DISTRIBUTION OF INVASIVE PLANT SPECIES AND RECOMMENDATION FOR MANAGEMENT ACTIONS AT BUKIT DUABELAS, JAMBI, SUMATRA

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STATEMENT OF RESEARCH ORIGINALITY AND INFORMATION SOURCE

This is to verify that my thesis entitled: Distribution of Invasive Plant Species and Recommendation for Management Actions at Bukit Duabelas, Jambi, Sumatra is my own work and has never been submitted to any institution before. All the incorporated data and information are valid and stated clearly in the text and listed in the references.

Bogor, April 2016

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SUMMARY

INDAH WAHYUNI. Distribution of Invasive Plant Species and Recommendation for Management Actions at Bukit Duabelas, Jambi, Sumatra. Supervised by SULISTIJORINI and SOEKISMAN TJITROSOEDIRDJO.

Bukit Duabelas National Park (BDNP) is one of the remaining lowland rainforest in Jambi Province (Sumatra, Indonesia). The surrounding areas up to the national park borders has already been converted into jungle rubber agroforest and rubber and oil palm plantations that might lead to an increased spread of invasive plant species (IPS). The invasive plant has been reported able to alter the species richness, diversity, and composition in a habitat (Alvarez & Cushman 2002). Here, we listed IPS in Bukit Duabelas; determined their distribution in each ecosystem type (forest, jungle rubber, rubber and oil palm plantation); and prioritized the IPS for management program.

Vegetation surveys were carried out at each permanent plots (50 m × 50 m) of the EFForTS project (Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation Systems). Two replicate plots were selected for each land use system resulting in a total of eight plots. Investigation and sample collection were conducted inside the plots and the surrounding area of each ecosystem plots. Spatial distribution pattern was carried out by creating vegetation profile diagram horizontally on the plots. Scoring system of risk analysis was also conducted based on the protocol of risk management of IPS (Tjitrosoedirdjo *et.al.* 2013).

A total of 76 IPS were identified at Bukit Duabelas and the surrounding area which belongs to 64 genera and 30 families. The richest family is Poaceae (15 sp.), followed by Asteraceae (11 sp.), and Euphorbiaceae (5 sp.). Oil palm plantation has the highest number of IPS compare against jungle rubber. We found strong influence of light and air temperature on the IPS distribution. The IPS invasion was higher in open areas i.e. oil palm and rubber plantation than in the shaded systems jungle rubber and forest. The IPS were not found in the forest plots. The forest condition might not be suitable for IPS establishment due to high canopy cover creating a low of light penetration and air temperature.

Dicranopteris linearis and *Clidemia hirta* were found to be the most widely distributed invasive species. These species were found dominating the three ecosystem (jungle rubber, oil palm and rubber plantation). The distribution pattern of *D. linearis* was clumped at the open canopy as a huge colony. While *C. hirta* was the shade intolerant species that spread randomly as a small to huge colony. The spread of these species must be prevented due to its high risk of invasion inside BDNP region. The spread of IPS is facilitated by forest disturbance such as illegal logging and land use change. Therefore, illegal loging must be prevented and reforestation of disturbed areas of the national park is must be promoted.

Keywords: Invasive Plant Species (IPS), distribution, Bukit Duabelas National Park, *Clidemia hirta*, *Dicranopteris linearis*

RINGKASAN

INDAH WAHYUNI. Distribusi Jenis Tumbuhan Invasif dan Rekomendasi Pengelolaannya di Bukit Duabelas, Jambi, Sumatra. Dibimbing oleh SULISTIJORINI dan SOEKISMAN TJITROSOEDIRDJO.

Taman Nasional Bukit Duabelas (TNBD) tergolong ke dalam tipe ekosistem hutan hujan dataran rendah. Wilayah di sekitar batas kawasan TNBD telah mengalami konversi fungsi lahan menjadi hutan agroforestri karet, perkebunan karet, dan kelapa sawit. Dampak penyebaran tumbuhan invasif telah dilaporkan dapat mengubah kekayaan, diversitas, dan komposisi jenis di suatu habitat (Alvarez & Cushman 2002). Penelitian ini bertujuan membuat daftar jenis tumbuhan invasif di Bukit Duabelas dan sekitarnya; mengetahui distribusi jenis tumbuhan invasif pada empat tipe ekosistem yang berbeda (hutan karet, kebun karet, dan kelapa sawit); dan membuat prioritas pengelolaan jenis tumbuhan invasif.

Survey vegetasi dilakukan di plot permanen 50 m × 50 m proyek EFForTS (*Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation Systems*). Survey vegetasi ini dilakukan di empat tipe ekosistem dengan dua kali ulangan pada setiap ekosistem (total delapan plot). Eksplorasi dan pengambilan sampel jenis tumbuhan invasif juga dilakukan di dalam plot dan di sepanjang tepi jalan sekitar area yang mewakili setiap tipe ekosistem. Pola distribusi jenis tumbuhan invasif pada setiap plot dikaji dengan membuat diagram profil vegetasi secara horizontal. Selain itu, analisis resiko jenis tumbuhan invasif dengan sistem skor dilakukan berdasarkan protokol pengelolaan resiko jenis tumbuhan invasif (Tjitrosoedirdjo *et.al.* 2013).

Sebanyak 76 jenis tumbuhan invasif meliputi 64 marga dan 30 suku telah ditemukan di Bukit Duabelas dan sekitarnya. Poaceae (15 jenis) merupakan suku dengan jumlah jenis terbanyak, diikuti oleh Asteraceae (11 jenis), dan Euphorbiaceae (5 jenis). Kebun karet dan kelapa sawit memiliki jumlah jenis lebih banyak dibandingkan dengan hutan karet. Pada penelitian ini, distribusi jenis tumbuhan invasif sangat dipengaruhi cahaya dan suhu udara. Penyebaran jenis tumbuhan invasif cenderung tinggi di habitat terbuka seperti kebun karet dan kelapa sawit dibandingkan di habitat ternaungi seperti hutan karet dan hutan TNBD. Bahkan tidak ditemukan jenis tumbuhan invasif di hutan. Kondisi hutan dengan penutupan kanopi tinggi mungkin tidak sesuai bagi mapannya tumbuhan invasif karena rendahnya cahaya yang masuk dan suhu udara di bawah pohon menjadi rendah.

Dicranopteris linearis dan *Clidemia hirta* ditemukan mendominasi di tiga ekosistem dengan tingkat resiko tinggi. *D.linearis* banyak ditemukan mengelompok di habitat terbuka. Sedangkan *C. hirta* merupakan jenis tidak tahan naungan yang menyebar secara acak. Penyebaran kedua jenis tumbuhan ini harus di cegah karena ancaman invasinya yang tinggi di TNBD. Penyebaran jenis tumbuhan invasif dipacu apabila terjadi kerusakan hutan seperti adanya penebangan liar dan alih fungsi lahan. Oleh karena itu integritas hutan harus dijaga, penebangan liar harus dicegah, dan reforestasi wilayah taman nasional yang rusak sangat direkomendasikan untuk mencegah masuk dan mapannya jenis tumbuhan invasif ke ekosistem hutan.

Kata kunci: jenis tumbuhan invasif, distribusi, Taman Nasional Bukit Duabelas, *Clidemia hirta*, *Dicranopteris linearis*

DISTRIBUTION OF INVASIVE PLANT SPECIES AND RECOMMENDATION FOR MANAGEMENT ACTIONS AT BUKIT DUABELAS, JAMBI, SUMATRA

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INTRODUCTION

Background

Invasive alien species are plants, animals, pathogens and other organisms that are non-native to an ecosystem, and which may cause economic or environmental harm or adversely affect human health (CBD 2000). In general, Invasive plants species (IPS) are defined as plant species that live outside their natural habitat, able to dominate the vegetation in the new habitat because it has no natural enemies and impact negatively on local species, habitat and human interests (Wijanarko 2001; Radosevich *et al*. 2007). In particular, they impact adversely upon biodiversity, including decline or elimination of native species, and the disruption of local ecosystems and ecosystem functions. Thus, article 8(h) of the Biodiversity Convention asks for measures "to prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats, or species" (CBD 2000).

Indonesia is one of the world biodiversity hotspots and are known as mega-biodiversity country. According Ihalainen (2007), Indonesia's forests represent ten percent of the world's tropical forests. The introduced invasive plant species are threat to Indonesian biodiversity. Invasive plants respond readily to human-induced changes in the environment such as disturbance but also may initiate environmental change through their dominance on the landscape. Disturbances in the ecosystem provide an opportunity for the expansion of IPS (Raghubanshi & Tripathi 2009). Excessive plantation development is one of the main factors causing disturbances in the ecosystem.

In Indonesia, the construction of large-scale plantations has occurred in the Sumatran forest. Sumatran forest belonging to the type of lowland rain forest ecosystem has undergone a conversion of land use system into intensive agriculture and monoculture forestry, i.e. rubber and oil palm plantations, as well as acacia forest industry. Approximately 12.5 million hectares or 49% of the total area of forest in Sumatra disappeared within a period of a quarter century (1985-2009) (WWF 2010). It creates the alteration of ecosystem function. Jambi province is the third largest of forest loss occurred in Sumatra with 13.4% of the total area of forest loss over period of 1985 – 2009 (WWF 2010). The land use changes may facilitate the introduction and establishment of invasive plants. According to Sanderson *et al*. (2012), exploitation of resources will enhance the development of plant species which potentially invasive.

The plant species that become potentially invasive and have a serious threat should always be monitored. The development of post-border risk management of invasive plant species can be used to rank the invasiveness level of plant species that already exist in Indonesia. It will help in prioritizing them for control programs (Virtue 2008). Therefore, prevention, control, eradication and knowledge on IPS distribution in Indonesia are needed to reduce the impact caused by invasive plants.

Objectives

Invasive plant species respond positively to environmental disturbance either natural or anthropogenic disturbance. The availability of light and exposed soil facilitated the establishment of IPS. The aims of this study are:

1. To compile a list of IPS in Bukit Duabelas National Park and the surrounding areas.
2. To determine the distribution of IPS in each ecosystem types: forest, jungle rubber, rubber plantation, oil palm plantation.
3. To prioritize the management of IPS based on risk management.

LITERATURE REVIEW

Convention on Biological Diversity

Convention on biological diversity (CBD) has been ratified by 130 countries in the world in 1992. The CBD is an international legal effort to conserve biodiversity. Indonesia is one of mega biodiversity country who signed the CBD on 5 June 1992. Then it was ratified through the Law No. 5, 1994 on the Ratification of the UN Convention on Biodiversity Conservation (Wijanarko 2001). Directly, this international law is associated with the invasive species risk which specified in the Article 8 (h): each country should prevent the introduction of, control or eradicate the alien species which threaten ecosystems, habitats or species (Andow 2005). The lack of scientific certainty should not be used as a barrier to against the invasive species in minimizing the biological diversity loss. In this case, the CBD has a strong principle to restrict and regulate invasive species.

Invasive Plant Species Definition

There were several definition of IPS. FE. Clements on his paper of “Research Methods in Ecology” in 1905, stated that invasion was the movement of plants from an area of a certain character into one of different character, and finally colonized an area a few decades later. Then, Braun-Blanquet used the term of invasive plants to the plants that could colonize new unoccupied land (Alpert *et.al.* 2000). The invasive plants could be native and non-native plants species. The IPS are able to dominate and damage the native / natural ecosystem and cause the extinction of local species (Wijanarko 2001). In the Convention Biological Diversity (CBD) at the 1992 Earth Summit in Rio de Janeiro, world leaders agreed on a comprehensive strategy for “sustainable development” including to restrict and regulate the invasive alien plant species. Based on CBD, the definition of invasive alien species are plants, animals, pathogens and other organisms that are non-native to an ecosystem, and which may cause economic or environmental harm or adversely affect human health (CBD 2000). In conclusion, IPS are defined as plant species that live outside its natural habitat, able to dominate the vegetation in a new habitat because it has no natural enemies, and has negative impact to local species, habitat, as well as human interests (Wijanarko 2001; Radosevich *et.al.* 2007). It is realized that IPS are became a major threat of the environmental integrity.

Process of Biological Invasion

The successful invasions are rare event, only about 10% species were able to invade a new area (Booth *et.al.* 2010). A plant species must go through barriers to become successful invasions, i.e. large-scale geographical barriers and survival barriers (NISC 2006). However, the small proportion of successful invasion may cause some negative impacts on population, community, and ecosystems. This invasion has occurred due to the combination of several factors and mechanisms. Catford *et.al.* (2009) has identified six phases that lead to successful invasion:

transport, introduction, colonization, naturalization, spread, and impact. Each phase can only be achieved after overcoming an earlier phase. (1). Tranport is a phase where plants or plants propagule were moved / transferred into a new location. (2). Introduction is the arrival of plants or plants propagule to a new area. Generally, transport and introduction phase were facilitated by human. For instance, a plant was transported and introduced through globalization and modernization such as trade, travel and tourism, humanitarian aid, international military operations, as well as ease the entry and exit of agricultural commodities (Mathew 2004). (3). Colonization is a phase in which the plant is able to survive in a new habitat, at least plants has been successfully produced one generation. After succesully colonizing a new habitat, plants can enter through the naturalization stage. (4). Naturalization means that plants are able to survive and reproduce themselves without human cultivated, enabling pioneer population to be self-sustaining. (5). The next phase is spread in which plant is able to disperse its propagules and populations into outside of area where they first introduced. In this stage, plants invade other locations with similar environment or even different environment condition. (6). If those five phases were passed by the plants, then they pottentially has negative impact on other species ecologically and economically. Then Catford *et.al.* (2009) also described that those succesfull of invasion process were driven by many factors such as propagule pressure, biotic characteristics, abiotic characteristics, with the additional influence of human.

The Successful Invasion

The success of a plant species to invade a new area is very small, as stated before only about 10% (Booth 2010). Many factors are bringing the failure to some species in invading an area: (1) the unfavorable abiotic condition (the species cannot survive); (2) the non-native species is less competitive than the native or local species; (3) the presence of natural enemies like herbivore and disease; (4) the absence of pollinators or disseminator agent; and (5) the species population has low density therefore difficult to mate. Although the opportunity of plant species to be invasive is very few (10%), it should be alerted due to its large impact on population, community, or ecosystem. These plants are species which can grow in a new habitat and become naturalized, grow prolifically, and as a result become invasive in a new habitat (Booth 2010). A number of studies assumes that invasive plants has a steady characteristics, so it is successful to occupy a new habitat. The characteristics are (1) it has a high dispersal rate, has modified reproductive morphology which make it easier to spread; (2) it has high fecundity; (3) it has high growth rate; (4) reproduce vegetatively if it has long-lived; (5) it has high tolerance to several physical condition such as temperature, humidity, and soil type (van der Velde *et.al.* 2006).

