Biodiversity Conservation in Relation to Plants Used for Medicines and Other Products in Indonesia[1]

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ABSTRACT

Biological diversity, or biodiversity, refers to all organisms occurring on Earth. Biodiversity is a manifestation of biochemical diversity and can be viewed at three levels: ecosystem, species and genetic. Indonesia has one of the richest endowments of biodiversity – at all levels -- of all countries in the world; it is often referred to as a "*megadiversity*" country. Plant diversity in Indonesia encompasses more than 30,000 species of ferns and flowering plants distributed over a wide range of ecosystems, ranging from mangrove swamps in coastal areas to tropical forests in the lowland and mountain regions to low scrub areas and grasslands at high elevations. Many plant species in Indonesia have high genetic diversity as well. Of the 30,000 known species, only a fraction -- about 1000 -- has been recorded as being useful for medicinal purposes. There has been considerable evidence that Indonesia's plant diversity is decreasing at an alarming rate. It is imperative, therefore, that we intensively explore, collect, study and identify additional plants that may provide new drugs, before the resources are lost forever. This effort must be broad-based, encompassing ethnobotanical, taxonomic, phytochemical, chemosystematic, random and ecopharmacognosic approaches. Studies based on leads provided by herbalists and folk medicine practitioners should be one important area of focus. Conservation of biodiversity is crucial in part because a diverse array of plants (and other organisms) is needed for human well-being, by providing food, shelter and medicines. For this reason, biodiversity conservation must be balanced with utilization. Local people have extensive knowledge of many uses of biodiversity. Access to this traditional knowledge and to genetic materials and biochemical resources should be compensated and intellectual property rights should be protected.

Key words : biodiversity, medicinal plant, natural product

INTRODUCTION

Biodiversity refers to all organisms on Earth and may be viewed from three levels: ecosystem, species and genetic. An ecosystem has both biotic and abiotic elements. The biotic element comprises all living organisms (plants, animals, fungi and microbes), or biodiversity at species level. Within species, there may be high genetic variability, or diversity, as expressed in appearance, behavior and habitat features. The abiotic element of an ecosystem encompasses all non-living physical resources, such as water, soil and air. The interactions among living

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organisms and the interactions between the biotic and abiotic elements within a given area constitute an ecological system, or ecosystem. Ecosystems range from small and relatively simple, such as a patch of lichens on a rock surface, to highly complex, such as a tropical rain forest. Ecosystems can be grouped into different types and viewed in a variety of contexts. Below I will discuss the usefulness of ecosystem, species and genetic diversity, particularly in regard to medicinal plants, and why it is important that we conserve biodiversity.

ECOSYSTEM DIVERSITY

Indonesia has a vast range of land and aquatic systems extending from west to east across the archipelago; they encompass a great variety of geologic formations, soils, water sources, topographies, altitudes, and climates. Geological events that shaped the estimated 17,000 islands that now make up Indonesia created a heavily mountainous land with a large number of volcanoes. The interaction of plants, animals and microbes within Indonesia's highly diverse environmental conditions led to the formation of many different kinds of ecosystems (Kartawinata, 1989). For example, in the lowland, usually defined as an area with an altitude of 0 to 1000 m and topography ranging from flat to undulating to hilly, a wide variety of wetland and dry land ecosystems can be found. .

The wetland is an ecological system in which water is the main controlling environmental factor for all or much of the year. Wetland ecosystems include the following:

(1) Open sea (saline open water ecosystems),
(2) Littoral ecosystems in shallow waters along the coast,
(3) Mangrove areas, which emerge in muddy and saline waters, mostly in estuaries,
(4) Freshwater swamp forests, found in stagnant freshwater sites,
(5) Peat swamp forests, which develop in stagnant, acidic water that causes peat deposits as plant debris slowly decomposes,
(6) Swampy meadows, comprising herbaceous and low shrubby ecosystems that arise in freshwater or peaty habitats, and
(7) Lakes, or open freshwater ecosystems with submerged and floating plants.

