shrub species found included *Barleria lupulina* (Acanthaceae), *Orophea enneandra* (Annonaceae), *Capparis micracantha* (Capparaceae), *Jatropha curcas* (Euphorbiaceae), *Scaevola taccada* (Goodeniaceae), *Hibiscus macrophyllus* (Malvaceae), *Ficus montana* (Moraceae), *Ardisia crispa* (Myrsinaceae), *Cephaelis ipecacuanha* (Rubiaceae), *Ixora javanica* (Rubiaceae), *Allophylus cobbe* (Sapindaceae), *Clerodendrum buchananii* (Verbenaceae), etc.

#### Climbers (general, woody and creeping)

Climber plant was classified into general climber, woody climber and creeping climber. In general climber plants, it was recorded about 23 species (Figure 3) under 18 genera and 10 families. Some climber plants were identified as new records in Bawean Island, i.e. *Hoya verticillata* (Asclepiadaceae), *Freycinetia excelsa* (Pandanaeae), *Freycinetia scandens* (Pandanaeae) and *Smilax zeylanica*. *Hoya verticillata* which are relatively widespread, occurring in India, Myanmar, Thailand, Indo-China, Malay Peninsula, and Sumatra to North Borneo (Kidyue et al. 2007). Those two Pandanaeae species were distributed in northern Australia to New Guinea (Hyland et al. 2010). *Smilax zeylanica* were found abundantly in Borneo Island (Purwodadi Botanic Garden and Indo Tambangraya Megah 2016) but no record in Java Island (Priyadi et al. 2010).

Woody climber plants were recorded about 11 species (Figure 3) under 10 genera and 9 families. Woody climber plants commonly found were *Gnetum gnemoides* (Gnetaceae) and *Tinospora crispa* (Menispermaceae). The plants grew very well and produced many fruits; it became fodder for wild animals on the island as evidenced by the bitten marks on the fruit peels. *Tinospora crispa* are widely cultivated in Java, it is used as herbal medicine (Backer 1963). The other woody climber species were *Uvaria* sp. (Annonaceae) (Figure 4.D), *Zizyphus oenoplia* (Rhamnaceae), *Poikilospermum suaveolens* (Cecropiaceae), *Hiptage benghalensis* (Malpighiaceae), *Schefflera elliptica* (Araliaceae), *Anamirta cocculus* (Menispermaceae), *Olex scanden* (Nephrolepidaceae), and

*Harrisonia perforata* (Simaroubaceae). Whilst, creeping climbers were recorded about 5 species (Figure 3) under 1 genus and 1 family i.e. *Piper cubeba*, *Piper retrofractum* and *Piper* spp. of the Piperaceae Family.

#### Clumps

Bamboo plants (Poaceae) have growth habit in form of clumps. It was recorded about 7 species (Figure 3) under 4 genera. It was found mostly around the river banks and water sources. Ecological functions of the bamboos are very important on soil erosion control, water conservation, land rehabilitation, and carbon overcoming (Zhou et al. 2005). In addition, some bamboo species are also found distributed in the forest and forest border. Bamboo species found included Bambu Duri (*Bambusa blumeana*), Bambu Ampel (*Bambusa vulgaris*), Bambu Ater/Betung Jawa (*Dendrocalamus asper*), Bambu Apus (*Gigantochloa apus*), Bambu Betung (*Gigantochloa ater*), Bambu Kuning (*Schizostachyum brachycladum*) (Figure 4.G), and Bambu Buluh (*Schizostachyum iraten*). Bamboos are utilized as popular material for building of traditional houses for local residents.

#### Herbaceous/herbs (annual and perennial)

Perennial herbs showed higher diversity than annual herbs. Annual herbs were recorded to have about 6 species (Figure 3) under 5 genera and 5 families i.e. *Cyathula prostrata* (Amaranthaceae), *Ageratum conyzoides* (Asteraceae), *Begonia* spp. (Begoniaceae), *Hyptis brevipes* (Lamiaceae) and *Hibiscus tiliaceus* (Malvaceae). Whilst, perennial herbs were recorded to have about 39 species (Figure 3) under 32 genera and 11 families including grasses (Poaceae), bananas (Musaceae), aroids (Araceae), etc (Table S1).

There are 19 species of grasses identified (Table S1). *Homalomena pendula* (Araceae) were mostly distributed in the wet land (Figure 4.H). *Crinum asiaticum* and *Pancratium zeylanicum* (Amaryllidaceae) were found only in coastal area. *Calathea lietzei* (Marantaceae) and *Curculigo orchioides* (Hypoxidaceae) were distributed in large populations but on specific location with high humidity. Wild banana species of *Musa acuminata* ssp. (Figure 4.H) and *Musa balbisiana* ssp. were found only in Kastoba Montane Forest. Wild *Musa acuminata* and *Musa balbisiana* were widespread in tropical and subtropical regions in Asia; however for *Musa balbisiana* in Bawean Island was suspected to be introduced by the local residents since it was endemic in northern India, China, most of Indochina to the Philippines (De Langhe et al. 2009).

#### Rhizome herbs

Rhizome herbs were recorded to have about 4 species (Figure 3) under 4 genera and 2 families i.e. Costaceae (*Costus speciosus*) and Zingiberaceae (*Alpinia galanga*, *Etilingera elatior*, *Gastrochilus panduratus*). Both families are mostly found in the lowland sites with high humidity. *Alpinia galanga* (local name= laos or lengkuas) is widely cultivated by local residents in their home garden for food spices and medicine. *Etilingera elatior* is consumed by local residents as side dishes.



**Figure 4.** Some of plant species found in 13 montane forests of Bawean Island Nature Reserve, Indonesia: A. *Irvingia malayana*, B. *Ficus variegata*, C. *Podocarpus rumphii*, D. *Uvaria* sp, E. *Hoya diversifolia*, F. *Freycinetia scandens*, G. *Schizolatum braci cladum*, H. *Homalomena pendula*, I. *Musa acuminata* wild *Musa*), J. *Amorphophallus mulerii*, K. *Tacca leontopetaloides*, L. *Tacca palmata*, M. *Dioscorea hispida*, N. *Selaginella plana*, and O. *Phalaenopsis amabilis*

### Tuberous herbs

Tuberous herbs were recorded to have about 15 species (Figure 3) under 5 genera and 3 families comprised of Araceae (*Amorphophalus* spp., *Colocasia esculenta*, *Xanthosoma sagittifolium*), Dioscoreaceae (*Dioscorea* spp.) and Taccaceae (*Tacca* spp.) (Figure 4.J-M). They were mostly found in the lower plains and grew well at dry and sandy soil. They were prospected as alternative food sources for consumption.