Moser *et.al.* (2009) revealed that disturbance, ability to compete, resources availability, and propagule pressure were four important factors which influence the successfulness of species invasion. In short, an invasion was the result of interaction between conformity habitat and propagule pressure (Rejmànek *et.al.* 2005). A habitat should be less invasible when it is populated by the high competitive plants. Nevertheless, changes or environmental stress may affect the invasion level of a species. The existence of environmental stress can disrupt the balance of competition between non-native species and native species.

Environmental stress is a condition that can limit metabolism, for example a high temperature or toxins. The non-native plants could be more effective and efficient in absorbing the resources, therefore the native plants will lose competition (Alpert *et.al.* 2000).

The Impact of Invasion

Biological invasion of invasive plants has been recognized threatening biodiversity and altering ecosystems. IPS has been reported able to alter the species richness, diversity, and composition in a habitat (Alvarez & Cushman 2002). Based on Radosevich *et.al.* (2007), there are several ecological impact of invasive plants including biodiversity reduction; some local insects, birds, and other living organism loss their habitat; loss of food sources; changes in fire frequency and intensity; and the disruption to the association of plants and animals, such as pollination and seed dispersal.

Lately, the introduction of invasive plant outside its natural habitat increased sharply, either intentionally or unintentionally. The IPS has interfered several national park in Indonesia. *Acacia nilotica* reported disrupted the ecosytems of Baluran National Park (Setiabudi *et.al.* 2013). *A. nilotica* have been introduced to Baluran National Park in 1969, which was intended as firebreaks. The problem arise when *A. nilotica* dominated grazing area of herbivores (banteng, deer, and buffalo) in savannas. Another invasive plants i.e. water hyacinth (*Eichornia crassipes*), Ki rinyuh (*Chromolaena odorata*), and Jarong (*Stachitarpeta urticaefolia*) were reported threatening the endemic flora. In Indonesia, Water Hyacinth leads to the disrupted water transportation and causing sedimentation in the river, because the roots bind the mud around it. The presence of Ki rinyuh is a potential forest fire hazard in dry season (Wijanarko 2001). In the Mount Gede Pangrango National Park it was reported that there were two important IPS, namely *Chimonobambusa quadrangualris* and *Cestrum aurantiacum* (Tjitrosoedirdjo *et.al.* 2014).

Deforestation and Forest Degradation

Over the last 30 years, Indonesia dramatically planted crops production increasingly on the area that was previously natural forests. Deforestation in Indonesia was usually followed by plantation establishment. Forest conversion leads to the declining of biodiversity. The dominancy of homogenous plant and high intensity of human activity will limit the dynamics of biological life (USDA, NRCS 1999). Habitat fragmentation may cause the genetic isolation of plants and animals, so it would reduce genetic diversity.

In addition, disturbances in an ecosystem also provide opportunities for invasive species introduction (Raghubanshi & Tripathi 2009). The disturbed area serves sufficient resources for invasive plants. The response of invasive plant species and native plant species differ against the interference. Some invasive plants have a higher ability to colonize disturbed habitats (Obiri 2011). Herbs often emerge as pioneer of the disturbed forest. Their seeds are spread by wind or carried by animals. According to Campbell (1999), if the disturbed area are not interfered by human activities, the pioneer herbs will be replaced by woody shrubs, and finally forest trees replaced most of the shrubs. Some pioneer herbs are weedy species. These species have a good survival ability, occupying the areas that recently disturbed before the competition stabilized the ecosystem.

The human activities in Jambi reduced natural forest and established rubber and oil palm plantation. Rasnovi (2006) considered that in the period of 1993 to 2002, the land conversion was more into oil palm plantation. Rubber agroforestry in Sumatra is a continuation of slash and burn shifting cultivation system. Their seeds were planted together with crops and rice in the first year of the system. In the monoculture system either rubber or oil palm plantation, the land was planted with only one species. Generally, rubber agroforestry will be left unattended by the farmers if it was not productive anymore, then the land will turn into shrubs vegetation. Rubber plantation has the higher organic matter compared with oil palm plantation. It is due to oil palm plantation contribute the organic material less and its soil become poor of nutrition. However invasive plants still interfere the system because of wide the planting distance, hence exposing a considerable soil surface.

Risk Management of IPS

Risk is defined as a chance or likelihood ocuring of events upon objectives. In conjunction with invasion, the risk may be defined to its final objective of establishment or negative impact to the environmental invaded. If the final objective is “establishment” then the effort must be directed toward preventing the establishment. However, if the final objective is negative impact, even if the invasive species did establish but did not have negative impact it did not have a risk. Generally it was accepted that the final objective is “establishment”, so IPS should not establish (Tjitrosoedirdjo *et.al.* 2013). Indonesia categorizes IPS into (1) IPS that already exist in the country and (2) IPS (not entered yet into the country). The post border weed risk management system is used to prevent the spread of IPS that has been existing in the country. Whereas the pre border weed risk assessment system is mainly prepared to prevent entries of IPS into the country (Kohli *et.al.* 2009). The post-border weed risk management based on Tjitrosoedirdjo *et.al.* (2013) developed from Virtue (2008) is applied in this research to help in prioritizing IPS for control program. According to International Standard Organization (ISO), risk management is recognized as an integral part of management practices and is core to managing environmental impacts, with the main elements of identification, evaluation, and interference the risk. Different with The International Plant Protection Convention (IPPC) standard in the phytosanitary methodology, risk analysis is the integrated process, whereas risk management is equals to the action of risk intervention only.

The national park in Indonesia, Gunung Gede Pangrango National Park (GGPNP) have applied the Virtue (2008) risk management model to prioritize the invasive risk plant species (Tjitrosoedirdjo 2014). The model produces a ranking of invasive plant species by combining expert opinion, the real condition, and documented information for answering questions representing the two primary factors that is risk analysis and feasibility of containment. The system can be broadly applied to many geographic scales of land use, such as aquatic, crop, forestry, pastures, native vegetation, non-arable grazing, perennial horticulture, and urban area. This system is a tool to help in making standard, informed decision on

IPS control priorities. It can then be used by the decision maker to decide the amount of time and resources devoted to protecting each land use from IPS.

METHODOLOGY

Study Site

The study was conducted from June 2014 to January 2015 at Bukit Duabelas National Park (BDNP) and its surrounding area, Jambi Province, Sumatra. BDNP is one of the lowland rain forest area in Jambi Province which covers an area of 60,500 hectares. BDNP possesses flat, undulating, and hill types of topography that ranges from 50 m to 438 m above sea level. This forest area is used as odyssey area by the local people "suku Anak Dalam" (Orang Rimba). The activities of Orang Rimba includes hunting, fishing, and looking for honey to meet their needs of life. The surrounding areas of BDNP are residential area and some plantations such as jungle rubber (rubber agroforestry), rubber and oil palm plantations (monoculture plantation).

The research works were conducted in four different ecosystem types, located at BDNP represented by three different villages, i.e. Dusun Baru, Lubuk Kepayang, and Pauh. The four ecosystem types are forest (BF), jungle rubber (BR), rubber plantation (BR), and oil palm plantation (BO), as shown in Figure 1. The symbols of each ecosystem were given based on the research location and the type of ecosystem that is "B" for Bukit Duabelas and the following characters are "F" (forest), "J" (jungle rubber), "R" (rubber plantation), and "O" (oil palm plantation). Vegetation surveys were carried out within the permanent plots (50 m × 50 m) of EFForTS project (Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation Systems, http://www.uni-goettingen.de/crc990). Two replicate plots were selected for each ecosystem types resulting in total of eight plots (BF3, BF4, BJ4, BJ5, BR3, BR4, BO2, and BO4) were studied. The research plot locations map are shown in Appendix 1.

Materials and Methods

Investigation and Collection of IPS

Investigation and sample collection of IPS were conducted inside the plots i.e. forest, jungle rubber, rubber and oil palm plantations. The specimens that were collected covering the whole plants of grasses and small herbs, flower buds and seeds of the plants, fertile and sterile fronds of fern and some field notes on the locality information and detail of plant morphology in the field were recorded. Herbarium specimens were identified at the Herbarium BIOTROP (BIOT), and Herbarium Bogoriense (BO)-LIPI, Bogor, Indonesia. Each species was then classified into its family name, habitus types (herbs, liana, shrubs, trees), and their invasiveness status were determined according to some invasive species database, such as invasive alien plant species in Indonesia database by BIOTROP, Invasive Species Specialist Group database (ISSG database), the Global Compendium of Weeds (GCW), Hawaiian Ecosystem at Risk Project (HEAR), and some book references.

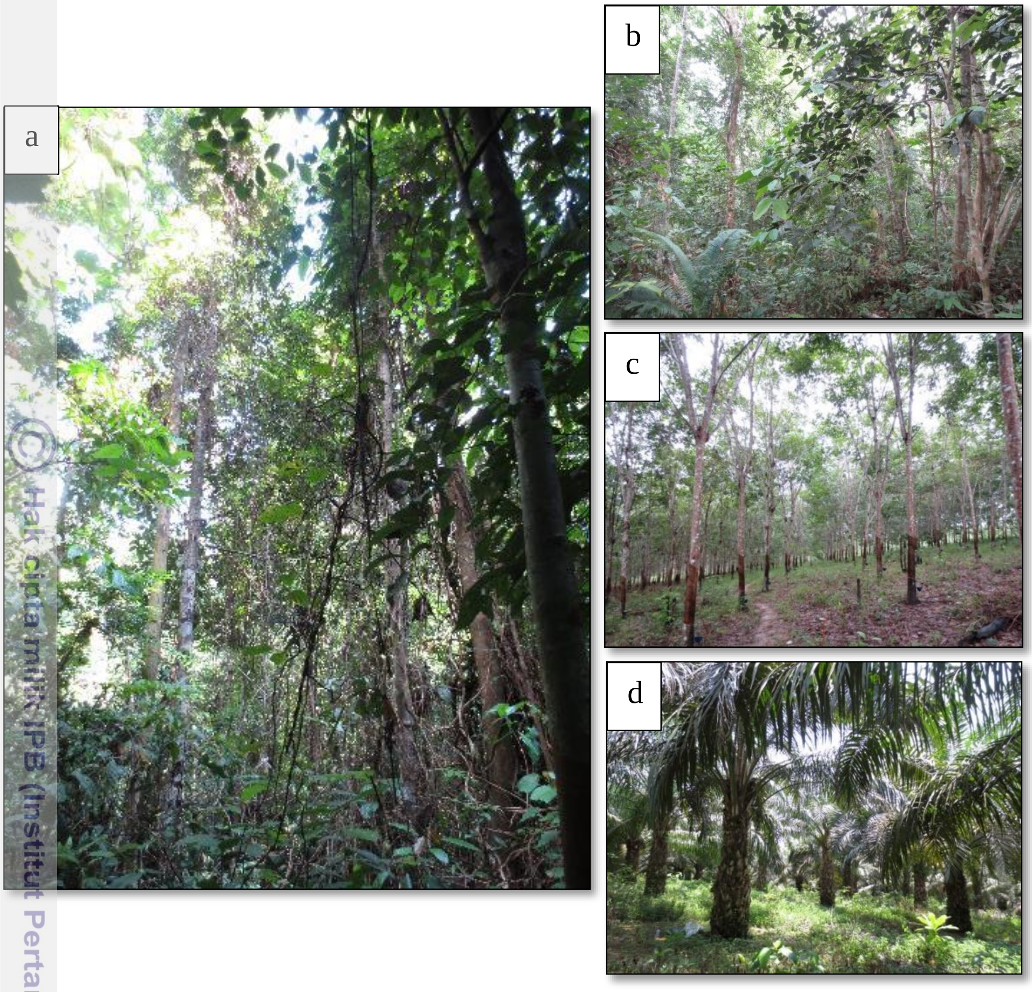

Figure 1 The locations of invasive plants exploration and sample collection at BDNP and the vicinity: forest (a), jungle rubber (b), rubber plantation (c), oil palm plantation (d)

Spatial Distribution Patterns – the abundance and presence of IPS

Horizontal profile diagrams for all invasive plants were created by projecting their coverage onto the floor. Each 50 m × 50 m plot was divided into 25 subplots (10 m × 10 m) to simplify the calculation and delineation of IPS coverage. The coverage was drawn on the graph paper with a scale of 1:100 in the field. The sketches were then scanned and digitized in the ArcView 3.3 program.

The dominance of IPS were determined by Important Value Indices (IVI), based on the frequency and coverage of IPS. To calculate the IVI, the percentage values of the relative frequency and relative dominance were summed up and calculated with the following formulas (Cox 1972).

$$\text{Relative frequency} = \frac{\text{Absolute frequency of the species}}{\text{Total frequency of all species}} \times 100\%$$

$$\text{Relative dominance} = \frac{\text{Absolute coverage of the species}}{\text{Total coverage of all species}} \times 100\%$$

$$\text{IVI} = \text{relative frequency} + \text{relative dominance}$$

The cluster analysis was carried out to compare the IPS community within the ecosystem. The cluster analysis was conducted based on IVI and calculated into similarity index, which was then converted into dissimilarity index with single linkage clustering. The formulas are as follow (Mc Garigal *et.al.* 2000).

$$IS = \frac{2C}{A+B} \; ; \; D = 1 - IS$$

Where, IS is Similarity Index, A is total IVI of IPS in ecosystem A, B is total IVI of IPS in ecosystem B, C is the comparison of total IVI of IPS in ecosystem A and B, and D is dissimilarity index.

A matrix of D with 4 × 4 dimension was obtained. From D matrix, the smallest distance pairs was selected to be combined. If the distance is d {x,y}, it means that the community x and y are the most likely to be combined because they have similar composition. As the minimum distance si d = {x,y} to the vegetation composition of x and y may be combined into a new vegetation composition, ay (x,y). After combination it is important to adjust D matrix into the folowing way:

a) Select column and row related to x and y.
b) Add row and column containing value of vegetation composition distance (x,y) the remaining vegetation composition.
c) The distance value among community pairs (x,y) and z is determined by following formula: d {(x,y), z } = min {d / x , z} d (y,z).
d) The sheet b and c repeated 3 times until all combined into one.

Risk Assessment of the IPS

Scoring system was used to assess the risk of IPS. The scoring system is based on the protocol of risk management of IPS by Tjitrosoedirdjo *et.al.* (2013) developed from Virtue (2008). The system consisting of 22 multiple choices, devided into two aections: (a) invasive plant risk, and (b) the feasibility of containment. The risk assessment was based on three components, i.e. invasiveness, impact, and its potential distribution. Greater scores were allocated to answer which indicated high degree of invasivenesss, greater the magnitude of impact and greater potential distribution. If the invasion is to be halted and its successful a high cost means feasibility is low, is so when the area invaded is wide and the control is not effective, so a higher number of feasibility indicated a low feasibility. The questionnaire of this scoring system is shown in Appendix 2.