In dry land below an altitude of 1000 m, a variety of environmental factors and biotic elements interact to produce ecosystems such as these:

(1) Lowland and hill forests on different types of soil,
(2) Heath forests, which grow on very acidic white sandy and peaty soils,
(3) Limestone forests, which occur on limestone formations, usually on hilly terrain,
(4) Ultra basic forests, on soils made from ultra basic rocks, which have very low acidity,
(5) Monsoon forests, developed in areas where the climate is very dry, which causes all or most plants in this ecosystem to shed their leaves,
(6) savannas, usually found in areas with a dry climate, in which trees grow in a scattered pattern on grasses or low scrub matrix, and

(7) natural grasslands, occurring most commonly in areas with a dry climate and man-induced grasslands, such as that dominated by *Imperata* or *alang-alang*, which can be found in both dry and wet areas.

At increasingly higher altitudes, temperature changes are the dominant factor that influences ecosystem development. At elevations from 1000 to 4600 m elevation, the following kinds of major ecosystems occur:

(1) Lower montane forests, which can be found at altitudes of about (750) 1000 to 2500 m on gentle to steep slopes and a variety of soils (within this kind of ecosystem many different forest types arise as a result of a variety of environmental factors),
(2) Upper montane forests, at altitudes of (1500) 2500 to 3300 m, usually occurring on steep slopes and rugged topography with a variety of soils,
(3) Mossy forests, which develop at altitudes of 3300 to 3800 m,
(4) Alpine forests, at altitudes of 3300 to 4100 m,
(5) Alpine grasslands, found at altitudes of 3300 to 4100 m on different habitats, including tussock grasslands;
(6) Alpine meadows, occurring at 3400 to 4200 m and comprising herbaceous and scrubby swamp vegetation,
(7) Lakes, appearing at 1000 to 4100 m,
(8) Dry alpine tundra, which occurs at 4200 to 4600 m and has a habitat consisting mainly of rocks covered with mosses and lichens, and
(9) Snow ecosystems, which in Indonesia occur near Jaya Peak in Papua (formerly Irian Jaya) at about 5000 m.

In Indonesia, all ecosystems at altitudes of 4000 to 5000 m are found in Papua. At this elevation there is a rich variety of ecosystem types as well as species diversity within each type. The more than 40 types of ecosystems in that region are often mosaic and each type has developed specific habitats (Kartawinata & Widjaja, 1988). In a single stretch across Papua, ecosystem types range from a littoral ecosystem on the coast to the snow ecosystem at Jaya Peak.

SPECIES DIVERSITY

Globally, the total amount of already described biodiversity is estimated to be 1. 4 million living species (Parker 1982, as cited by Wilson 1988). This consists of 250,000 plant species and 791,000 animal species that include invertebrates, fungi, algae and microorganisms (Wilson 1982). These figures are a rough estimate based on existing data; the real total may be several times higher. We have very incomplete knowledge of how many species exist overall because inventories compiled over the last two centuries recorded only a small fraction. It is widely agreed, however, that most of the world's flora and fauna is still largely unknown to science.

Indonesia is so rich in biodiversity and is regarded as one of a few "megadiversity" countries. Although Indonesia covers only 1.3 % of the Earth's surface, it has 10 % of the world's flowering plant species, 12 % of all mammals, 17 % of all birds and 35 % of all fish (Sastrapradja *et al.* 1989).

In terms of flora, Indonesia is estimated to have 1500 fern species and 30,000 species of flowering plants. The biggest family is the Orchidaceae, which has about 5000 species . Anther large family is Dipterocarpaceae; it has 386 species and constitutes the most important timber family in the country. *Eugenia* and *Rhododendron* are some of the biggest genera, containing 500 and 286 species, respectively. About 40 % of all plant species are endemic (Whitmore, 1984) or confined in their distribution to the Malesian region, which comprises Indonesia, Malaysia, Brunei, the Philippines, Papua New Guinea, and Timor Leste. The tree flora that can be found on a one-hectare plot in East Kalimantan further illustrates the richness of Indonesia's flora at a local scale. In Malinau, recent studies showed that the number of species of trees with diameter class greater than 20 cm ranged from 79 to 121 (Kartawinata, unpublished). The highest number in the world for this particular species diversity, though now surpassed, was at one time recorded in Wanariset Samboja, where, on a 1.5-hectare plot, the number of species of trees greater than 10 cm in diameter was 239; the number of trees was about 600, meaning that, on average, the number of trees per species was two (Kartawinata *et al.,* 1981). In the mountane forest of Gunung Gede, the total number of species ranging from herbs to epiphytes and trees was found to be 350 species per hectare (Meijer, 1952). Kalimantan and Papua (formerly Irian Jaya) have been recorded as the areas richest in species, while Nusa Tenggara has the lowest number of species, which is attributed in part to the dry climatic conditions.