*Tacca leontopetaloides* is geophyte tuber which commonly grows in grasslands, forests, river banks, under shades or full sun (Contu 2013). It was distributed from Western Africa through Southeast Asia to Northern Australia. The finding of *Tacca leontopetaloides* (Figure 4.K) in Bawean Island was a new record. It was found in small population at Payung-payung Montane Forest.

### Ferns (terrestrial and epiphytic)

Ferns were recorded to have about 33 species under 21 genera and 18 families. Terrestrial ferns were more diverse and abundant (26 species) than epiphytic ferns (7 species) (Figure 3). The terrestrial ferns were dominated by *Selaginella plana* (Sellaginellaceae) (Figure 4.N). In surrounding of water springs, there were several ferns grow well such as *Angiopteris evecta* (Angiopteridaceae), *Adiantum caudatum* (Adiantaceae), *Lygodium cyrcinatum* (Schizaeaceae), *Pteris ensiformis* (Pteridaceae). Tree fern such as *Cyathea contaminans* (Cyatheaceae) was only found in high elevation. According to Posthumus (1927), it is noted that ferns in Bawean Island are also found on Java Island, and some found in Borneo. There were about 49 species of ferns during 1924-1928 (Posthumus 1927). From this study, it can be revealed that there was a decrease of fern species in Bawean Island with about 32, 65% in 2014 (33 species).

### Orchids (terrestrial and epiphytic)

Orchids were recorded to have about 19 species under 17 genera (Table S1). It comprised of 6 terrestrial orchids and 13 epiphytic orchids (Figure 3). The terrestrial orchids found were *Nervilia aragoana*, *Nervilia plicata*, *Habenaria digitata*, *Malaxis* sp., *Calanthe* sp., and *Geodorum* sp. with *Nervilia aragoana* as the dominant species. Whilst, epiphytic orchids found in Bawean Island included *Phalaenopsis amabilis* (Figure 4.O), *Aerides odorata*, *Eria javanica*, *Cymbidium aloifolium*, *Dendrobium anosmum*, *Liparis condylobulbon*, *Rhynchostylis retusa*, *Pholidota imbricata*, *Taeniophyllum bicuspidatum*, *Cymbidium* sp., *Dendrobium* sp., *Aerides* sp. and *Eria* sp.

*Phalaenopsis amabilis* (Figure 4.O) was the most abundance epiphytic orchid found in several Montane Forests. The host trees (phorophytes) recorded included *Euonimus javanicus* (Celastraceae), *Leea angulata* (Leeaceae), *Schleicera oleosa* (Sapindaceae), *Antidesma petandrum* (Euphorbiaceae), *Ficus variegata* (Moraceae) (Figure 4.B) and *Tectona grandis* (Verbenaceae). Most of epiphytic orchids live on zone 3 (the basal; one third of large branches), 4 (the middle third) and 5 (the upper third) of the trunk (Marsusi et al. 2001).

### Conservation status of plant bioresources in Bawean Island

Conservation status evaluation showed that there are at least 33 species of plants which were included in the IUCN list whereas the others were unknown. About 30 plant species were categorized as least concern which means at lower risk of extinction. It was found widespread and abundant in Bawean Island (Table 1). Three plant species considered in higher risk of extinction in the wild including *Podocarpus rumphii* (Near threatened/NT); *Pterocarpus indicus* and *Memecylon myrtilloides* (Vulnerable/VU). *Podocarpus rumphii* and *Pterocarpus indicus* are tree plant species which are good sources of timber, therefore special attentions are needed in advocating the conservation of those plant species.

*Podocarpus rumphii* is widely distributed in South East ASia to New Guinea (Lemmens et al. 1995). It is a constituent of lowland to lower montane tropical rainforests, where it can be locally common. Despite its vast range and occurrence in many locations where the forest remains undisturbed, there is evidence of decline due to logging, especially in the Philippines. The extent of the decline may be approaching 30% over the past 75 years (Farjon 2013).

*Pterocarpus indicus* has wide geography distribution ranges from southern Myanmar to the Philippines and throughout the Malay Archipelago to New Guinea and the Solomon Islands with considerable morphological and ecological variation when viewed throughout its range. Subpopulations of *Pterocarpus indicus* have declined because of overexploitation, sometimes illegal exploitation for its timber, as well as the increasing general habitat loss (World Conservation Monitoring Centre 1998b; Orwa 2009).

*Memecylon myrtilloides* is shrub or small tree reaching 3 m, mostly found in upland rainforest. *Memecylon* species is reported having potential pharmacological activities (Sivu et al. 2013). However, there is a continuing decline in the extent and the quality of habitat of this species so that it is concluded as vulnerable (IUCN SSC East African Plants Red List Authority 2013).

### Bio-prospecting of local plant genetic resources

#### Food sources

Plants which are prospected to become alternative food sources in Bawean Island are mostly from tuberous plants belong to the families of Dioscoreaceae, Taccaceae and Araceae (Table 2). Root and tuber crops are plants that produced starchy organs in forms of roots, rhizomes, corms, stems and tubers. It contained of approximately 70-80% water, 16-24% starch and trace quantities (<4%) of proteins and lipids (Hoover 2000). Each of tubers has their own nutrition and anti-nutrition properties which are also potential characters (Table 2.A). Some antinutritional substances including total free phenolics, tannins, hydrogen cyanide, total oxalate, amylase and trypsin inhibitor however it can be inactivated and eliminated by moist heat treatment and soaking followed by cooking before consumption (Shajeela et al. 2011).