Furthermore, the comparative invasive plant risk and the feasibility of containment scores were calculated with the following formula.

(a). The comparative invasive plant risk score

This value is calculated by adjusting the score of invasiveness, impacts, and potential distribution, then multiplying these.

Invasive plant risk = invasiveness × impacts × potential distribution

(b). The feasibility of containment score

The value is calculated by adjusting the score of control cost, current distribution, and control persistence, then multiplying these.

Feasibility of containment = control cost × current distribution × control persistence

Subsequently, management priorities determined by comparing the comparative risk and feasibility of containment to obtain the proper management of invasive plants. It is stated in the matrix is as follow in Table 1.

Table 1 Matrix of comparison between the comparative risk and feasibility of containment for weed management action

Invasive Plants Risk	**Feasibility of Containment**				
	Negligible >113	Low >56	Medium >31	High >14	Very high <14
Negligible <14	LIMITED ACTION	LIMITED ACTION	LIMITED ACTION	LIMITED ACTION	MONITOR
Low <39	LIMITED ACTION	LIMITED ACTION	LIMITED ACTION	MONITOR	MONITOR
Medium <101	MANAGE SITES	MANAGE SITES	MANAGE SITES	PROTECT SITES	CONTAIN SPREAD
High <192	MANAGE WEED	MANAGE WEED	PROTECT SITES	CONTAIN SPREAD	DESTROY INFESTATION
Very high >192	MANAGE WEED	Protect sites and manage weed	CONTAIN SPREAD	DESTROY INFESTATION	ERADICATE

ALERT

Environmental Data

The environmental data were secondary data which were collected by CRC 990-EFForTS scientist member Dr. Ana Meijide for the microclimate data collection and Prof. Holger Kreft, Dr. Katja Rembold, and Ms. Miki Nomura for the canopy openness data. The microclimate data which were used were air temperature, air humidity, soil temperature, and soil moisture (Table 2).

Table 2 The environmental data of the four ecosystem type (forest, jungle rubber, rubber and oil palm plantation) at Bukit Duabelas

Environmental Data	Forest	Jungle Rubber	Rubber Plantation	Oil Palm Plantation
Air temperature (ºC)	24.47^{a}	25.05^{ab}	25.58^{b}	25.44^{b}
Air humidity (ºC)	91.87^{c}	87.61^{b}	82.58^{a}	83.76^{a}
Soil moisture (%)	25.00^{a}	30.39^{ab}	43.54^{c}	35.39^{b}
Soil temperature (%)	25.18^{a}	25.34^{a}	25.33^{a}	26.35^{b}
Canopy Openness	2.14^{a}	5.40^{b}	15.22^{c}	18.70^{d}

Notes: The data of air temperature, humidity, moisture, and soil temperature were mean of 10 replications, whereas data of canopy openness were mean of 60 replications. The value which followed by different character at the same row are significantly different at 5% significant level.

Data Analysis

One way ANOVA with LSD-test were used to identify significant differences in the number and coverage of IPS among the ecosystems type. Principal Component Analysis (PCA) was used to evaluate the correlation between the environmental factors and the richness as well as abundance of IPS on each ecosystems type. The one way ANOVA, LSD-test, and PCA were performed using XSLSTAT 2014 software (Microsoft Excel add-in). Whereas cluster analysis was calculated in Microsoft Excel 2013.

RESULTS AND DISCUSSIONS

Results

Inventory of IPS at Bukit Duabelas and the Vicinity

There are a total of 76 IPS at Bukit Duabelas plots and the surrounding area which belongs to 64 genera and 30 families. The highest number is Poaceae (15 sp.), followed by Asteraceae (11 sp.), and Euphorbiaceae (5 sp.). The remaining families consist of one to four species, as shown in Figure 2.

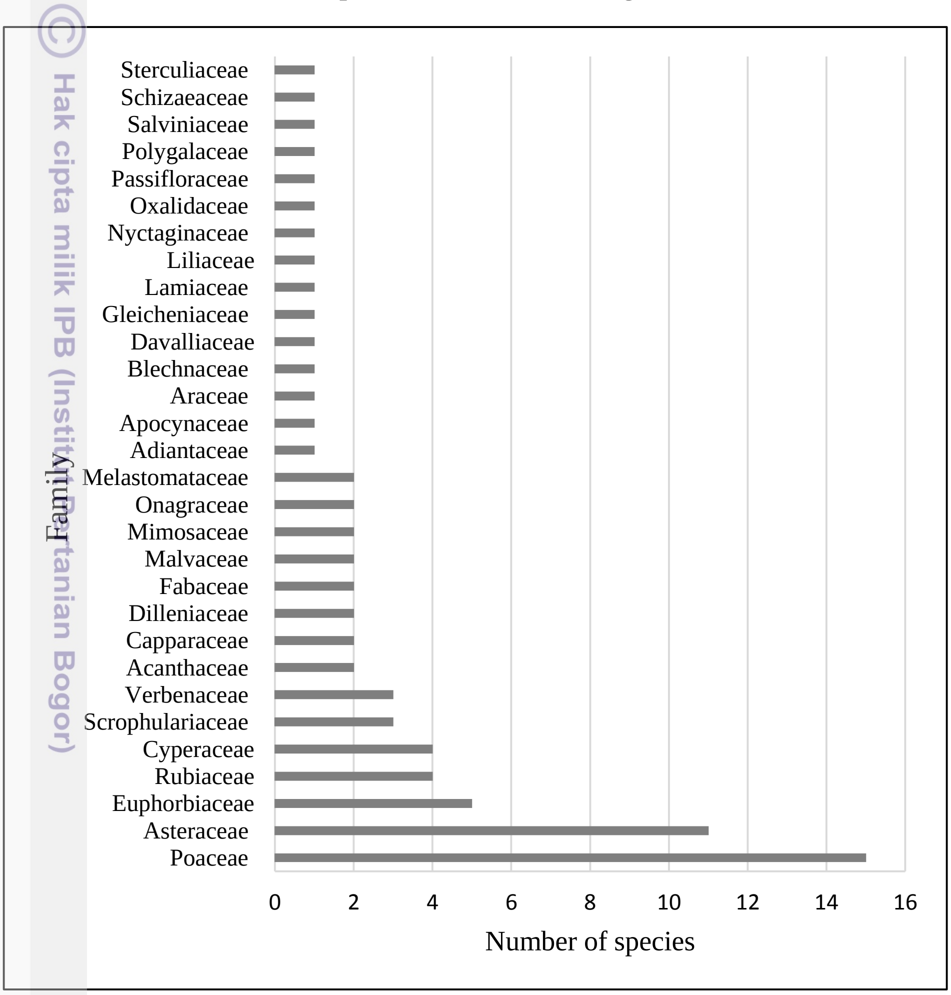

Figure 2 The number of IPS at Bukit Duabelas, Jambi, Sumatra

Nine plant life forms were recognized among the invasive plant species. These were herbs, herbaceous climbers, grasses, shrubs, climbing shrubs, ferns, climbing ferns, and aquatic herbs.

The group with the highest number of species, genera, and family was the herbs which accounted for 42.11% of all the invasive plant species growing in the study area (Table 3). These were followed by grasses (25.00%), and shrubs (18.42%). The remaining life forms; climbing shrubs, ferns, herbaceous climbers, climbing ferns, and aquatic herbs showed up as 3.95%, 3.95%, 3.95%, 1.32%, and 1.32% of the species respectively.

Table 3 Plant life form of invasive plants at Bukit Duabelas and surrounding area

No.	Plant Group	Number of Family	Number of Genera	Number of IPS	Percentage of number of IPS (%)
1	Herbs	18	29	32	42.11
2	Grasses	2	14	19	25.00
3	Shrubs	8	13	14	18.42
4	Climbing shrubs	2	2	3	3.95
5	Ferns	3	3	3	3.95
6	Herbaceous climbers	3	3	3	3.95
7	Climbing ferns	1	1	1	1.32
8	Aquatic herbs	1	1	1	1.32

The Origin of the IPS

Twenty three species (30%) of invasive plants were recognized as native species and 53 sp. (70%) as alien species. Most of the alien species originated from America (32 sp.). Seven species came from Asia, four species came from Africa, the origin of three species were not known yet, and the rest of the species has a wide origin, as shown in Figure 3.

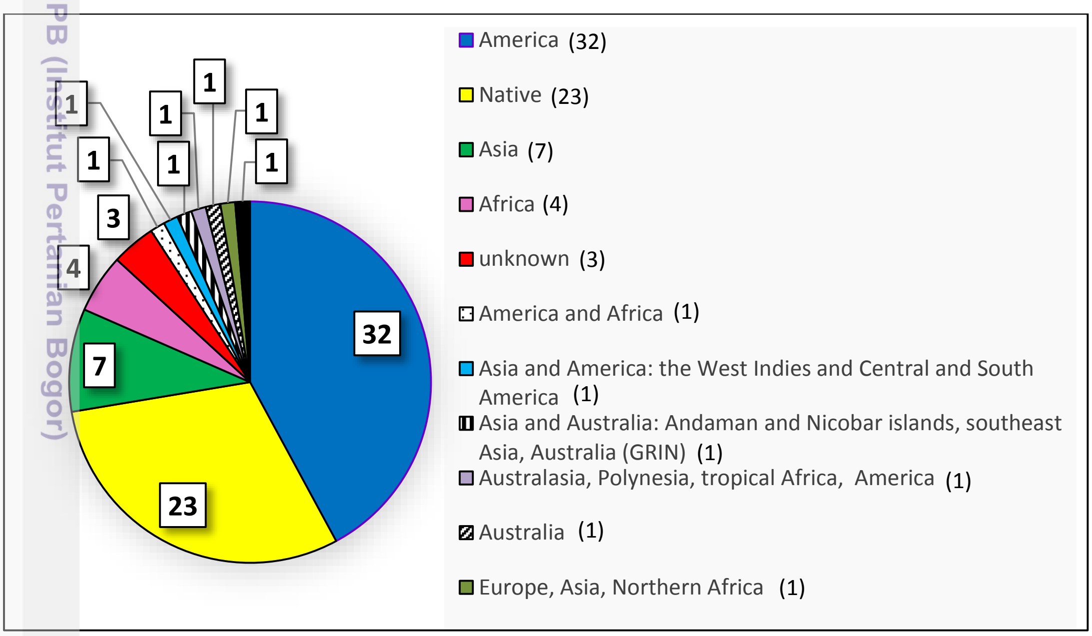

Figure 3 The origin of IPS found at Bukit Duabelas, and the surrounding area

The plant species originating from another country could invade the study area at Bukit Duabelas and the surrounding area, as the alien plant species adapt to local settings.

Diversity and Distribution Pattern of IPS within the Ecosystem

Forty IPS were identified in jungle rubber, rubber and oil palm plantation plots. The ecosystem type with the largest species richness of IPS was oil palm plantation (28 sp.), other ecosystems with relatively large number of invasive plants were rubber plantation (27 sp.), and jungle rubber (10 sp.). However IPS were not found inside the forest plots, as shown in Figure 4. The average number of IPS at jungle rubber was lower (8.00) than rubber (19.50; P = 0.02) and oil palm plantation (21.00; P = 0.01; Table 4).

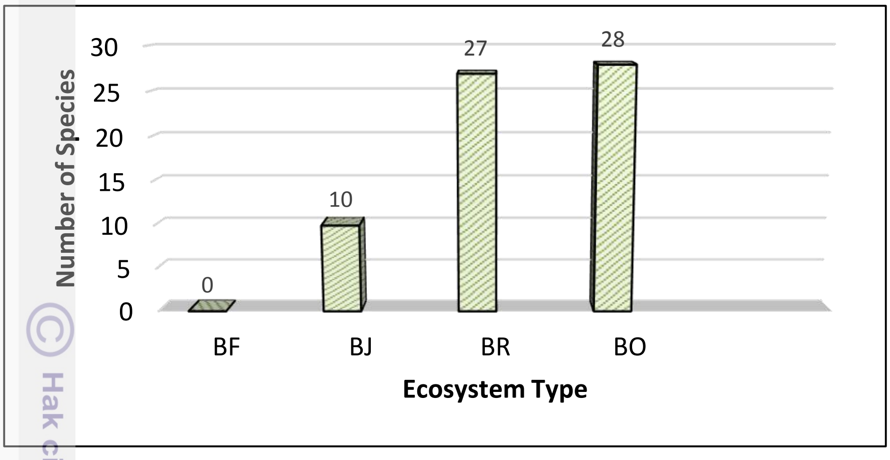

Figure 4 The number of IPS on each ecosystem type: forest (BF), jungle rubber (BJ), rubber plantation (BR), and oil palm plantation (BO)

Table 4 The average of species number of invasive plant per plot (50 m × 50 m) and total coverage (%) of IPS per plot at the four ecosystem type at Bukit Duabelas, Jambi

Data	BF (Forest)	BJ (Jungle Rubber)	BR (Rubber Plantation)	BO (Oil Palm Plantation)
The average of IPS number per plots (50 m × 50 m)	0.00[a]	8.00[a]	19.50[b]	21.00[b]

Notes: The data are mean of 2 replications. The value which followed by different character at the same row are significantly different at 5% significant level.

Cluster analysis separated the IPS community into 3 groups (Figure 5). The first, IPS communities in oil palm and rubber plantation were in one group, they were from similar community. The second community was that under jungle rubber and the last was those under forest.

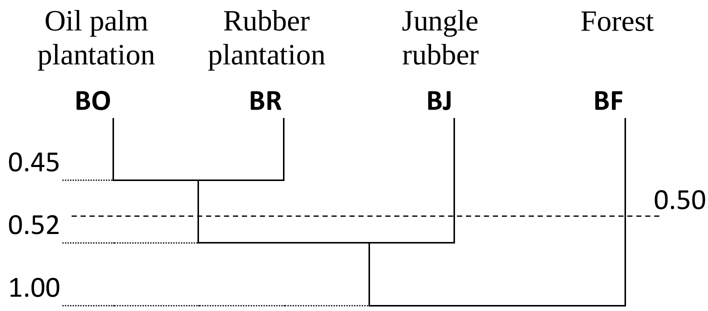

Figure 5 IPS community comparing within the ecosystems in Bukit Duabelas defined in a cluster analysis based on IVI which were the summed up of the presence and the abundance of IPS

Based on PCA, The number of IPS was higher in plots with high canopy openness and air temperature (Figure 6). The highest coverage of IPS was found in oil palm plantation which also had the highest canopy openness (18.70%; Table 1). Additionally, the number of IPS were increased parallel with the increasing of air temperature (Figure 6).