GENETIC DIVERSITY

Genetic variability within a species is common, but this may or may not be recognizable as sub-species, varieties or forma. Genetic variation within a species often correlates well with biochemical compound variability. The genetic diversity may be related to differences in environmental conditions, such as variation in climate, altitudes, soils and topography. Indonesia is one of the world's centers of genetic diversity.

Every plant population has a set of characters that are controlled by a genetic system. Thus, every individual in a population has germplasm, i.e., a complex nuclear substance that transfers heredity from one generation to another (Thain and Hickman, 2000) and makes certain populations different from others. Hence, a population of *pasakbumi (Eurycoma longifola)* occurring on the eastern slope of Gunung Meratus in South Kalimantan may differ in genetic make-up from one found on Bukit Lawang in North Sumatra; the differences may be expressed in their resistance to certain diseases, the size of their root systems, their chemical contents, their ability to grow on poor soils and other traits (Rifai and Kartawinata, 1991). If a population becomes extinct, the whole body of germplasm and the characters it controls in that population disappear.

Many plant species consist of thousands of populations, which together form a gene pool in which more or less free exchange of genes occurs. It is this ability that plant breeders draw on to create new high-yielding varieties through breeding (Sastrapradja *et al.,* 1989). Through well planned and systematic crossing of individuals from various populations (or biotype, forma, cultivar, variety or clone), a set of desirable characters can be produced in a new cultivar. No such selection and breeding efforts involving medicinal plants in Indonesia have been done (Rifai and Kartawinata, 1991). To date, breeding practices have not been employed to produce high-quality medicinal plants with desirable traits such as strong pharmacological properties, high productivity and low ash content.

Various natural and human-induced events have led to the extinction of some populations and the germplasm they carry. This suggests that high genetic diversity is continually undergoing degradation and depletion, although the degree of genetic erosion differs from one plant species to another. The degree of erosion may be measured by scoring based on the status and degree of rareness of species, as adopted by IUCN Plant Red Data Book (Lucas and Synge, 1978).

In Indonesia, the increasing demand by modern *jamu* industries for large quantities of plants with medicinal properties is met through collection from natural populations because cultivated sources are not available. This in turn has led to the genetic erosion of medicinal plants that have not been cultivated. Seventeen years ago, for instance, several species of wild *Curcuma* could be found growing abundantly in teak forests near Randublatung, East Java (Rifai and Kartawinata, 1991). People harvested the plants and produced powder in large quantities to supply large-scale *jamu* industries. Today, such activities have ceased because all the wild populations were depleted as a result of excessive harvesting. The earlier tradition of sustainable harvesting, in which some rhizomes were left in the ground so wild plants could regenerate, has been abandoned in favor of intense harvesting for quick profits because of high demand, high prices and steep competition.

Other examples of this situation are *kedawung (Parkia roxburghii)* and *ki kuning (Arcangelisia flava)*. *Kedawung* is one of the important species used in *jamu* preparations. It grows wild abundantly in monsoon forests, particularly in East Java, but in recent years it has become rare as a result of excessive and indiscriminate harvesting of the fruits by felling of the trees. No doubt it will be soon extinct if such practices continue. Efforts to cultivate this species were initiated on an experimental scale by Lembaga Alam Tropika Indonesia (LATIN) and Institut Pertanian Bogor (IPB) in the buffer zone of Meru Betiri National Park; landless farmers who usually collect *kedawung* from the wild to satisfy their daily needs are participating in the project. The results are very promising. The rapid disappearance of rare *Arcangelisia flava* has also resulted largely from indiscriminate and unsustainable harvesting, which is done by collecting the whole stems that are used in *jamu* industries. This plant rarely produces seeds, so its natural population is small. At the same time, requests by pharmaceutical companies in Europe for large quantities of the fine hairs of *Cybotium baranetz*, the rhizomes of a rare species of *Curcuma (temu badur)* and the seeds of *Voacanga grandifolia* could eventually destroy nearly all these populations and lead to the plants' extinction (Rifai and Kartawinata, 1991).