**Table 1.** Plant species in 13 montane forests of Bawean Island Nature Reserve, Indonesia which included in IUCN list

Species name	Local name (Indonesian)	Family	IUCN status
<i>Aglaia lawii</i>	Sampar Kidang	Meliaceae	Least Concern
<i>Aglaia odoratissima</i>	-	Meliaceae	Least Concern
<i>Alstonia scholaris</i>	Pulai	Apocynaceae	Least Concern
<i>Arytera littoralis</i>	-	Sapindaceae	Least Concern
<i>Avicennia alba</i>	Api-api	Avicenniaceae	Least Concern
<i>Calophyllum inophyllum</i>	Nyamplung	Clusiaceae	Least Concern
<i>Calophyllum soulattri</i>	Bintangur	Clusiaceae	Least Concern
<i>Canarium asperum</i>	Kenari	Burseraceae	Least Concern
<i>Centella asiatica</i>	Pegagan	Apiaceae	Least Concern
<i>Colocasia esculenta</i>	Bentul	Araceae	Least Concern
<i>Dolichandrone spathacea</i>	Kijaran	Bignoniaceae	Least Concern
<i>Eleusine indica</i>	Rumput Belulang	Poaceae	Least Concern
<i>Erythrina variegata</i>	Dadap	Fabaceae	Least Concern
<i>Euonymus javanicus</i>	-	Celastraceae	Least Concern
<i>Excoecaria agallocha</i>	Kibuta	Euphorbiaceae	Least Concern
<i>Gnetum gnemon</i>	Melinjo	Gnetaceae	Least Concern
<i>Gnetum gneumonoides</i>	Melinjo	Gnetaceae	Least Concern
<i>Horsfieldia irya</i>	Kayu Rah	Myristicaceae	Least Concern
<i>Irvingia malayana</i>	Bongin	Simaroubaceae	Least Concern
<i>Mangifera foetida</i>	Mangga	Anacardiaceae	Least Concern
<i>Memecylon myrtilloides*</i>	Tulangan	Melastomataceae	Vulnerable
<i>Michelia champaca</i>	Cempaka	Magnoliaceae	Least Concern
<i>Myristica guatteriiifolia</i>	Pala Hutan	Myristicaceae	Least Concern
<i>Paspalum conjugatum</i>	Rumput Kerbau	Poaceae	Least Concern
<i>Podocarpus bracteatus</i>	Jamuju	Podocarpaceae	Least Concern
<i>Podocarpus rumphii*</i>	Jamuju	Podocarpaceae	Near Threatened
<i>Pogonatherum panicum</i>	Rumput pring-pringan	Poaceae	Least Concern
<i>Pongamia pinnata</i>	Kacang Kayu Laut	Papilionaceae	Least Concern
<i>Prunus arborea</i>	Kayu Tinggi	Rosaceae	Least Concern
<i>Prunus javanica</i>	Kayu Tinggi	Rosaceae	Least Concern
<i>Pterocarpus indicus*</i>	Sena, Angsana	Fabaceae	Vulnerable
<i>Tacca leontopetaloides</i>	-	Taccaceae	Least Concern
<i>Tetrameles nudiflora</i>	Winong	Datisceae	Least Concern

**Table 2.** Plants bioprospeted as food sources in Bawean Island Nature Reserve, Indonesia

Species name	Local name	Family	Notes
<i>Dioscorea alata</i>	Uwi	Dioscoreaceae	High carbohydrates, fiber, mineral and vitamin (Wanasundera and Ravindan 1994); high protein, carbohydrate and vitamin C (Udensi et al. 2008)
<i>Dioscorea bulbifera</i>	Uwi gantung	Dioscoreaceae	High carbohydrates and easy to produces tubers; rich of flavonoid, phenolics, reducing sugars, starch, diosgenin, ascorbic acid, and citric acid (Chopade et al. 2012)
<i>Dioscorea hispida</i>	Gadung	Dioscoreaceae	High demands, can be processed into variety of foods, hypoglycemic index which is good for diabetes diet (Estiasih et al. 2012),
<i>Tacca leontopetaloides</i>	Iles-iles	Taccaceae	High carbohydrates; contains of chemical compounds for medication, flavonoid, saponin and antioxidant (Contu 2003; Ubwa et al. 2011)
<i>Tacca palmata</i>	Iles-iles	Taccaceae	High carbohydrates; contains of chemical compounds for medication, potentially useful lead compounds for anti-cancer properties (Contu 2003; Hemscheidt 2004)
<i>Amorphophallus campanulatus</i>	Suweg	Araceae	High carbohydrates, glucomannan (for foods and pharmaceutical) and fiber. High demands in international market, have potentials as antibacterial, antifungal and cytotoxic activities (Sumarwoto 2005; Khan et al. 2007)
<i>Amorphophallus variabilis</i>	Suweg	Araceae	High carbohydrates, glucomannan (for foods and pharmaceutical) and fiber. High demand in international market, lowered blood cholesterol levels (Sumarwoto 2005; Harijati et al. 2011)
<i>Amorphophallus muelleri</i>	Iles-iles, Porang	Araceae	High glucomannan and fiber. As water purifier and floating colloid in beer, sugar, and oil industry (Indriyani et al. 2011)
<i>Colocasia esculenta</i>	Talas	Araceae	Easy to be cultivated and harvested; high carbohydrates, protein and fiber also low fat (Sefa-Dedeh and Agyir-Sackey 2004).
<i>Xanthosoma sagittifolium</i>	Kimpul	Araceae	Easy to be grown and harvested, produce big size of tubers. High carbohydrates, protein and fiber, low fat (Sefa-Dedeh and Agyir-Sackey 2004).



**Table 3.** Plants bioprospected as timber in Bawean Island Nature Reserve, Indonesia

Species name	Local name	Family	Wood density (gr/cm <sup>3</sup> )
<i>Diospyros blancoi</i>	Bisbul	Ebenaceae	0.88
<i>Irvingia malayana</i>	Kayu buluh	Irvingiaceae	0.84
<i>Garcinia celebica</i>	Manggis hutan	Clusiaceae	0.76
<i>Protium javanicum</i>	Trenggulun	Burseraceae	0.75
<i>Adenantha pavonina</i>	Saga	Mimosaceae	0.70
<i>Leea angulata</i>	Birang	Leeaceae	0.68
<i>Aglaia lawii</i>	Sampar kidang	Meliaceae	0.61
<i>Calophyllum inophyllum</i>	Nyamplung	Clusiaceae	0.60
<i>Dysoxylum densiflorum</i>	Keduya	Melastomataceae	0.57
<i>Diospyros maritima</i>	Kayu hitam	Ebenaceae	0.56
<i>Pterocarpus indicus</i>	Angsana	Papilionaceae	0.54
<i>Sterculia foetida</i>	Kepuh	Sterculiaceae	0.51
<i>Canarium hirsutum</i>	Kenari	Burseraceae	0.50
<i>Canarium asperum</i>	Kenari	Burseraceae	0.48
<i>Podocarpus bracteatus</i>	Jamuju	Podocarpaceae	0.46
<i>Podocarpus rumphii</i>	Jamuju	Podocarpaceae	0.46
<i>Macaranga tanarius</i>	Karahan	Euphorbiaceae	0.43
<i>Calophyllum soulattri</i>	Bintangur	Clusiaceae	0.43
<i>Planchonella nitida</i>	-	Sapotaceae	-