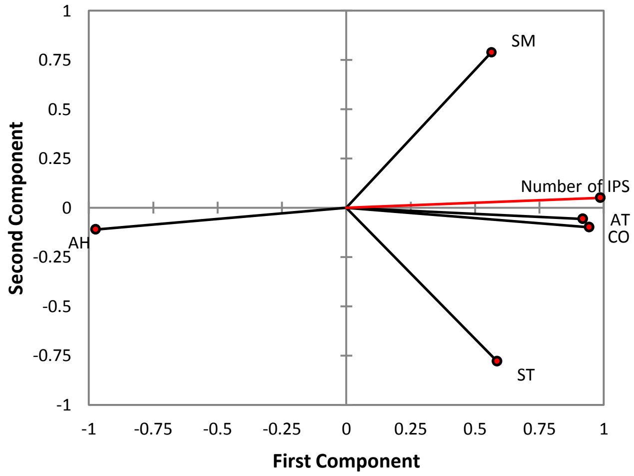

Figure 6 The relation of the number of IPS to the environmental factors: air temperature (AT), air humidity (AH), soil temperature (ST), soil moisture (SM), and canopy openness (CO)

The horizontal profile diagram resulting the mapping of IPS distribution, as shown on Appendix 3, 4, and 5 respectively. More than 30% of plot (50m x 50m) on the three ecosystems (jungle rubber, rubber plantation, and oil palm plantation) were invaded by IPS. The highest IPS infestation found in oil palm plantation with 74.02% invasive plants cover, followed by jungle rubber (45.38%), and rubber plantation (30.53%; Table 5).

According to the distribution map, the coverage of IPS were calculated as shown in Table 5. *Clidemia hirta* and *Dicranopteris linearis* were abundant at the three ecosystem type (jungle rubber, rubber and oil palm plantation*). Clidemia hirta's* cover was high at jungle rubber and oil palm plantation plots with the total coverage of 21.73% and 40.88% respectively. However *D. linearis* was found abundant at BJ and BR plots with a total coverage of 16.33% and 12.19% respectively.

The species dominance has been analyzed based on the Important Value Indices (IVI) which were summed up from the presence (percentage values of relative frequency) and the coverage of invasive plants (relative dominance) of each species, as shown in Table 6. *Clidemia hirta* was the most dominant species among the weeds in jungle rubber with IVI of 34.23% followed by *Dicranopteris linearis* (28.84%), and *Tetracera scandens* (14.05%). *Clidemia hirta* (45.65%) was also the most dominant species in oil palm plantation followed by *Asystasia gangetica* subsp. *Micrantha* (11.65%), and *Dicranopteris linearis* (11.13%). In rubber plantation, the most dominant species was *Dicranopteris linearis* (17.32%), followed by *Scleria ciliaris* (8.10%), and *Stenochlaena palustris* (7.71%).

Table 5 The coverage of IPS at the four ecosystem plots: lowland forest (BF), jungle rubber (BJ), rubber plantation (BR), and oil palm plantation (BO)

No.	Species	Coverage (%)			
		BF	BJ	BR	BO
1.	*Ageratum conyzoides* L.	0.00	0.00	0.00	0.32
2.	*Asystasia gangetica T.*Anderson subsp. *micrantha* (Nees) Ensermu	0.00	0.00	0.01	6.88
3.	*Axonopus compressus* P.Beauv.	0.00	0.00	0.27	2.95
4.	*Borreria alata* DC.	0.00	0.00	0.12	0.72
5.	*Borreria laevis* Griseb.	0.00	0.00	0.31	0.00
6.	*Breynia stipitata* Müll.Arg.	0.00	0.00	0.11	0.06
7.	*Bridelia insulana* Hance	0.00	0.00	0.09	0.04
8.	*Centotheca lappacea* Desv.	0.00	0.56	0.15	3.17
9.	*Chromolaena odorata* (L.) R.M.King & H.Rob.	0.00	0.00	0.00	0.02
10.	***Clidemia hirta* D.Don**	0.00	**21.73**	2.04	**40.88**
11.	*Cyperus difformis* L.	0.00	0.00	0.00	0.00
12.	*Cyrtococcum accrescens* Stapf	0.00	0.00	0.03	0.00
13.	*Cyrtococcum patens* A.Camus	0.00	0.00	4.83	0.00
14.	*Cyrtococcum trigonum* A.Camus	0.00	3.69	0.00	0.00
15.	*Dianella ensifolia* (L.) DC.	0.00	0.00	0.03	0.00
16.	***Dicranopteris linearis* (Burm.f.) Underw.**	0.00	**16.34**	**12.19**	6.37
17.	*Fimbristylis dura* (Zoll. & Moritz) Merr.	0.00	0.00	0.00	0.00
18.	*Imperata cylindrica* (L.) P.Beauv.	0.00	0.00	1.19	1.01
19.	*Lantana camara* L.	0.00	0.00	0.00	0.51
20.	*Lygodium flexuosum* (L.) Sw.	0.00	0.13	0.00	0.58
21.	*Macaranga triloba* Müll.Arg.	0.00	0.00	0.14	0.00
22.	*Melastoma affine* D. Don	0.00	0.12	0.21	1.83
23.	*Mikania micrantha* Kunth	0.00	0.00	0.00	0.67
24.	*Mussaenda frondosa* Blanco	0.00	0.00	0.01	0.29
25.	*Oplismenus compositus* (L.) P.Beauv.	0.00	0.30	0.00	0.00
26.	*Ottochloa nodosa* (Kunth) Dandy	0.00	0.00	0.00	1.81
27.	*Paspalum conjugatum* P.J.Bergius	0.00	0.00	0.04	0.00
28.	*Paspalum dilatatum* Poir.	0.00	0.00	0.25	0.93
29.	*Pennisetum purpureum* Schumach.	0.00	0.00	0.00	0.04
30.	*Polygala paniculata* Leconte ex Torr. & A.Gray	0.00	0.00	0.00	0.01
31.	*Scleria ciliaris* Nees	0.00	0.68	2.97	2.47
32.	*Sporobolus diander* P.Beauv.	0.00	0.00	0.00	0.19
33.	*Stachytarpheta indica* Vahl	0.00	0.00	0.00	0.57
34.	*Stachytarpheta jamaicensis* (L.) Vahl	0.00	0.00	0.00	0.58
35.	*Stenochlaena palustris* (Burm.) Bedd.	0.00	0.00	5.15	0.01
36.	*Taenitis blechnoides* (Willd.) Sw.	0.00	0.29	0.15	0.86
37.	*Tetracera scandens* Gilg & Werderm.	0.00	0.00	0.14	0.00
38.	*Tetracera indica* Merr.	0.00	1.55	0.00	0.00
39.	*Uncaria* cf. *glabrata* (Lour.) Merr.	0.00	0.00	0.07	0.12
40.	*Urena lobata* L.	0.00	0.00	0.01	0.14
	Total Coverage (%)	0.00	45.38	30.53	74.02

Note: The species with the highest coverage are highlighted in bold.

Table 6 Important value index of IPS at the four ecosystem plots: lowland forest (BF), jungle rubber (BJ), rubber plantation (BR), and oil palm plantation (BO)

No.	Species	IVI (%)			
		BF	BJ	BR	BO
1.	*Ageratum conyzoides* L.	0.00	0.00	2.57	2.70
2.	***Asystasia gangetica T.*****Anderson subsp. *****micrantha***** (Nees) Ensermu**	0.00	0.00	2.57	**11.65**
3.	*Axonopus compressus* P.Beauv.	0.00	0.00	5.40	7.71
4.	*Borreria alata* DC.	0.00	0.00	5.25	3.10
5.	*Borreria laevis* Griseb.	0.00	0.00	2.87	0.00
6.	*Breynia stipitata* Müll.Arg.	0.00	0.00	5.24	4.82
7.	*Bridelia insulana* Hance	0.00	0.00	2.66	2.42
8.	*Centotheca lappacea* Desv.	0.00	6.81	5.28	7.93
9.	*Chromolaena odorata* (L.) R.M.King & H.Rob.	0.00	0.00	0.00	2.40
10.	***Clidemia hirta***** D.Don**	0.00	**34.23**	7.17	**45.65**
11.	*Cyperus difformis* L.	0.00	0.00	2.57	0.00
12.	*Cyrtococcum accrescens* Stapf	0.00	0.00	2.60	0.00
13.	*Cyrtococcum patens* A.Camus	0.00	0.00	7.40	0.00
14.	*Cyrtococcum trigonum* A.Camus	0.00	9.94	0.00	0.00
15.	*Dianella ensifolia* (L.) DC.	0.00	0.00	5.16	0.00
16.	***Dicranopteris linearis***** (Burm.f.) Underw.**	0.00	**28.84**	**17.32**	**11.13**
17.	*Fimbristylis dura* (Zoll. & Moritz) Merr.	0.00	0.00	2.57	0.00
18.	*Imperata cylindrica* (L.) P.Beauv.	0.00	0.00	6.32	3.39
19.	*Lantana camara* L.	0.00	0.00	0.00	2.89
20.	*Lygodium flexuosum* (L.) Sw.	0.00	6.38	0.00	5.34
21.	*Macaranga triloba* Müll.Arg.	0.00	0.00	2.71	0.00
22.	*Melastoma affine* D. Don	0.00	12.62	5.34	6.59
23.	*Mikania micrantha* Kunth	0.00	0.00	0.00	3.05
24.	*Mussaenda frondosa* Blanco	0.00	0.00	2.58	2.67
25.	*Oplismenus compositus* (L.) P.Beauv.	0.00	6.55	0.00	0.00
26.	*Ottochloa nodosa* (Kunth) Dandy	0.00	0.00	0.00	6.57
27.	*Paspalum conjugatum* P.J.Bergius	0.00	0.00	2.60	0.00
28.	*Paspalum dilatatum* Poir.	0.00	0.00	5.38	5.69
29.	*Pennisetum purpureum* Schumach.	0.00	0.00	0.00	2.42
30.	*Polygala paniculata* Leconte ex Torr. & A.Gray	0.00	0.00	0.00	2.39
31.	***Scleria ciliaris***** Nees**	0.00	**13.18**	**8.10**	7.24
32.	*Sporobolus diander* P.Beauv.	0.00	0.00	0.00	4.95
33.	*Stachytarpheta indica* Vahl	0.00	0.00	0.00	2.95
34.	*Stachytarpheta jamaicensis* (L.) Vahl	0.00	0.00	0.00	5.34
35.	***Stenochlaena palustris***** (Burm.) Bedd.**	0.00	0.00	**7.71**	2.39
36.	*Taenitis blechnoides* (Willd.) Sw.	0.00	12.79	5.28	5.62
37.	*Tetracera scandens* Gilg & Werderm.	0.00	0.00	2.71	0.00
38.	*Tetracera indica* Merr.	0.00	14.05	0.00	0.00
39.	*Uncaria* cf. *glabrata* (Lour.) Merr.	0.00	0.00	2.63	2.50
40.	*Urena lobata* L.	0.00	0.00	2.58	2.52
	Total	0.00	145.38	130.53	174.02

Note: The species with the highest IVI are highlighted in bold.

Risk Analysis of IPS using Scoring Systems

The risk assessment of IPS at Bukit Duabelas and the surrounding area were calculated by scoring system protocol of Virtue (2008) which were developed by Tjitrosoedirdjo *et.al.* (2013). The scoring system were resulting the classifications of plant risk analysis and feasibility of containment (Table 7). Therefore the recommendation for IPS management were determined based on the matrix of comparison of risk analysis and feasibility of containment (Table 8).

The coverage of suitable area for IPS distribution was estimated by the vegetation map of BDNP and the surrounding area (Appendix 6). The coverage area of the vegetation type based on the map is shown in Table 9. This information was useful to calculate the potential distribution in the risk analysis section (Table 7). Risk assessment of plant species at Bukit Duabelas showed that the invasive risks and the feasibility of containment has various category from very high to negligible (Table 8).

Table 7 Scoring of risk analyis and feasibility of containment of the IPS at Bukit Duabelas with the questions on risk analysis: invasiveness (Inv.), impact (Imp.), potential distribution (PD); and feaseability of containment: control cost (CC), current distribution (CD), and persistency (P)

No.	Species	Risk Analysis (RA)			Feasibility of Containment (FC)		
		Inv.	Imp.	PD	CC	CD	P
1.	*Chromolaena odorata* (L.) R.M.King & H.Rob.	6.00	5.26	6.00	2.67	1.00	4.55
2.	*Imperata cylindrica* (L.) P.Beauv.	4.00	5.26	8.00	1.33	1.25	2.73
3.	*Urena lobata* L.	6.67	3.16	8.00	2.67	0.13	5.46
4.	*Mikania micrantha* Kunth	5.33	3.68	8.00	0.67	0.17	5.46
5.	*Clibadium surinamense* L.	6.00	2.63	8.00	3.33	1.67	7.27
6.	*Dicranopteris linearis* (Burm.f.) Underw.	6.00	2.63	8.00	2.00	3.33	6.00
7.	*Stenochlaena palustris* (Burm.) Bedd.	5.33	2.63	8.00	3.33	1.67	4.55
8.	*Passiflora foetida* L.	6.67	2.11	8.00	2.00	0.04	6.36
9.	*Lantana camara* L.	5.33	3.16	6.00	0.67	0.13	4.55
10.	*Clidemia hirta* D.Don	6.00	2.11	8.00	2.00	4.25	6.36
11.	*Pennisetum purpureum* Schumach.	4.67	2.63	8.00	1.33	0.50	3.64
12.	*Ageratum conyzoides* L.	7.33	1.58	8.00	4.00	0.08	5.46
13.	*Cyperus difformis* L.	4.67	3.16	6.00	2.67	0.13	6.00
14.	*Jatropha gossypiifolia* L.	5.33	3.68	4.00	2.67	0.04	5.45
15.	*Centrosema pubescens* Benth.	6.00	1.58	8.00	1.33	0.04	5.45
16.	*Tetracera indica* Merr.	4.00	3.16	6.00	3.33	0.96	4.55
17.	*Mimosa pigra* L.	7.33	4.74	2.00	2.00	0.04	6.36
18.	*Croton hirtus* L'Hér.	5.33	3.16	4.00	2.67	0.04	4.55
19.	*Bidens pilosa* L.	5.33	1.58	8.00	2.00	0.08	5.46
20.	*Asystasia gangetica T.*Anderson subsp. *micrantha* (Nees) Ensermu	6.00	1.58	6.00	1.33	1.33	7.27
21.	*Cyrtococcum patens* A.Camus	6.00	1.05	8.00	0.67	1.29	4.55
22.	*Scleria ciliaris* Nees	5.33	1.05	8.00	2.00	2.08	5.46
23.	*Centotheca lappacea* Desv.	4.67	1.05	8.00	2.67	0.96	4.55
24.	*Paspalum conjugatum* P.J.Bergius	4.67	1.05	8.00	1.33	0.08	5.46
25.	*Uncaria* cf. *glabrata* (Lour.) Merr.	4.00	1.58	6.00	2.67	0.92	3.64
26.	*Nephrolepis biserrata* (Sw.) Schott	6.00	1.58	4.00	2.00	0.04	6.36
27.	*Mussaenda frondosa* Blanco	3.33	1.05	8.00	1.33	2.08	2.73
28.	*Borreria alata* DC.	6.00	0.53	8.00	1.33	0.08	0.91
29.	*Tetracera scandens* Gilg & Werderm.	2.67	1.58	6.00	4.00	1.29	4.55