Wood density reference: Chave et al. 2009; Zanne et al. 2009)

**Table 4.** Plants bioprospected as ornamental in Bawean Island Nature Reserve, Indonesia

Species name	Local name	Family	Notes
<i>Adiantum caudatum</i>	Suplir	Adiantaceae	Beautiful foliage of fern
<i>Adiantum hispidatum</i>	Suplir	Adiantaceae	Beautiful foliage of fern
<i>Tectaria polymorpha</i>	-	Aspidiaceae	Liana fern, can be used to ornaments pergola
<i>Asplenium nidus</i>	Paku Sarang Burung	Aspleniaceae	Epiphytic fern, bird nest-like
<i>Blechnum orientale</i>	Paku Lencir, Paku Lubang	Blechnaceae	Epiphytic fern, unique foliage
<i>Pteris biaurita</i>	Paku Pedang	Pteridaceae	Terrestrial fern, beautiful foliage
<i>Cyathea contaminans</i>	Paku tiang	Cyatheaceae	Beautiful tree fern
<i>Angiopteris evecta</i>	Paku Gajah	Angipteridaceae	Beautiful tree fern
<i>Crinum asiaticum</i>	Bakung	Amaryllidaceae	White beautiful flower
<i>Dischidia imbricata</i>	Benikan	Asclepiadaceae	Liana, beautiful foliage and flowers
<i>Hoya diversifolia</i>	Hoya	Asclepiadaceae	Liana, beautiful foliage and flowers
<i>Hoya verticillata</i>	Hoya	Asclepiadaceae	Liana, beautiful foliage and flowers
<i>Homalomena pendula</i>	Nampu	Araceae	Herbaceous, beautiful foliage and fragrant, suitable for indoor plant
<i>Curculigo orchioides</i>	Bedur, Kokrok	Hypoxidaceae	Herbaceous, beautiful foliage and flowers
<i>Phalaenopsis amabilis</i>	Anggrek Bulan	Orchidaceae	Epiphytic orchid, beautiful flower
<i>Aerides odorata</i>	Anggrek Kuku Macan	Orchidaceae	Epiphytic orchid, beautiful flower
<i>Cymbidium aloifolium</i>	Anggrek Cymbidium Daun Gaharu	Orchidaceae	Epiphytic orchid, beautiful flower
<i>Eria javanica</i>	Anggrek Eria Kancil	Orchidaceae	Epiphytic orchid, beautiful flower
<i>Rhynchostylis retusa</i>	Angrek Ekor Tupai	Orchidaceae	Epiphytic orchid, beautiful flower
<i>Liparis condylobulbon</i>	-	Orchidaceae	Epiphytic orchid, beautiful flower
<i>Dendrobium bracteosum</i>	Anggrek Karang	Orchidaceae	Epiphytic orchid, beautiful flower
<i>Dendrobium anosmum</i>	Anggrek Mata Sapi	Orchidaceae	Epiphytic orchid, beautiful flower
<i>Freycinetia excelsa</i>	Pandan rambat	Pandanaceae	Creeping pandan, suitable for outdoor plants
<i>Cissus javana</i>	-	Vitaceae	Vine, color-full foliage, and climber
<i>Costus speciosus</i>	Pacing	Costaceae	Herbaceous, beautiful foliage and flowers
<i>Areca catechu</i>	Pinang	Arecaceae	Beautiful foliage of palm, suitable for outdoor plants
<i>Areca montana</i>	Jambe rende	Arecaceae	Beautiful foliage of palm, suitable for outdoor plants
<i>Caryota mitis</i>	Gendaru/ Palem Ekor Ikan	Arecaceae	Beautiful foliage of palm, suitable for outdoor plants

The tuber production of *Amorphophallus* spp. in agroforestry system may reach up to 8-9 tonnes/ha (Arisoesilansih et al. 2009). Farmers in Nganjuk Regency, East Java mostly planted *Dioscorea* spp. in agroforestry system intercropped with tree plants or in land

between rice fields without any special agronomy practices and may harvested about 15-20 tubers per plant (Trimanto and Hapsari 2015). Agro-climatic condition of Bawean Island which is low land area with low intensity of rain and loose soil are optimum for the growth of tuberous plants.

Domestication of those tuberous plants followed by adoption of agricultural techniques may enhance its yield productivity.

#### *Timber*

The uses of woods to build local traditional houses (local name: rumah panggung) must take into account the conservation aspect of woody plants in Bawean Island. Local residents of Bawean Island cultivated some woody plants in their private lands to harvest its timber such as *Tectona grandis* (Verbenaceae), *Gmelina arborea* (Verbenaceae), and *Swietenia macrophylla* (Meliaceae) but yet illegal logging to forests in nature reserve are also still happening according to informations from the rangers of Bawean Island Nature Reserve.

There are at least 19 species of woody plants from the montane forests that have the potential to be developed as timber plants (Table 3). The wood of *Irvingia malayana* is good to build heavy construction, wall paneling, cabinet work, furniture, pulp for making paper, railway sleepers and supporting goods, etc. (Sosef et al. 1998). The local residents use its woods mostly for pole structures and roofs of the local house. Its wood density is quite high, only slightly lower than *Diospyros blanchoi* (Family of Ebony wood) (Table 3). Woods of the Genus *Diospyros* has good quality timber and it is easy to propagate in the low lands by seeds (Lemmens et al. 1995). In addition to its wood, *Diospyros blanchoi* also produced edible fruits for dessert. In some countries *Diospyros blanchoi* fruit are processed into various foods (Regucivilla 2013). *Podocarpus bracteatus* is an important timber species in Java. The wood is used for house construction and for making oars; spars and masts ship so that conservation is important for this species (Sosef et al. 1998).

Based on data obtained from the Central Conservation of Bawean Nature Reserve (unpublished), it is shown that illegal logging is a problem as it often happens in the conservation area. Illegal logging occurs in some montane forests *i.e.* Besar, Taneden, Payung-payung, and Alas Timur. Any cultivation efforts are needed instead of extracting from the forests in order to stop illegal logging practices and also to improve the economic level of surrounding local community. Cultivation efforts especially to those three higher risks IUCN list *i.e.* *Podocarpus rumphii*, *Pterocarpus indicus* and *Memecylon myrtilloides* may support and lower its conservation status.

#### *Ornamentals*

Most of the local houses in Bawean Island were decorated with ornamental plants gathered from the forests. There are at least 28 local plant species in the forest which are prospected as ornamental plant (Table 4). It consists of orchids, ferns, herbaceous plants, epiphytes, vines, palm, *etc.* Orchid species commonly found in the home garden are *Phalaenopsis amabilis* and *Dendrobium anosmum*. Plants of Genus *Hoya* also have potential as ornamental plants including *Hoya verticillata* which was considered as a new record in Bawean Island and *Hoya diversifolia* (Figure 4.E). *Hoya* plant is easy to propagate by its vegetative parts. They have beautiful flowers and suitable

as indoor ornamental plants. The cultivation and development of ornamental plants in Bawean Island is very potential to be carried out.

#### **Bawean Island as conservation area or tourism destination?**

Small islands, whether located in the tropics or higher latitudes, have characteristics which make them especially vulnerable to the effects of climate change, sea-level rise, and extreme events of disasters. It is worsened by anthropogenic activities such as destruction and fragmentation of natural habitats, conversion of forests into residential areas and well-being for food, timber production/logging, tourism, *etc.* It becomes threats for plant bioresources degradation and extinction in small island (Mimura et al. 2007). Interview to forest police officers in Bawean Island Nature Reserve has given information that illegal logging and forest fires are common problem in the forest, and also tourism which are not well managed.

The increasing population, along with the development progress in Bawean Island, advocates the importance to note aspects of conservation of the island. However, the economic need enforces people to open the conservation area for tourism destination *i.e.* Kastoba Lake which is located in the hilltop of Kastoba Montane Forest with 725 ha width; it offers calm and crystal clear water with natural hilly landscape of forests (Figure 5.A) and the sanctuary of endemic Bawean deer in Tampo Sangkapura Village (Figure 5.B). The sanctuary is objected as conservatory for critically endangered Bawean deer due to deterioration of its natural habitat. Mandala and Lumut Montane Forests are also potential as tourism destinations. In addition to tourism in mountains environment, coastal environments in Bawean island are also attractive and potential as popular tourism destinations.

The development of some places in Bawean Island into tourism destination must consider its initial functions as conservation areas. It supposed to be eco-tourism destinations. Ecotourism focuses on socially responsible travel, personal growth, and environmental sustainability; is intended as a low-impact and often at small scale, as an alternative to standard commercial (mass) tourism (Honey 2008). Eco-tourists should be very caring towards environmental sustainability. In term of the opening access of natural protected areas in Bawean Island as eco-tourism destination, in addition to improved economic needs of local government and residents, it also give negative impacts to the environment which may occur in form of unexpected changes including pollution or degradation to landscapes, vegetation community structure, wildlife, invasive alien species, piled of garbage, *etc.* Therefore, some regulations must be created by local and central government to support the development of eco-tourism in Bawean Island.

It is widely recognized that invasive alien species are the second most severe threat to biodiversity after habitat destruction and that the impacts of invasive species are particularly severe on small island ecosystems (Clubbe and Hamilton 2010). Such movement, like tourism, may



**Figure 5.** Some tourism destinations in Bawean Island Nature Reserve, Indonesia: A. Kastoba Lake, B. Bawean deer sanctuary

become one of ways to introduce and spread the species wider. From this study, it is showed that at least 7 invasive alien plant species were identified to be occurred in Bawean Island including *Ageratum conyzoides*, *Chromolaena odorata*, *Eupatorium inulifolium*, *Lantana camara*, *Imperata cylindrica*, *Stachytarpheta jamaicensis* and *Themeda arguens* (Lowe et al. 2000; Tjitrosoedirdjo 2005).

The invasive plant species were mostly in form of shrubs, small trees and herbaceous habitats. They grow abundantly, forms dense stands and mostly have allelopathic effects that prevent the establishment of other plant species. It becomes serious problem as it spreads rapidly via seeds and root suckers (Hapsari et al. 2014). The environmental impact of an alien plant species whether it becomes invasive at its destination depends on its biological key point, what ecological role the species may play, and on additional factors such as its tolerance of the gross features of the environment in the new range (GISP-CITES 2000). It was reported that the invasion of exotic plant species *Chromolaena* and regrowth of *Tectona grandis* caused deterioration quality the natural habitat of Bawean deer, in which resulted population decrease of Bawean deer (Semiadi et al. 2015). Thus, active management of habitat through control of invasive plant species is needed.

Active conservation on the botanical heritage is needed to face rapidly acceleration impact of human development as well as global climate change. This study provides important information about the richness, conservation status, valuation of the economic prospects of plant genetic resources and some notes on potential tourism in Bawean Island. This information is essential for decision making process concerned with biodiversity conservation and sustainable natural resources management in the island.

In addition to in-situ conservation on the natural protected areas, botanic gardens have opportunity and responsibility for significant involvement in conservation of local plant genetic resources. Botanic gardens form

effective network for biodiversity conservation and sustainable utilization besides their role in maintaining ecological balance preventing environmental degradation. Some conservation efforts may include ex-situ conservation in botanic gardens, develop seed banks, raise nursery and cultivation of economic prospected plants in the island to prevent from illegal logging and over extraction, eco-tourism development, etc. (Singh et al. 2014). From this botanical survey in Bawean Island, it was collected about 197 access numbers of plants to be ex-situ conserved in Purwodadi Botanic Garden, Pasuruan, East Java. It consists of 692 specimens in form of seedlings, cuttings, seeds, suckers, corms, tubers and bulbils.

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**Table S1.** List of inventory plant species in Bawean Island