Table 7 Scoring of risk analyis and feasibility of containment of the IPS at Bukit Duabelas with the questions on risk analysis: invasiveness (Inv.), impact (Imp.), potential distribution (PD); and feaseability of containment: control cost (CC), current distribution (CD), and persistency (P) (continued)

No.	Species	Risk Analysis (RA)			Feasibility of Containment (FC)		
		Inv.	Imp.	PD	CC	CD	P
30.	*Melastoma affine* D. Don	4.67	0.53	8.00	2.00	1.00	5.46
31.	*Taenitis blechnoides* (Willd.) Sw.	4.67	0.53	8.00	1.33	0.96	5.46
32.	*Axonopus compressus* P.Beauv.	5.33	0.53	6.00	2.00	0.96	3.64
33.	*Borreria laevis* Griseb.	4.00	0.53	8.00	2.00	0.08	4.55
34.	*Lygodium flexuosum* (L.) Sw.	4.00	1.05	4.00	2.67	0.96	4.55
35.	*Ottochloa nodosa* (Kunth) Dandy	2.67	1.05	6.00	0.67	0.46	1.82
36.	*Stachytarpheta jamaicensis* (L.) Vahl	5.33	1.58	2.00	3.33	1.75	4.55
37.	*Cleome rutidosperma* DC.	6.00	2.63	1.00	3.33	0.04	6.36
38.	*Sphagneticola trilobata* (L.) Pruski	6.00	2.63	1.00	3.33	0.04	4.55
39.	*Rolandra fruticosa* Kuntze	5.33	2.11	1.00	2.00	0.04	4.55
40.	*Themeda arguens* (L.) Hack.	5.33	2.11	1.00	2.67	0.08	8.18
41.	*Panicum sarmentosum* Roxb.	4.67	1.58	1.00	2.67	0.83	4.55
42.	*Fimbristylis dichotoma* Hook.f.	6.00	1.58	1.00	2.67	0.04	3.64
43.	*Cyrtococcum accrescens* Stapf	2.67	0.53	6.00	0.67	0.46	4.55
44.	*Cleome viscosa* L.	4.67	1.58	1.00	3.33	0.04	5.45
45.	*Sonchus oleraceus* L.	4.67	1.58	1.00	3.33	0.04	5.45
46.	*Crassocephalum crepidioides* (Benth.) S.Moore	4.67	1.58	1.00	2.67	0.04	4.55
47.	*Fimbristylis dura* (Zoll. & Moritz) Merr.	3.33	0.53	4.00	2.00	0.08	1.82
48.	*Cyperus kyllingia* Endl.	6.00	1.05	1.00	3.33	0.04	5.45
49.	*Hyptis rhomboidea* M.Martens & Galeotti	4.00	1.58	1.00	2.67	0.04	4.55
50.	*Mimosa pudica* Mill.	4.67	0.53	6.00	3.33	0.04	6.36
51.	*Porophyllum ruderale* (Jacq.) Cass.	4.67	1.05	1.00	2.00	0.04	2.73
52.	*Hibiscus rosa-sinensis* L.	4.00	1.05	1.00	2.00	0.04	2.73
53.	*Mirabilis jalapa* L.	4.00	1.05	1.00	2.67	0.04	4.55
54.	*Ludwigia octovalvis* (Jacq.) P.H.Raven	2.00	1.67	1.00	2.67	0.04	4.55
55.	*Cyrtococcum trigonum* A.Camus	2.67	0.53	2.00	2.00	1.25	3.64
56.	*Oplismenus compositus* (L.) P.Beauv.	5.33	0.53	1.00	3.33	0.17	1.82
57.	*Lindernia crustacea* (L.) F.Muell.	4.67	0.53	1.00	3.33	0.04	2.73
58.	*Oxalis barrelieri* L.	4.67	0.53	1.00	2.67	0.04	4.55
59.	*Synedrella nodiflora* Gaertn.	4.67	0.53	1.00	3.33	0.04	5.45
60.	*Scoparia dulcis* L.	3.33	0.53	1.00	2.67	0.04	4.55
61.	*Typhonium trilobatum* (L.) Schott	3.33	1.05	0.50	2.67	0.04	5.46
62.	*Torenia violacea* (Azaola ex Blanco) Pennell	2.67	0.53	1.00	3.33	0.04	2.73
63.	*Breynia stipitata* Müll.Arg.	1.33	0.00	6.00	0.00	0.08	1.82
64.	*Bridelia insulana* Hance	1.33	0.00	6.00	0.00	0.08	1.82
65.	*Crotalaria mucronata* Desv.	2.00	0.00	0.50	2.67	0.04	3.64
66.	*Dianella ensifolia* (L.) DC.	1.33	0.00	4.00	2.00	0.08	0.91
67.	*Ludwigia perennis* Burm.f.	2.67	0.00	1.00	1.33	0.04	0.91
68.	*Macaranga triloba* Müll.Arg.	1.33	0.00	6.00	0.00	0.92	0.91
69.	*Melochia corchorifolia* Wall.	2.67	0.00	1.00	2.67	0.04	3.64
70.	*Paspalum dilatatum* Poir.	2.67	0.00	8.00	1.33	2.50	1.82
71.	*Polygala paniculata* Leconte ex Torr. & A.Gray	2.67	0.00	2.00	2.67	0.08	3.64
72.	*Salvinia molesta* D.Mitch.	4.67	3.68	0.00	2.67	0.04	6.36
73.	*Sporobolus diander* P.Beauv.	4.00	0.00	2.00	2.67	0.42	2.73
74.	*Stachytarpheta indica* Vahl	4.00	0.00	2.00	2.67	0.88	4.55
75.	*Ruellia tuberosa* L.	2.67	0.00	0.50	2.67	0.04	5.46
76.	*Catharanthus roseus* (L.) G.Don	3.33	0.00	0.50	2.00	0.04	4.55

Table 8 The level of risk analysis (RA), feasibility of containment (FC), and recommendation for management of IPS

No.	Species	RA		FC		Recommendation
		Score	Criteria	Score	Criteria	
1.	*Chromolaena odorata* (L.) R.M.King & H.Rob.	189.47	High	12.12	Very high	Destroy infestation
2.	*Imperata cylindrica* (L.) P.Beauv.	168.42	High	4.55	Very high	Destroy infestation
3.	*Urena lobata* L.	168.42	High	1.82	Very high	Destroy infestation
4.	*Mikania micrantha* Kunth	157.19	High	0.61	Very high	Destroy infestation
5.	*Clibadium surinamense* L.	126.32	High	40.40	Medium	Protect sites
6.	*Dicranopteris linearis* (Burm.f.) Underw.	126.32	High	42.42	Medium	Protect sites
7.	*Stenochlaena palustris* (Burm.) Bedd.	112.28	High	25.25	High	Contain spread
8.	*Passiflora foetida* L.	112.28	High	0.53	Very high	Contain spread
9.	*Lantana camara* L.	101.05	High	0.38	Very high	Contain spread
10.	*Clidemia hirta* D.Don	101.05	High	54.09	Medium	Protect sites
11.	*Pennisetum purpureum* Schumach.	98.25	Medium	2.42	Very high	Contain spread
12.	*Ageratum conyzoides* L.	92.63	Medium	1.82	Very high	Contain spread
13.	*Cyperus difformis* L.	88.42	Medium	2.00	Very high	Contain spread
14.	*Jatropha gossypiifolia* L.	78.60	Medium	0.61	Very high	Contain spread
15.	*Centrosema pubescens* Benth.	75.79	Medium	0.30	Very high	Contain spread
16.	*Tetracera indica* Merr.	75.79	Medium	14.52	High	Protect sites
17.	*Mimosa pigra* L.	69.47	Medium	0.53	Very high	Contain spread
18.	*Croton hirtus* L'Hér.	67.37	Medium	0.51	Very high	Contain spread
19.	*Bidens pilosa* L.	67.37	Medium	0.91	Very high	Contain spread
20.	*Asystasia gangetica T.*Anderson subsp. *micrantha* (Nees) Ensermu	56.84	Medium	12.93	Very high	Contain spread
21.	*Cyrtococcum patens* A.Camus	50.53	Medium	3.91	Very high	Contain spread
22.	*Scleria ciliaris* Nees	44.91	Medium	22.73	High	Protect sites
23.	*Centotheca lappacea* Desv.	39.30	Medium	11.62	Very high	Contain spread
24.	*Paspalum conjugatum* P.J.Bergius	39.30	Medium	0.61	Very high	Contain spread
25.	*Uncaria* cf. *glabrata* (Lour.) Merr.	37.90	Low	8.89	Very high	Monitor
26.	*Nephrolepis biserrata* (Sw.) Schott	37.89	Low	0.53	Very high	Monitor
27.	*Mussaenda frondosa* Blanco	28.07	Low	7.58	Very high	Monitor
28.	*Borreria alata* DC.	25.26	Low	0.10	Very high	Monitor
29.	*Tetracera scandens* Gilg & Werderm.	25.26	Low	23.49	High	Monitor
30.	*Melastoma affine* D. Don	19.65	Low	10.91	Very high	Monitor
31.	*Taenitis blechnoides* (Willd.) Sw.	19.65	Low	6.97	Very high	Monitor
32.	*Axonopus compressus* P.Beauv.	16.84	Low	6.97	Very high	Monitor
33.	*Borreria laevis* Griseb.	16.84	Low	0.76	Very high	Monitor
34.	*Lygodium flexuosum* (L.) Sw.	16.84	Low	11.62	Very high	Monitor
35.	*Ottochloa nodosa* (Kunth) Dandy	16.84	Low	0.56	Very high	Monitor
36.	*Stachytarpheta jamaicensis* (L.) Vahl	16.84	Low	26.52	High	Monitor
37.	*Cleome rutidosperma* DC.	15.79	Low	0.88	Very high	Monitor
38.	*Sphagneticola trilobata* (L.) Pruski	15.79	Low	0.63	Very high	Monitor
39.	*Rolandra fruticosa* Kuntze	11.23	Negligible	0.38	Very high	Monitor
40.	*Themeda arguens* (L.) Hack.	11.23	Negligible	1.82	Very high	Monitor
41.	*Panicum sarmentosum* Roxb.	11.05	Negligible	10.10	Very high	Monitor
42.	*Fimbristylis dichotoma* Hook.f.	9.47	Negligible	0.40	Very high	Monitor
43.	*Cyrtococcum accrescens* Stapf	8.42	Negligible	1.39	Very high	Monitor
44.	*Cleome viscosa* L.	7.37	Negligible	0.76	Very high	Monitor
45.	*Sonchus oleraceus* L.	7.37	Negligible	0.76	Very high	Monitor

Table 8 The level of risk analysis (RA), feasibility of containment (FC), and recommendation for management of IPS (continued)

No.	Species	RA		FC		Recommendation
		Score	Criteria	Score	Criteria	
46.	*Crassocephalum crepidioides* (Benth.) S.Moore	7.37	Negligible	0.51	Very high	Monitor
47.	*Fimbristylis dura* (Zoll. & Moritz) Merr.	7.02	Negligible	0.30	Very high	Monitor
48.	*Cyperus kyllingia* Endl.	6.32	Negligible	0.76	Very high	Monitor
49.	*Hyptis rhomboidea* M.Martens & Galeotti	6.32	Negligible	0.51	Very high	Monitor
50.	*Mimosa pudica* Mill.	4.91	Negligible	0.88	Very high	Monitor
51.	*Porophyllum ruderale* (Jacq.) Cass.	4.91	Negligible	0.23	Very high	Monitor
52.	*Hibiscus rosa-sinensis* L.	4.21	Negligible	0.23	Very high	Monitor
53.	*Mirabilis jalapa* L.	4.21	Negligible	0.51	Very high	Monitor
54.	*Ludwigia octovalvis* (Jacq.) P.H.Raven	3.33	Negligible	0.51	Very high	Monitor
55.	*Cyrtococcum trigonum* A.Camus	2.81	Negligible	9.09	Very high	Monitor
56.	*Oplismenus compositus* (L.) P.Beauv.	2.81	Negligible	1.01	Very high	Monitor
57.	*Lindernia crustacea* (L.) F.Muell.	2.46	Negligible	0.38	Very high	Monitor
58.	*Oxalis barrelieri* L.	2.46	Negligible	0.51	Very high	Monitor
59.	*Synedrella nodiflora* Gaertn.	2.46	Negligible	0.76	Very high	Monitor
60.	*Scoparia dulcis* L.	1.75	Negligible	0.51	Very high	Monitor
61.	*Typhonium trilobatum* (L.) Schott	1.75	Negligible	0.61	Very high	Monitor
62.	*Torenia violacea* (Azaola ex Blanco) Pennell	1.40	Negligible	0.38	Very high	Monitor
63.	*Breynia stipitata* Müll.Arg.	0.00	Negligible	0.00	Very high	Monitor
64.	*Bridelia insulana* Hance	0.00	Negligible	0.00	Very high	Monitor
65.	*Crotalaria mucronata* Desv.	0.00	Negligible	0.40	Very high	Monitor
66.	*Dianella ensifolia* (L.) DC.	0.00	Negligible	0.15	Very high	Monitor
67.	*Ludwigia perennis* Burm.f.	0.00	Negligible	0.05	Very high	Monitor
68.	*Macaranga triloba* Müll.Arg.	0.00	Negligible	0.00	Very high	Monitor
69.	*Melochia corchorifolia* Wall.	0.00	Negligible	0.40	Very high	Monitor
70.	*Paspalum dilatatum* Poir.	0.00	Negligible	6.06	Very high	Monitor
71.	*Polygala paniculata* Leconte ex Torr. & A.Gray	0.00	Negligible	0.81	Very high	Monitor
72.	*Salvinia molesta* D.Mitch.	0.00	Negligible	0.71	Very high	Monitor
73.	*Sporobolus diander* P.Beauv.	0.00	Negligible	3.03	Very high	Monitor
74.	*Stachytarpheta indica* Vahl	0.00	Negligible	10.61	Very high	Monitor
75.	*Ruellia tuberosa* L.	0.00	Negligible	0.61	Very high	Monitor
76.	*Catharanthus roseus* (L.) G.Don	0.00	Negligible	0.38	Very high	Monitor