<b>Acanthaceae</b>	<i>Caryota mitis</i>	<b>Capparaceae</b>	<i>Homalanthus populneus</i>
<i>Barleria lupulina</i>	<i>Caryota</i> sp1	<i>Capparis micracantha</i>	<i>Jatropha curcas</i>
<i>Clinacanthus nutans</i>	<i>Caryota</i> sp2	<b>Cecropiaceae</b>	<i>Macaranga tanarius</i>
<i>Gendarussa vulgaris</i>	<i>Cocos nucifera</i>	<i>Poikilospermum suaveolens</i>	<i>Phyllanthus buxifolius</i>
<i>Hypoestes polythyrsa</i>	<i>Daemonorops</i> sp.	<b>Celastraceae</b>	<i>Suregada glomerulata</i>
<i>Pararuellia napifera</i>	<i>Licuala</i> sp.	<i>Euonymus javanicus</i>	<b>Flacourtiaceae</b>
<i>Ruellia tuberosa</i>	<i>Livistona chinensis</i>	<b>Clusiaceae</b>	<i>Flacourtia</i> sp.
<b>Adiantaceae</b>	<i>Metroxylon sagu</i>	<i>Calophyllum inophyllum</i>	<i>Scolopia spinosa</i>
<i>Adiantum caudatum</i>	<i>Pinanga caesia</i>	<i>Calophyllum soulattri</i>	<b>Flagellariaceae</b>
<i>Adiantum hispidulum</i>	<i>Pinanga coronata</i>	<i>Calophyllum</i> sp.	<i>Flagellaria indica</i>
<b>Amaranthaceae</b>	<i>Plectocomia elongata</i>	<i>Calophyllum</i> sp.	<b>Gleicheniaceae</b>
<i>Achyranthes aspera</i>	<b>Asclepiadaceae</b>	<i>Garcinia celebica</i>	<i>Gleichenia linearis</i>
<i>Cyathula prostrata</i>	<i>Dischidia imbicata</i>	<i>Garcinia dioica</i>	<b>Gnetaceae</b>
<b>Amaryllidaceae</b>	<i>Hoya diversifolia</i>	<i>Garcinia dulcis</i>	<i>Gnetum gnemon</i>
<i>Crinum asiaticum</i>	<i>Hoya verticillata</i>	<i>Garcinia glaucifolia</i>	<i>Gnetum gnemonoides</i>
<i>Pancratium zeylanicum</i>	<b>Aspidiaceae</b>	<i>Garcinia parviflora</i>	<i>Gnetum latifolius</i>
<b>Anacardiaceae</b>	<i>Tectaria polymorpha</i>	<i>Garcinia</i> sp.	<b>Goodeniaceae</b>
<i>Anacardium occidentale</i>	<i>Tectaria</i> sp.	<i>Garcinia</i> sp.	<i>Scaevola taccada</i>
<i>Buchanania arborescens</i>	<b>Aspleniaceae</b>	<b>Combretaceae</b>	<b>Hypoxidaceae</b>
<i>Dracontomelon mangiferum</i>	<i>Asplenium nidus</i>	<i>Terminalia catappa</i>	<i>Curculigo orchinoides</i>
<i>Dracontomelon dao</i>	<i>Asplenium</i> sp.	<i>Terminalia microcarpa</i>	<i>Curculigo</i> sp.
<i>Gluta renghas</i>	<b>Asteliaceae</b>	<i>Terminalia</i> sp.	<b>Lamiaceae</b>
<i>Lansea coromandelica</i>	<i>Cordyline fruticosa</i>	<b>Convolvulaceae</b>	<i>Gmelina arborea</i>
<i>Mangifera foetida</i>	<b>Asteraceae</b>	<i>Ipomoea pes-caprae</i>	<i>Gmelina asiatica</i>
<i>Mangifera indica</i>	<i>Ageratum conyzoides</i>	<i>Merremia peltata</i>	<i>Hyptis brevipes</i>
<i>Spondias pinnata</i>	<i>Chromolaena odorata</i>	<b>Costaceae</b>	<i>Salvia riparia</i>
<i>Spondias malayana</i>	<i>Eupatorium inulifolium</i>	<i>Costus speciosus</i>	<i>Vitex pinnata</i>
<i>Spondias</i> sp.	<i>Eupatorium riparium</i>	<b>Cyatheaceae</b>	<i>Vitex trifolia</i>
<b>Angiopteridaceae</b>	<i>Synedrella nodiflora</i>	<i>Cyathea contaminans</i>	<i>Vitex</i> sp.
<i>Angiopteris evecta</i>	<i>Wedelia trilobata</i>	<i>Cyathea</i> sp.	<b>Lauraceae</b>
<b>Annonaceae</b>	<b>Athyriaceae</b>	<b>Cyperaceae</b>	<i>Actinodaphne glomerata</i>
<i>Orophea enneandra</i>	<i>Athyrium esculentum</i>	<i>Cyperus kyllingia</i>	<i>Cinnamomum</i> sp.
<i>Polyalthia lateriflora</i>	<b>Averrhoaceae</b>	<b>Datisaceae</b>	<i>Cinnamomum verum</i>
<i>Saccopetalum</i> sp1	<i>Averrhoa bilimbi</i>	<i>Tetrameles nudiflora</i>	<i>Dehaasia caesia</i>
<i>Saccopetalum</i> sp2	<b>Avicenniaceae</b>	<b>Davalliaceae</b>	<i>Litsea firma</i>
<i>Trivalvaria macrophylla</i>	<i>Avicennia alba</i>	<i>Davallia trichomanoides</i>	<i>Litsea glutinosa</i>
<i>Trivalvaria</i> sp.	<b>Begoniaceae</b>	<b>Dennstaedtiaceae</b>	<i>Litsea</i> sp1
<i>Uvaria</i> sp1	<i>Begonia</i> sp1	<i>Microlepia speluncae</i>	<i>Litsea</i> sp2
<i>Uvaria</i> sp2	<i>Begonia</i> sp2	<b>Dilleniaceae</b>	<i>Neolitsea cassia</i>
<b>Apiaceae</b>	<b>Bignoniaceae</b>	<i>Tetracera scandens</i>	<i>Persea rimosa</i>
<i>Centella asiatica</i>	<i>Crescentia cujete</i>	<b>Dioscoreaceae</b>	<b>Leeaceae</b>
<b>Apocynaceae</b>	<i>Dolichandrone spathacea</i>	<i>Dioscorea bulbifera</i>	<i>Leea angulata</i>
<i>Alstonia scholaris</i>	<i>Oroxylum indicum</i>	<i>Dioscorea hispida</i>	<i>Leea rubra</i>
<i>Cerbera manghas</i>	<i>Radermachera gigantea</i>	<i>Dioscorea pentaphylla</i>	<b>Loganiaceae</b>
<i>Cerbera</i> sp.	<i>Radermachera</i> sp.	<i>Dioscorea</i> sp1	<i>Fagraea fragrans</i>
<i>Wrightia tomentosa</i>	<b>Blechnaceae</b>	<i>Dioscorea</i> sp2	<b>Lythraceae</b>
<b>Araceae</b>	<i>Blechnum orientale</i>	<b>Ebenaceae</b>	<i>Lagerstroemia speciosa</i>
<i>Alocasia macrorrhiza</i>	<i>Stenochlaena palustris</i>	<i>Diospyros javanica</i>	<b>Magnoliaceae</b>
<i>Alocasia</i> sp.	<b>Bombacaceae</b>	<i>Diospyros maritima</i>	<i>Michelia champaca</i>
<i>Amorphophallus campanulatus</i>	<i>Bombax ceiba</i>	<i>Diospyros</i> sp1	<b>Malpighiaceae</b>
<i>Amorphophallus variabilis</i>	<i>Ceiba pentandra</i>	<i>Diospyros</i> sp2	<i>Hiptage benghalensis</i>
<i>Amorphophallus blumei</i>	<i>Durio zibethinus</i>	<b>Euphorbiaceae</b>	<b>Malvaceae</b>
<i>Amorphophallus muelleri</i>	<b>Boraginaceae</b>	<i>Antidesma bunius</i>	<i>Abelmoschus manihot</i>
<i>Colocasia esculenta</i>	<i>Cordia bantamensis</i>	<i>Antidesma montanum</i>	<i>Hibiscus macrophyllus</i>
<i>Colocasia</i> sp1	<b>Burseraceae</b>	<i>Antidesma pentandrum</i>	<i>Hibiscus rosa-sinensis</i>
<i>Colocasia</i> sp2	<i>Canarium asperum</i>	<i>Antidesma</i> sp.	<i>Hibiscus tiliaceus</i>
<i>Homalomena pendula</i>	<i>Canarium hirsutum</i>	<i>Baccaurea</i> sp.	<i>Urena lobata</i>
<i>Typhonium trilobatum</i>	<i>Canarium oleosum</i>	<i>Blumeodendron tokbrai</i>	<b>Marantaceae</b>
<i>Xanthosoma sagittifolium</i>	<i>Canarium</i> sp.	<i>Codiaeum</i> sp.	<i>Calathea lietzei</i>
<b>Araliaceae</b>	<i>Garuga floribunda</i>	<i>Codiaeum</i> sp.	<b>Melastomataceae</b>
<i>Antrophyum</i> sp.	<i>Protium javanicum</i>	<i>Croton argyriatus</i>	<i>Melastoma malabathricum</i>
<i>Polyscias nodosa</i>	<b>Caesalpiniaceae</b>	<i>Croton caudatus</i>	<i>Memecylon floribundum</i>
<i>Schefflera elliptica</i>	<i>Peltophorum pterocarpum</i>	<i>Drypetes neglecta</i>	<i>Memecylon myrsinoides</i>
<b>Arecaceae</b>	<i>Senna alata</i>	<i>Drypetes</i> sp.	<i>Memecylon myrtilloides</i>
<i>Areca catechu</i>	<i>Senna multijuga</i>	<i>Excoecaria agallocha</i>	<b>Meliaceae</b>
<i>Areca montana</i>	<i>Senna siamea</i>	<i>Glochidion molle</i>	<i>Aglai eximia</i>
<i>Arenga pinnata</i>	<i>Tamarindus indica</i>	<i>Glochidion</i> sp.	<i>Aglai lawii</i>

**Table S1.** List of inventory plant species in Bawean Island (continued)

<b>Meliaceae</b>	<i>Syzygium</i> sp1	<i>Eleusine indica</i>	<i>Lepisanthes rubiginosa</i>
<i>Aglaiia</i> sp1	<i>Syzygium</i> sp2	<i>Eulalia amaura</i>	<i>Manilkara kauki</i>
<i>Aglaiia</i> sp2	<i>Syzygium</i> sp3	<i>Gigantochloa apus</i>	<i>Mischocarpus pentapetalus</i>
<i>Aglaiia</i> sp3	<i>Syzygium</i> sp4	<i>Gigantochloa atter</i>	<i>Mischocarpus</i> sp.
<i>Aphanamixis grandifolia</i>	<b>Nephrolepidaceae</b>	<i>Imperata cylindrica</i>	<i>Planchonella nitida</i>
<i>Melia azedarach</i>	<i>Nephrolepis cordifolia</i>	<i>Oplismenus burmannii</i>	<b>Sapotaceae</b>
<i>Sandoricum koetjape</i>	<i>Nephrolepis</i> sp.	<i>Oplismenus compositus</i>	<i>Schleichera oleosa</i>
<i>Aphanamixis</i> sp.	<i>Jasminum multiflorum</i>	<i>Paspalum conjugatum</i>	<i>Tristiropsis</i> sp1
<i>Chisocheton</i> sp.	<i>Olax scandens</i>	<i>Pogonatherum paniceum</i>	<i>Tristiropsis</i> sp2
<i>Dysoxylum densiflorum</i>	<b>Ophioglossaceae</b>	<i>Schizostachyum brachycladum</i>	<b>Simaroubaceae</b>
<i>Dysoxylum gaudichaudianum</i>	<i>Helminthostachys zeylanica</i>	<i>Schizostachyum iraten</i>	<i>Brucea javanica</i>
<i>Dysoxylum</i> sp.	<i>Helminthostachys</i> sp.	<i>Themeda arguens</i>	<i>Harrisonia perforata</i>
<i>Swietenia mahagoni</i>	<b>Orchidaceae</b>	<b>Podocarpaceae</b>	<i>Irvingia malayana</i>
<i>Toona sureni</i>	<i>Aerides odorata</i>	<i>Podocarpus bracteatus</i>	<i>Picrasma</i> sp.
<b>Menispermaceae</b>	<i>Aerides</i> sp.	<i>Podocarpus rumphii</i>	<b>Smilacaceae</b>
<i>Anamirta cocculus</i>	<i>Calanthe</i> sp.	<b>Polypodiaceae</b>	<i>Smilax zeylanica</i>
<i>Tinospora crispa</i>	<i>Cymbidium aloifolium</i>	<i>Drynaria quercifolia</i>	<b>Sterculiaceae</b>
<b>Mimosaceae</b>	<i>Cymbidium</i> sp.	<i>Drynaria rigidula</i>	<i>Helicteres hirsuta</i>
<i>Acacia auriculiformis</i>	<i>Dendrobium bracteosum</i>	<i>Pyrrhosia nummulariifolia</i>	<i>Kleinhovia hospita</i>
<i>Adenanthera pavonina</i>	<i>Dendrobium</i> sp.	<b>Proteaceae</b>	<i>Pterospermum javanicum</i>
<i>Albizia falcata</i>	<i>Eria javanica</i>	<i>Helicia serrata</i>	<i>Sterculia foetida</i>
<i>Albizia lebbekoides</i>	<b>Orchidaceae</b>	<i>Pteris biaurita</i>	<i>Sterculia</i> sp.
<i>Albizia procera</i>	<i>Eria</i> sp.	<i>Pteris ensiformis</i>	<i>Eurya nitida</i>
<b>Moraceae</b>	<i>Geodorum</i> sp.	<i>Pteris tripartita</i>	<b>Thelypteridaceae</b>
<i>Artocarpus elasticus</i>	<i>Habenaria</i> sp.	<i>Pteris</i> sp1	<i>Christella arida</i>
<i>Artocarpus heterophyllus</i>	<i>Liparis condylobulbon</i>	<i>Pteris</i> sp2	<i>Christella dentata</i>
<i>Artocarpus integer</i>	<i>Malaxis</i> sp.	<b>Rhamnaceae</b>	<i>Sphaerostephanos polycarpus</i>
<i>Artocarpus sericicarpus</i>	<i>Nervilia aragoana</i>	<i>Zizyphus oenoplia</i>	<b>Thymelaeaceae</b>
<i>Ficus ampelas</i>	<i>Nervilia</i> sp.	<b>Rhizophoraceae</b>	<i>Phaleria octandra</i>
<i>Ficus benjamina</i>	<i>Phalaenopsis amabilis</i>	<i>Rhizophora</i> sp.	<b>Tiliaceae</b>
<i>Ficus callophylla</i>	<i>Pholidota imbricata</i>	<i>Carallia</i> sp.	<i>Microcos tomentosa</i>
<i>Ficus callosa</i>	<i>Rhynchostylis retusa</i>	<b>Rosaceae</b>	<i>Schoutenia ovata</i>