Table 9 The coverage of each vegetation type in Bukit Duabelas

No.	Vegetation type	Covering area (hectares)	Covering percentage (%)
1.	Cleared area	2,400	0.74
2.	Mixed Agriculture	4,170	1.29
3.	Mixed Garden	765	0.24
4.	Forest medium open canopy (40-70%)	45,474	14.03
5.	Forest rather closed canopy (>70%)	8,105	2.50
6.	Forest very open canopy (10-40%)	8,190	2.53
7.	Oil palm plantation	60,730	18.74
8.	Old secondary regrowth on swampy	3,736	1.15
9.	Old secondary regrowth /Jungle rubber	34,286	10.58
10.	Paddy field	137	0.04
11.	Rubber plantation	120,585	37.21
12.	Settlement	762	0.24
13.	Shrubs	17,385	5.36
14.	Shrubs on swampy	3,458	1.07
15.	Swamp Grasses or Fernland	904	0.28
16.	Water body	2,343	0.72
17.	Young Plantation	10,675	3.29
	Total	**324,108**	**100.00**

Discussions

Inventory of IPS at Bukit Duabelas and the Surrounding area

The IPS threatens various ecosystem types in Indonesia, such as logged over forests, overgrazing pastures, aquatic ecosystems (lakes, rivers, dams, etc.), and agricultural production systems. In 2005, Tjitrosoedirdjo listed 339 alien plant species in Indonesia which potentially invasive. In this study, 76 IPS were found at the residential area and agricultural production systems i.e. jungle rubber, rubber and oil palm plantation, as well as at the surrounding area of those plantations in Bukit Duabelas, Jambi, Sumatra. Most of IPS are herbs which belongs to Poaceae family (15 species), followed by Asteraceae (11 species), and Euphorbiaceae (5 species). Germer (2003) reported that Asteraceae, Rubiaceae, and Euphorbiaceae were the richest families of weeds growing in association with oil palm plantation in West Sumatra. According to Tjitrosoedirdjo (2005), the highest record of weeds in Indonesia were found in Poaceae, followed by Asteraceae, Cyperaceae, and Euphorbiaceae.

Poaceae and Asteraceae are the highest plant families with worldwide distribution. These families have a wide range of distribution due to their rapid reproductions both generatively and vegetatively. They also establish via dorman seeds in the soil as a seed bank or via rhizomes. Some species of Poaceae family have allelopathic compound (Moreiras 2004). The IPS with allelopathic compound are more harmful to the environment, because they are able to inhibit germination and growth of other vegetation (Wentwoth 2013). Meanwhile, some IPS from the Asteraceae family have different invasivity mode. Most of their seeds has ‘pappus’ or other morphological adaptation for seeds dispersal by wind and water. It makes many species of the Asteraceae are distributed widely.

Plant species are differentiated into native and alien species. Native species is the one that is naturally found in a given area, with no human intervention. Meanwhile, an alien or non-native species is one which has been introduced by human action, deliberately or accidentally, into an area in which it would not occur naturally. Both native and non-native plants species can be invasive (Booth *et.al.* 2010). The IPS that has been listed at Bukit Duabelas and surroundings are originated from almost of all the continents (Europe, America, Asia, Africa, and Australia). Thirty percent of the species are native to Indonesia. Seventy percent of the species are recognized as alien plant species, but most of them (42%) are originated to America. The alien plant species originating from other ecosystem could invade the study area at Bukit Duabelas and surroundings, it showed that the alien plant species has adaptability to local settings. Disturbances in the ecosystem provide an opportunity for the expansion of IPS (Raghubanshi & Tripathi 2009).

Distribution Pattern of IPS within the Ecosystem

A total of 40 species of IPS were found in all ecosystem plots. High risk of IPS infestation found at the disturbed areas. Canopy cover was highest in forest where IPS were completely absent. Oil palm plantation (28 sp; $P = 0.01$) and rubber plantation (27 sp; $P = 0.02$) had higher number of IPS than jungle rubber (10 sp).

The cluster analysis separated the IPS community into three groups, as shown in the result (Figure 5). The first community, oil palm and rubber plantation were plantation ecosystem characterized by an extensive human interference with highest IPS. The second community, jungle rubber was characterized by a high density of plants and a limited for only 10 species of IPS. The third group was forest, a climax ecosystem representing a fully occupied niche, and difficult for IPS to establish.

Agroforestry system of jungle rubber creates a high biodiversity of local tree species followed by the high canopy cover. This condition caused the low number of IPS presence in jungle rubber. Most of the jungle rubber vegetation are shrubs, trees, and climbers. Meanwhile, rubber and oil palm plantation applied monoculture systems where the crops were planted in certain distance. These systems provide a soil space for establishment of IPS. Therefore the IPS in rubber plantation almost the same with the IPS in oil palm plantation and its number of species of IPS are higher than in jungle rubber.

In this study, the number of IPS distribution are influenced by the abiotic factors i.e. canopy openness and air temperature (Figure 6). The IPS invasion was higher of open areas such as oil palm and rubber plantation than in the shaded systems jungle rubber and forest. The air temperature as a consequences of the canopy openness was higher in oil palm and rubber plantation. A more open canopy increases air temperature (Lambers *et.al.* 2008) that favors IPS. These results are consistent with the study of Mc Alpine *et.al.* (2014) which revealed a higher abundance and biomass of IPS under highlight conditions. According to study of Cole and Weltzin (2005), light limitation is the primary factor that prevent the growth of IPS seedlings. Beside light intensity, Ibàñez *et.al.* (2009) revealed that relatively warmer areas is associated with invasive plants occurrence. Canopy cover was highest in forest where IPS were completely absent. The forest condition might not suitable for IPS establishment due to the canopy cover creates low of light penetration and air temperature. Junaedi & Dodo (2014) revealed that most of IPS cannot reach the forest interior where the forest structure is still relatively intact.

The dominant IPS which were distributed in Bukit Duabelas plots were *C. hirta* and *D. linearis*. These IPS were found in all three ecosystems area except forest. The distribution pattern of *C. hirta* spread randomly from small to huge colony. In the environment, this species tends to grow at open area (Gerlach 2006). *C. hirta* dominated areas under plantations until jungle rubber plot, but it was not found at the forest plot. It provides an indication that *C. hirta* is the shade intolerant plant species. The preferred habitat of *C. hirta* was at humid tropical lowlands (Dawson 2008). In some cases, *C. hirta* were introduced intentionally into Botanic Garden, such as Perediniya-Srilanka in 1894, Amani-Tanzania in 1930, and Wahiana-Hawai in 1941 (Dawson 2008). Some botanic gardens have introduced *C. hirta* due to it is economically valuable as ornamental plant. *C. hirta* is easily dispersed due to its edible fruits eaten by birds and other animals and large numbers of seeds (more than 100 seeds / fruit). In addition, the seeds are able to stay dormant for 4 years in the soil (Dawson 2008).

D. linearis is the native species. It became invasive due to the environmental changes as a result of the forest conversion into plantation establishment. This factor also reinforced by the biological characteristic of *D. linearis* and supported by the human activities. This species is commonly occurring on disturbed and eroded areas. It effectively build a large mats so that no seedlings of other species can establish (Farrér and Hertach 2009). They grow preferably at the wet habitat, open canopy site on low fertility soil (Russel *et.al.* 1998). This species was reported as an acid soil indicator (Kong 2003). The study area are covered by yellow podzolic soil, an acid soil of low fertility. The distribution pattern of *D. linearis* is clumped at the open canopy as a huge colony. However, it grew also at the jungle rubber where the canopy cover was relatively high compare to that of rubber and oil palm plantations. The condition in jungle rubber is not too shaded at the plot side border. There was a gap at the plot border and the light may penetrate the plot through side border. So that *D. linearis* able to occupy the area and became abundant at the side area of jungle rubber (Appendix 3). It also grows abundantly along roadside of the plantation gaps and along the trail leading to the forest. It was also reported as the dominant species at the Samosir Botanic Garden at North Sumatra (Hartini 2010).

In this case, the success of plant invasion is driven by the abiotic factor of receiving environment which also is dependent on propagule pressure with dispersal mediated by human and biological characteristic of invading species (Catford *et.al.* 2009). This mechanism includes the interaction between abiotic factor and propagule pressure, where certain ecosystems tend to be exposed to high propagule pressure (Catford *et.al.* 2009). Generally, the spread of IPS in Bukit Duabelas are driven by the ecosystem disturbances, either natural or anthropogenic disturbance. Besides the plantation development, recently forest fire has occurred in Jambi, including the forest plots in Bukit Duabelas. Fires often creates a new condition for invasions windows. Based on Obiri (2011), fires drove seedling dynamics, caused seedling mortality, species loss, and germination of seed in seed bank under intense conditions. It increases opportunities for invading species. Some activities that facilitate disturbances, i.e. land use change, illegal loging, forest fire should be prevented. Therefore immediate action of reforestation of disturbed area in the national park should be taken. The IPS which establish in the plantations should also be prevented from spreading into the national park. For example, fruit of *C. hirta* is easily attached to human cloth, to prevent intentional introduction, the gate for people going to the forest must be kept clean of *C. hirta*.

Recommendation of IPS Management in Bukit Duabelas and the Surrounding Area

The risk management system recommended various action appropriate for the respective plant invaders of Bukit Duabelas. The combination of assessment of risk analysis and feasibility of containment were resulting the recommendation for management action of IPS. Based on the risk management, the priorities of IPS management were classified into (1) eradication, (2) destroy infestation, (3) contain spread, (4) protect sites, (5) protect sites and manage weed, (6) manage weed, (7) manage sites, (8) monitor, and (9) limited action respectively. Eradication is the removal of every individual of IPS from an area. Generally, eradication is followed by restoration or management community or ecosystem resulting from the removal of a target species (Gherardi & Angiolini 2004). However there are no IPS at Bukit Duabelas area were included in the priority of “eradication”.

Some IPS needs immediate action to destroy infestation i.e. *C. odorata*, *I. cylindrica*, *U. lobata*, and *M. micrantha*. This management is aimed at reducing the IPS population significantly in an area. All of those species are not found in BDNP area. It is an opportunity to destroy the invasion when their populations are still small to prevent further their invasion. These IPS must be controlled seriously, no new invasion is allowed.

In the next classification, *S. palustris, P. foetida, L. camara, P. purpureum, A. conyzoides, C. diformis, J. gossypfolia, C. pubescens, C. hirtus, B. pilosa, C. lappacea,* and *P. conjugatum* are the species that needs to contain its spread. The spread of these species must be prevented. Then *C. surinamense, D. linearis, C. hirta, T. scandens,* and *S. ciliaris* are the plant species that needs to prevent its arrival into the BDNP (protect site). It must be prevented from invading to the forest area of BDNP (protect site). For example, *C. hirta* and *D. linearis* are already form a huge population in the rubber and oil palm plantation systems, as well as along roadside in Bukit Duabelas. However, these two species are not found in BDNP forest (protect site) because they are shade intolerant species and the canopy cover in the BDNP forest plot is still relatively intact. To protect the site, for example preventing the people carrying the propagul into the BDNP.

Meanwhile 51 other IPS have low and negligible level of invasive risk. However these species need to be monitored. If the population increases they need to be managed or controlled. Most of these species commonly occupied along roadsides. Generally, those priority program is likely to be succesfull when the protected area managers, stakeholders, and goverments are aware on (a) adequate funds and the commitment to complete the control or prevention program, (b) monitoring of the population size is feasible, and (c) eradication (if any) or controlled program should be followed by the restoration of the forest (GISP 2007). Although the IPS do not enter yet into the forest BDNP (protect site), restoration in the BDNP must be promoted when the national park were experiences by natural disasters and illegal loging must be prevented.

CONCLUSIONS

There are a total of 76 IPS at Bukit Duabelas plots and surrounding area which belongs to 64 genera and 30 families. High risk of IPS invasions found at the disturbed areas. Canopy cover was highest in the forest where IPS were completely absent. Oil palm plantation (28 sp) and rubber plantation (27 sp) had higher number of IPS than jungle rubber (10 sp). Canopy cover is a main factor influencing the distribution of IPS. The IPS invasions was higher in open areas such as oil palm and rubber plantation than in the shaded systems jungle rubber and forest. *D. linearis* and *C. hirta* were found to be the most widely distributed IPS. Some activities that facilitate disturbances, i.e. land use change, illegal loging, forest fire should be prevented. Immediate action of reforestation of disturbed area in the national park should be applied. The IPS which were establish in the plantations should also be prevented its spread into national park by preventing humans to carry the IPS propagule into forested area through avoiding the pathway which were invaded by invasive plants. The serious plants invader need immediate action to destroy infestation, contain its spread, protect the forest in order to prevent the IPS spread into BDNP.

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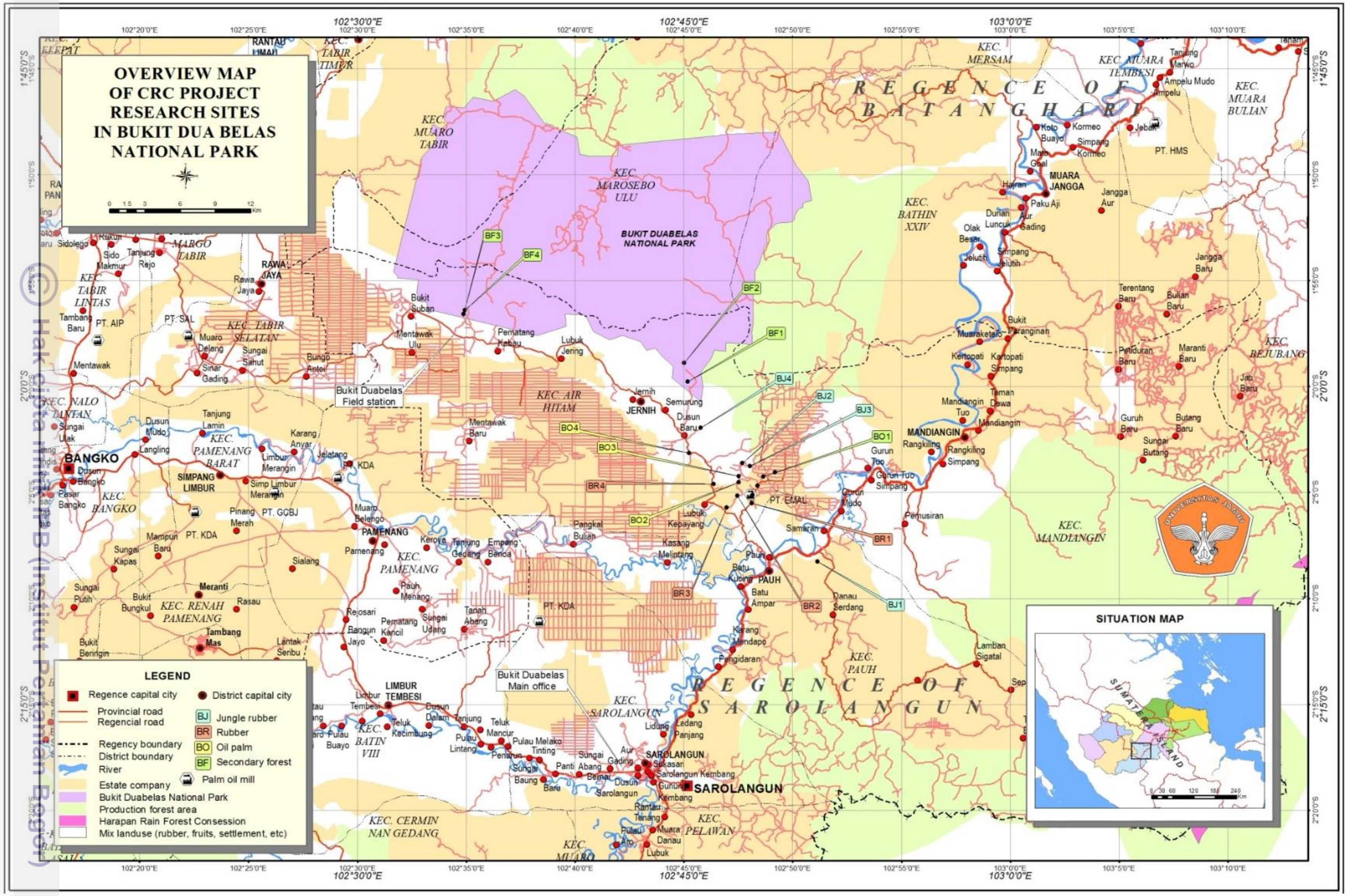
APENDICES

Appendix 1 The research plot locations at Bukit Duabelas National Park and the surrounding area



Appendix 2 The questionnaire of the scoring system based on Tjitrosoedirdjo *et.al.* (2013)

The questions to assess invasiveness of IPS

1. What is the weed's ability to establish amongst existing plants?		Score
□ very high	"Seedlings" readily establish within dense vegetation, or amongst thick infestations of other weeds.	3
□ high	"Seedlings" readily establish within more open vegetation, or amongst average infestations of other weeds.	2
□ medium	"Seedlings" mainly establish when there has been moderate disturbance to existing vegetation, which substantially reduces competition. This could include intensive grazing, mowing, raking, clearing of trees, temporary floods or summer droughts.	1
□ low	"Seedlings" mainly need bare ground to establish, including removal of stubble/leaf litter. This will occur after major disturbances such as cultivation, overgrazing, hot fires, grading, long-term floods or long droughts.	0
□ don't know		?

2. What is the weed's tolerance to average weed management practices in the land use?		Score
□ very high	Over 95% of weeds survive commonly used weed management practices.	3
□ high	More than 50% of weeds survive.	2
□ medium	Less than 50% of weeds survive.	1
□ low	Less than 5% of weeds survive.	0
□ don't know		?

3. What is the reproductive ability of the weed in the land use?							Total a+b+c	Score
a. *Fruiting periods*		b. *Seed prod.*		c. *Vegetative reprod.*				
□ 1 year	2	□ Banyak	2	□ Fast	2	high	5 -6	3
□ 2-3 yrs	1	□ Sedikit	1	□ Slow	1	Medium-high	3-4	2
□ >3 yrs	0	□ Tak ada	0	□ None	0	Medium-low	1-2	1
□ don't know	?	□ don't know	?	□ Don't know	?	low	0	0
						Don't know		?

4. How likely is long-distance dispersal (>100m) by natural means?				Total a+b+c+d	Score
a. Flying birds		b. Other wild animals		6,7,8	3
common	2	common	2	3,4,5	2
occasional	1	occasional	1	1,2	1
unlikely	0	unlikely	0	0	0
don't know	?	don't know	?	don't know	?
c. Water		d. Wind			
common	2	common	2		
occasional	1	occasional	1		
unlikely	0	unlikely	0		
don't know	?	don't know	?		

5. How likely is long-distance dispersal by human means?				Total a+b+c+d	Score
a. Deliberate spread by people		b. Accidentally by people and vehicles		6,7,8	3
common	2	common	2	3,4,5	2
occasional	1	occasional	1	1.2	1
unlikely	0	unlikely	0	0	0
don't know	?	don't know	?	don't know	?
b. Contaminated produce		d. Domestic/farm animals			
common	2	common	2		
occasional	1	occasional	1		
unlikely	0	unlikely	0		
don't know	?	don't know	?		

The questions to asses impact of IPS

1. Does the weed reduce the establishment of desired plants?		Score
>50% reduction	The weed stops the establishment of more than 50% of desired plants (e.g. regenerating pasture, sown crops, planted trees, regenerating native vegetation), by preventing germination and/or killing seedlings.	3
10 – 50% reduction	The weed stops the establishment of between 10% and 50% of desired plants.	2
< 10% reduction	The weed stops the establishment of less than 10% of desired plants.	1
None	The weed does not affect the germination and seedling survival of desired plants.	0
Don't know		?

2. Does the weed reduce the yield or amount of desired vegetation?		Score
>50% reduction	The weed reduces crop, pasture or forestry yield, or the amount of mature native vegetation by over 50%.	4
25 – 50% reduction	The weed reduces yield or amount of desired vegetation by between 25% and 50%.	3
10-25% reduction	The weed reduces yield or amount of desired vegetation by between 10% and 25%.	2
< 10% reduction	The weed reduces yield or amount of desired vegetation by up to 10%.	1
None	The weed has no effect on growth of the desired vegetation. Or the weed may become desirable vegetation at certain times of year (e.g. providing useful summer feed), which balances out its reduction in the growth of other desirable plants.	0
Don't know		?

3. Does the weed reduce the quality of products or services obtained from the land use?		Score
high	The weed severely reduces product quality such that it cannot be sold. This may be due to severe contamination, toxicity, tainting and/or abnormalities (chemical and/or physical). For native vegetation, the weed severely reduces biodiversity (plants and animals) such that it is not suitable for nature conservation and/or nature-based tourism. For urban areas, the weed causes severe structural damage to physical infrastructure such as buildings, roads and footpaths.	3
medium	The weed substantially reduces product quality such that it is sold at a much lower price for a low grade use. For native vegetation, the weed substantially reduces biodiversity such that it is given lower priority for nature conservation and/or nature-based tourism. For urban areas, the weed causes some structural damage to physical infrastructure such as buildings, roads and footpaths.	2
low	he weed slightly reduces product quality, lowering its price but still passing as first grade product. For native vegetation, the weed has only marginal effects on biodiversity but is visually obvious and degrades the natural appearance of the landscape. For urban areas, the weed causes negligible structural damage, but reduces the aesthetics of an area through untidy visual appearance and/or unpleasant odour.	1
none	The weed does not effect the quality of products or services.	0
don't know		?

4. Does the weed restrict the physical movement of people, animals, vehicles, machinery and/or water?		Score
high	Weed infestations are impenetrable throughout the year, preventing the physical movement of people, animals, vehicles, machinery and/or water.	3
medium	Weed infestations are rarely impenetrable, but do significantly slow the physical movement of people, animals, vehicles, machinery and/or water throughout the year.	2
low	Weed infestations are never impenetrable, but do significantly slow the physical movement of people, animals, vehicles, machinery and/or water at certain times of the year or provide a minor obstruction throughout the year.	1
none	The weed has no effect on physical movement.	0
don't know		?

5. Does the weed influencing the human or animal health?		Score
High	The weed is highly toxic and frequently causes death and/or severe illness in people, stock, and/or native animals.	3
medium	The weed occasionally causes significant physical injuries (due to spines or barbs) and/or significant illness (chronic poisoning, strong allergies) in people, stock, and/or native animals, occasionally resulting in death.	2
Low	The weed can cause slight physical injuries or mild illness in people, stock, and/or native animals, with no lasting effects.	1
None	The weed does not affect the health of animals or people.	0
Don't know		?

6. Does the weed have major, positive or negative effects on environmental health?				
	major positive effect	major negative effect	minor or no effect	Don't know
Score (a) – (f).	-1	1	0	?
(a). food/shelter ?	Invasive plants influence negatively i.e. *Digitaria ciliaris* which became the host of blast on rice, whereas *Cassia cobanensis, Antigonon leptopus, Turnera subulata, Euphorbia heterophylla* was influence possitively, they provide nectar for insect parasitoids of caterpillars bag (Metisa plana, Pteroma pendula, Mahasena corbeti) which attacks palm.			
(b). fire regime?	These section include changes on frequency, intensity and / or timing of fire. For example, the invasion of *Chromolaena odorata* in secondary forest fires that make them susceptible.			
(c). increase nutrient levels?	Leguminosae seperti *Acacia nilotica* meningkatkan kandungan unsur hara tanah, walupun menguntungkan bagi pertanian, tetapi memfasilitasi invasi gulma lain, seperti *Thespesia lampas, Bidens biternata,* Aciranthes aspera dsb.			
(d).Soil salinity?	Leguminosae such as *Acacia nilotica* increase the nutrient soil, even though favorable to agriculture, but it's facilitate the invasion of other weeds, such as *Thespesia lampas, Bidens biternata*, Aciranthes aspera, etc.			
(e).Soil stability?	Does the weed increase soil erosion, or silting of waterways?			
(f). Soil water table?	Does the weed substantially raise or lower the soil water table compared to other plants present? Is this positive or negative?			
Total a +b +c +d +e +f	>3	2-3	1	0 or less
Score for (6)	3	2	1	0

The questions to asses potential distribution of IPS

What percentage area of the land use is suitable for the weed?		Score
>80% of land use	The weed has a potential to spread to more than 80% of the land use	10
60-80% of land use	The weed has a potential to spread to between 60% and 80% of the land use	8
40-60% of land use	The weed has a potential to spread to between 40% and 60% of the land use	6
20-40% of land use	The weed has a potential to spread to between 20% and 40% of the land use	4
10-20% of land use	The weed has a potential to spread to between 10% and 20% of the land use	2
5-10% of land use	The weed has a potential to spread to between 5% and 10% of the land use	1
1-5% of land use	The weed has a potential to spread to between 1% and 5% of the land use	0,5
unsuited land use	The weed is not suited to growing in any part of the land use	0
don't know		?

The questions to assess control cost of IPS

1. How detectable is the weed?				Total (a + b + c + d)	Score
(a). *Height at maturity*		(b). *Shoot growth present*		7 or 8	3
□ <0,5 m	2	□ < 4 months	2	5 or 6	2
□ 0,5 – 2 m	1	□ 4 – 8 months	1	3 or 4	1
□ > 2 m	0	□ > 8 months	0	0,1 or 2	0
□ don't know	?	□ don't know	?		?
(c) *Distinguishing features*		(d). *Pre-reproductive height in relation to other vegetation*			
□ non descript	2	□ below canopy	2		
□ sometimes distinct	1	□ similar height	1		
□ always disticnt	0	□ above canopy	0		
□ don't know	?	□ don't know	?		

2. What is general accessibility of known infestations?		Score
□ low	Most infestation sites difficult to access	2
□ medium	Most infestation sites readily accessible	1
□ high	All infestation sites readily accessible	0
□ none	Not known to be present	0
□ don't know		?

3. How expensive is control of the weed, using techniques which both maximise efficacy and minimise off-target damage?						Score
(a). Chemicals, fuel and equipment operating costs		(b). Labor costs		Jumlah (a+b)		Range between 0 & 8
□ very high	4	□ very high	4			
□ high	3	□ high	3	□ don't know		?
□ medium	2	□ medium	2			
□ low	1	□ low	1			
□ not applicable	0	□ not applicable	0			
□ don't know	?	□ don't know	?			

4. What is the likely level of cooperation from landholders within the land use at risk?		Score
□ low	Weed control is rarely undertaken in the land use. Cost of control is beyond the financial and technical capacity of landholders.	2
□ medium	Control of the weed will require a significant change in existing weed management practices, but this will be within the financial and technical capacity of landholders.	1
□ high	Control of the weed will require minimal change in existing weed management practices.	0
□ don't know		?

The questions to assess the real distribution of IPS

1. What percentage area of the land use is currently infested by the weed?		Score
□ > 80% of land use	The weed infests more than 80% of the land use	10
□ 60-80% of land use	The weed infests between 60% and 80% of the land use	8
□ 40-60% of land use	The weed infests between 40% and 60% of the land use.	6
□ 20-40% of land use	The weed infests between 20% and 40% of the land use	4
□ 10-20% of land use	The weed infests between 10% and 20% of the land use	2
□ 5-10% of land use	The weed infests between 5% and 10% of the land use	1
□ 1-5% of land use	The weed infests between 1% and 5% of the land use	0,5
□ < 1% of land use	The weed is present in the land use but infests less than 1%	0,1
□ 0% of land use but in 20-40% of board	The weed is not known to be present in the land use but does infest between 20% and 40% of the Board area	2
□ 0% lahan terinvasi dan 10-20% of board	The weed is not known to be present in the land use but does infest between 10% and 20% of the Board area	1
□ 0% of land use but in 5-10% of board	The weed is not known to be present in the land use, but does infest between 5% and 10% of the Board	0,5
□ 0% of land use but in 1-5% of board	The weed is not known to be present in the land use, but does infest 1-5% of Board	0,1
□ 0% of land use but in < 1% of board	The weed is not known to be present in the land use, but does infest <1% of Board. Or the species is not naturalised in the Board but is cultivated (e.g. olives)	0,05
□ 0% of board	The species is not known to be present in the Board	0
□ don't know		?

2. What is the pattern of the weed's distribution across the Board area?		Score
□ widespread	The weed occurs in large and small infestations across most of the Board area	2
□ evenly scattered	The weed occurs as discrete, mainly small infestations across much of the Board area	1
□ restricted	The weed is localised to 1-2 hundreds of the Board area. Or the weed is not known to be naturalised in the Board area	0
□ not present	The species is not known to be present in the Board	0
□ don't know		?