<i>Ficus copiosa</i>	<i>Taeniophyllum bicuspidatum</i>	<i>Rubus rosaefolius</i>	<b>Ulmaceae</b>
<i>Ficus fistulosa</i>	<b>Pandanaceae</b>	<i>Prunus javanica</i>	<i>Celtis</i> sp.
<i>Ficus hispida</i>	<i>Freycinetia exelca</i>	<i>Prunus</i> sp.	<b>Urticaceae</b>
<i>Ficus montana</i>	<i>Freycinetia scandens</i>	<b>Rubiaceae</b>	<i>Laportea stimulans</i>
<i>Ficus padana</i>	<i>Pandanus tectorius</i>	<i>Anthocephalus cadamba</i>	<i>Pipturus argenteus</i>
<i>Ficus retusa</i>	<b>Papilionaceae</b>	<i>Cephaelis ipecacuanha</i>	<b>Verbenaceae</b>
<i>Ficus septica</i>	<i>Abrus precatorius</i>	<i>Ixora javanica</i>	<i>Clerodendrum buchananii</i>
<i>Ficus variegata</i>	<i>Centrosema pubescens</i>	<i>Ixora miquellii</i>	<i>Sterculia</i> sp2
<i>Ficus virens</i>	<i>Derris elliptica</i>	<i>Ixora paludosa</i>	<b>Taccaceae</b>
<i>Streblus asper</i>	<i>Derris</i> sp.	<i>Nauclea coadunata</i>	<i>Tacca leontopetaloides</i>
<b>Musaceae</b>	<i>Desmodium gangeticum</i>	<i>Nauclea lanceolata</i>	<i>Tacca palmata</i>
<i>Musa acuminata</i>	<i>Erythrina orientalis</i>	<i>Nauclea</i> sp.	<b>Theaceae</b>
<i>Musa balbisiana</i>	<i>Erythrina crista-gali</i>	<i>Paederia scandens</i>	<i>Planchonella nitida</i>
<i>Musa</i> sp.	<i>Moghania strobilifera</i>	<i>Pavetta indica</i>	<i>Palaquium</i> sp.
<b>Myristicaceae</b>	<i>Mucuna pruriens</i>	<i>Psychotria adenophylla</i>	<i>Palaquium</i> sp.
<i>Ardisia crispa</i>	<i>Mucuna</i> sp1	<i>Randia oppositifolia</i>	<i>Planchonella</i> sp.
<i>Ardisia humilis</i>	<i>Mucuna</i> sp2	<i>Tarenna fragrans</i>	<b>Schizaeaceae</b>
<i>Ardisia</i> sp1	<i>Pongamia pinnata</i>	<i>Canthium glabrum</i>	<i>Lygodium circinatum</i>
<i>Ardisia</i> sp2	<i>Pterocarpus indicus</i>	<i>Neonauclea</i> sp.	<b>Selaginellaceae</b>
<i>Embelia javanica</i>	<b>Piperaceae</b>	<i>Ixora</i> sp1	<i>Clerodendrum serratum</i>
<i>Knema laurina</i>	<i>Piper cubeba</i>	<i>Ixora</i> sp2	<i>Lantana camara</i>
<i>Myristica fatua</i>	<i>Piper retrofractum</i>	<b>Rutaceae</b>	<i>Selaginella plana</i>
<i>Myristica guatterifolia</i>	<i>Piper</i> sp1	<i>Acronychia trifoliolata</i>	<i>Stachytarpheta jamaicensis</i>
<i>Myristica</i> sp1	<i>Piper</i> sp2	<i>Clausena excavata</i>	<b>Vitaceae</b>
<i>Myristica</i> sp2	<i>Piper</i> sp3	<i>Zanthoxylum rhetsa</i>	<i>Cayratia trifolia</i>
<i>Myristica</i> sp3	<b>Pittosporaceae</b>	<i>Melicope</i> sp1	<i>Cissus javana</i>
<i>Myrsine</i> sp.	<i>Pittosporum moluccanum</i>	<i>Melicope</i> sp2	<i>Tetrastigma lanceolarium</i>
<i>Rapanea hasseltii</i>	<b>Poaceae</b>	<i>Zanthoxylum</i> sp.	<b>Vittariaceae</b>
<b>Myrtaceae</b>	<i>Axonopus compressus</i>	<b>Sapindaceae</b>	<i>Vittaria</i> sp.
<i>Acmena acuminatissima</i>	<i>Bambusa blumeana</i>	<i>Allophylus cobbe</i>	<b>Zingiberaceae</b>
<i>Acmena</i> sp.	<i>Bambusa vulgaris</i>	<i>Arytera littoralis</i>	<i>Alpinia galanga</i>
<i>Syzygium cumini</i>	<i>Centotheca lappacea</i>	<i>Chrysophyllum roxburghii</i>	<i>Etilingera elatior</i>
<i>Syzygium garciniifolium</i>	<i>Chrysopogon aciculatus</i>	<i>Harpullia arborea</i>	<i>Gastrochilus panduratus</i>
<i>Syzygium littorale</i>	<i>Cynodon dactylon</i>	<i>Harpullia</i> sp1	
<i>Syzygium polyanthum</i>	<i>Dendrocalamus asper</i>	<i>Harpullia</i> sp2	