The questions to assess persistence scoring system

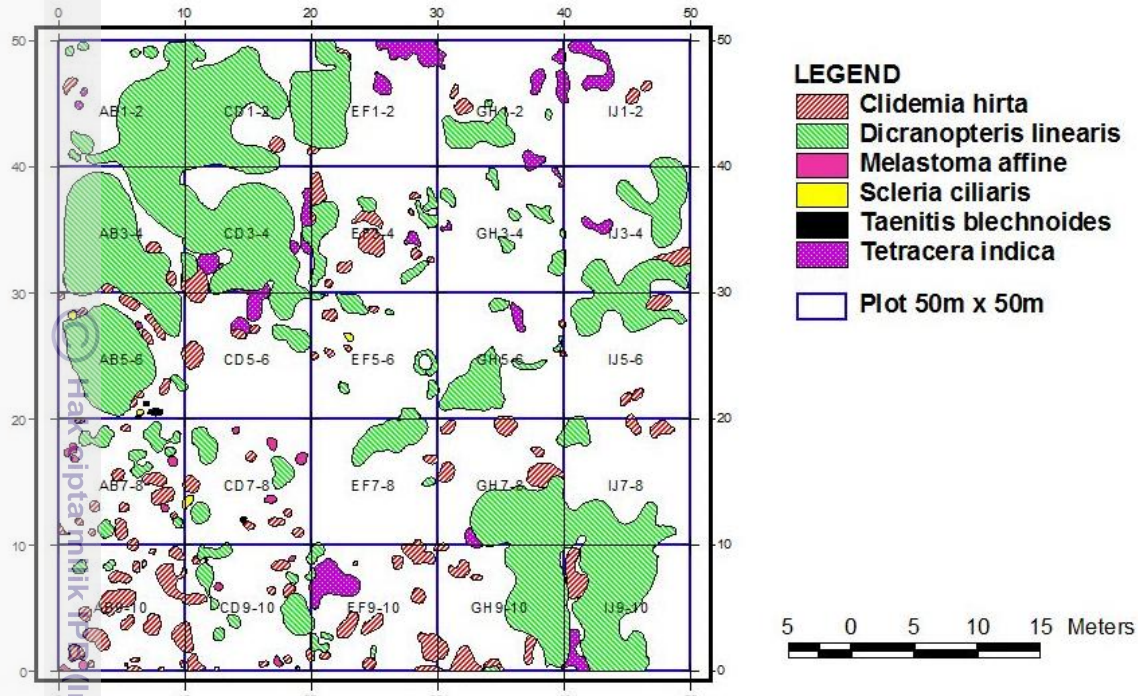
1. How effective are targeted control treatments applied to infestations of the weed?		Score
□ low	More than 25% of weeds survive annual targeted treatment/s	3
□ medium	Up to 25% of weeds survive annual targeted treatment/s.	2
□ migh	Up to 5% of weeds survive annual targeted treatment/s.	1
□ very high	Up to 1% of weeds survive annual targeted treatment/s	0
□ don't know		?

2. What is the minimum time period for reproduction of sexual or vegetative propagules?		Score
□ < 1 months	Minimum generation time <1 month.	3
□ <1 months	Minimum generation time 1-12 months.	2
□ < 2 years	Minimum generation time 12-24 months.	1
□ > 2 years	Minimum generation time >24 months.	0
□ don't know		?

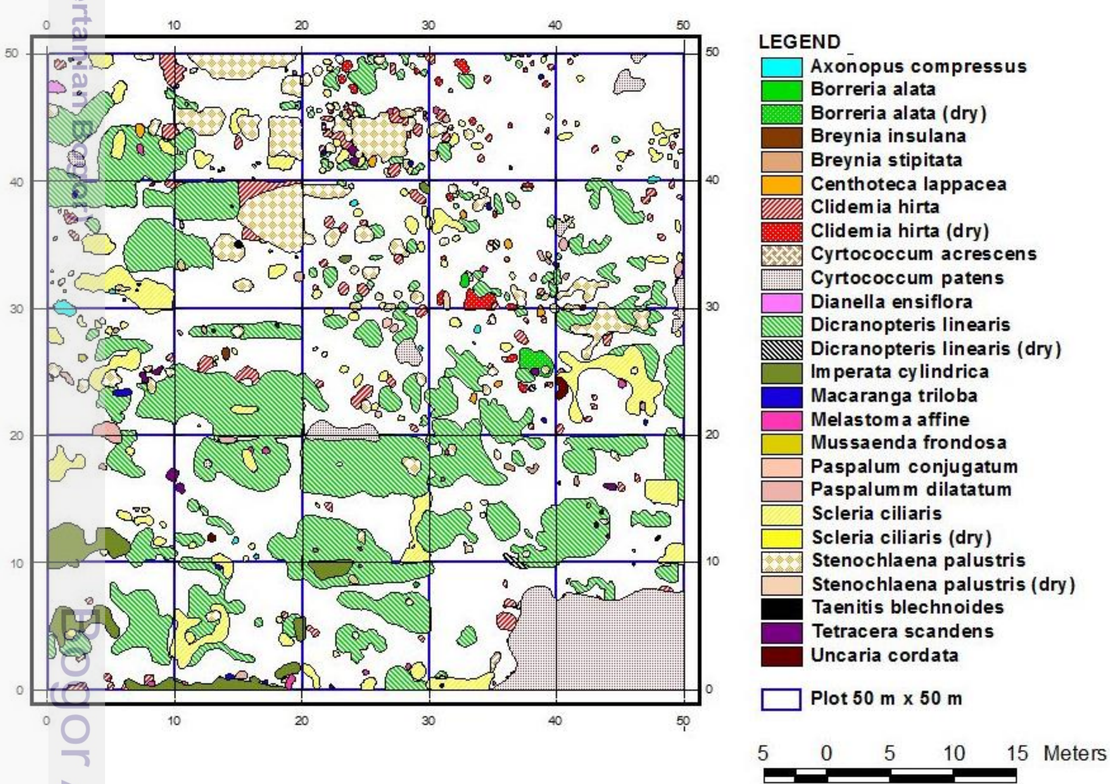
3. What is the maximum longevity of sexual or vegetative propagules?		Score
□ > 5 years	Sexual or vegetative propagules can remain dormant for at least 5 years	2
□ 2 – 5 years	Sexual or vegetative propagules can remain dormant for 2-5 years.	1
□ < 2 years	Sexual or vegetative propagules remain dormant for less than 2 years	0
□ don't know		?

4. How likely are new propagules to continue to arrive at control sites, or start new infestations?				Total (a +b)	Score
(a). Long-distance dispersal by natural means		(b).Grown		4	3
□ frequent	2	□ commonly planted	2	2-3	2
□ occasional	1	□ occasionally planted	1	1	1
□ rare	0	□ not planted	0	0	0
□ don't know	?	□ don't know	?	Don't know	?

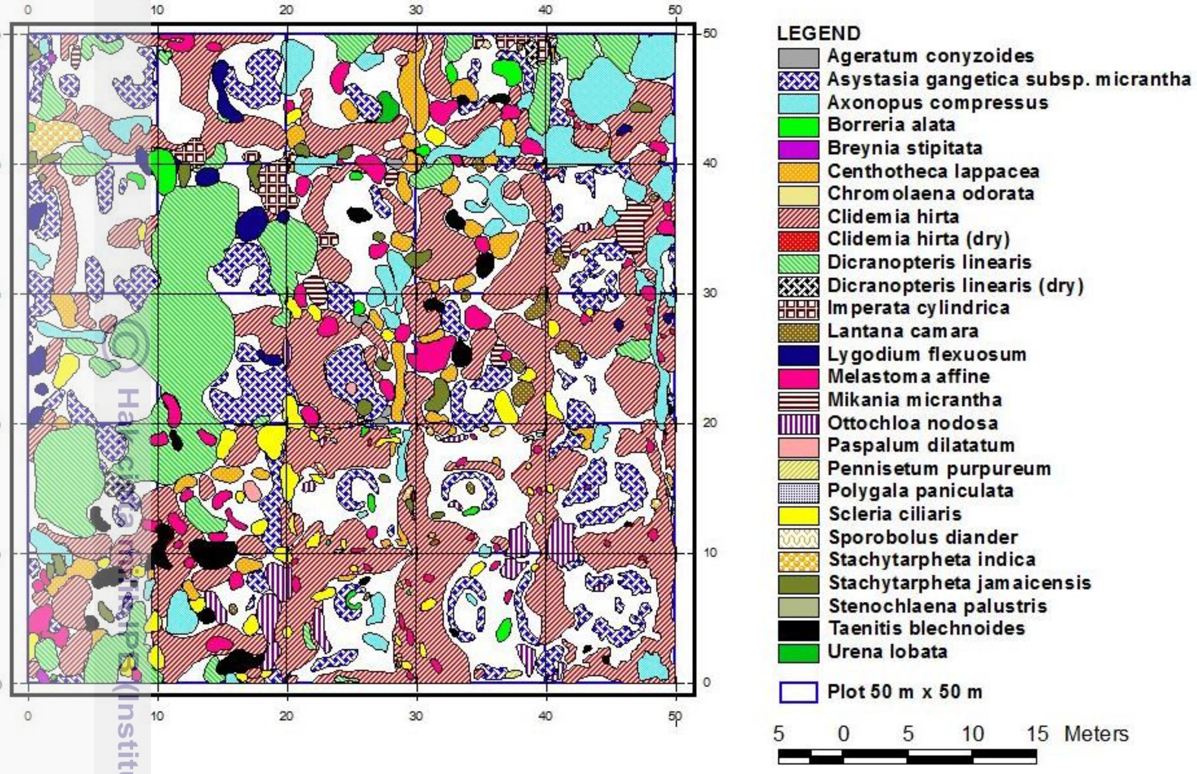
Appendix 3 The distribution pattern of IPS at jungle rubber plot



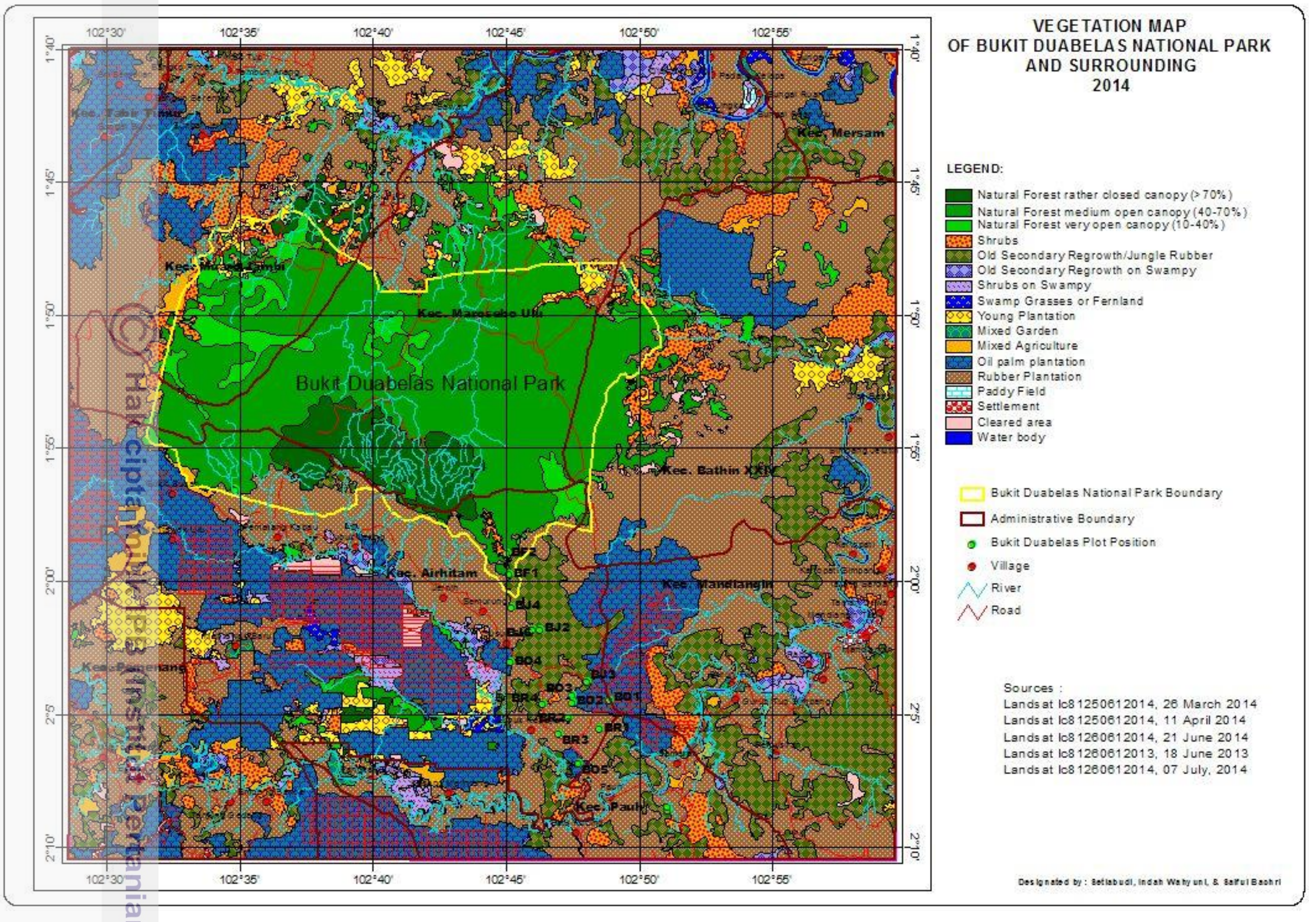
Appendix 4 The distribution pattern of IPS at rubber plantation plot



Appendix 5 The distribution pattern of IPS at oil palm plantation plot



Appendix 6 The vegetation map of BDNP and the surrounding area



CURRICULUM VITAE

The author is a girl, the second child from three children of Mr. Sutrisno and Mrs. Maryuni. She was born on 11 May 1987 in Bogor, West Java. In 2002, she was graduated from junior high school of SMP Negeri 6 Bogor and senior high school of SMU Negeri 2 Bogor in 2005, all in Bogor, West Java. She was continued her study at Department of Biology, Faculty of Mathematics and Natural Science, Bogor Agricultural University in Bogor and graduated in 2010.

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A paper on “Observation on the Development of Important Weeds and Invasive Alien Plant Species in Indonesia” was presented on The 24th Asia-Pacific Weed Science Society Conference, 22 – 25 October 2013 in Bandung, West Java. Her paper has appeared in its proceedings. Another paper on “Inventory of Invasive Plant Species in Bukit Duabelas, Jambi, Sumatra” was presented and submitted into the proceedings of The International Conference on Biosciences (ICoBio) 2015, which was held on 5 – 7 August 2015, in Bogor, West Java. And the article on “Distribution of Invasive Plant Species in Different Land-Use Systems in Sumatra, Indonesia” was submitted in Journal of BIOTROPIA.