UTILIZATION

Indonesia is rich in useful plants. Old records (Heyne, 1950) show that there are about 5000 species of recorded useful plants, comprising 1259 species of timber, 1050 species of medicinal plants, 984 species of food plants (vegetables, fruits, grains and tubers), 520 species of plants containing oils, resin dye and other natural products, 328 species of animal feeds and

885 species of other plants used by people for a variety of human needs. Nonetheless, the number of useful plants in Indonesia constitutes only 17 % of the total number of species in the country, and medicinal plants only 3 %. The total numbers today undoubtedly are greater than those earlier figures as a result of extensive plant exploration and ethnobotanical recording in the last 50 years. But no summaries are available.

Beside timber, Indonesian forests are rich in fruit species. *Rambutan (Nephelium lappaceum)* and its edible relatives in the genus *Nephelium* are abundant in lowland forests (Adema *et al.* 1994). The same is true of the genus *Lansium* (Mabberley *et al.*, 1995). The genus *Durio* contains 27 species and, in addition to common durian (*Durio zibethinus)*, there are other eight edible species growing mainly in the forests of Kalimantan (Kostermans, 1958). Not much more is known, however, by people living far from the forests.

A variety of chemical compounds can be extracted from forest plants. For this reason, forests are potentially a major source of raw material for biochemical and pharmacological technology. Many chemical products of plants are known to have commercial importance (Lowry, 1971, 1973; Mueller-Dombois *et al.*, 1983; Whitmore, 1984). Various compounds in tropical forest plants have been shown to have actual or potential use as insecticides, coloring materials, essential oils, drugs, medicines and other purposes. Rotenoids (a source of insecticides) are produced by species of *Derris, Milletia, Tephrosia* and other leguminous species; reserpine by *Rauvolfia;* diosgenin by *Dioscorea* species; and diterpene alcohol (used as a substitute for ambergris in the perfume industry) by *Dacrydium* (Lowry, 1971, 1973). It is known that edible protein can be extracted from leaves; lignin is used in the manufacture of plastics, ion-exchange resins, soil stabilizers, rubber reinforcers, fertilizers, vanillin, tanning agents, asphalt emulsion stabilizers, and dispersants for oil-well drilling and for ceramic processing; and cellulose can be used for rayon and plastics and as raw material for hydrolysis to sugar (Bray and Gorham, 1964; Whitmore, 1975, 1980). Essential oils are produced by rain forest species such as *Aquillaria* spp., *Cananga odorata, Cinnammomum* spp., *Dryobalanops aromatica, Eucalyptus* spp., *Ganua motleyana, Gaultheria* spp., *Illicium* spp., *Litsea* spp., *Melaleuca leucadendra, Michelia champaca, Payena* spp., *Pogostemon* spp. and *Sideroxylon glabrescens* (Lowry, 1977; Sastrapradja *et al.*, 1989). The essential oils from *Cinnamommum porrectum* and *Litsea odorifera* are comparable to those from Brazil and may be considered an alternative source (Lowry, 1977). The wood extracts from Rutaceae (*Euodia ridleyi, E. latifolia* and *Melicope suberosa)* contain essential oils showing anti-bacterial activity against gram-positive bacteria (*Bacilus subtilis* and *Staphylococcus aureus*) (Ali and Zakaria, 1989), while *Goniothalamus andersonii* has indicated action on the central nervous system of mice and anti-microbial activity against certain microbes (Jewers *et al.*, 1972). These are only a few examples of tropical forest plants that are known to contain chemical compounds with potential or proven commercial uses.

Plants are also a major source of energy-rich foods, vitamins and related compounds required by humans. About 80 % of the populations in developing countries use traditional medicine (Farnsworth *et al.*, 1985). De Beer and McDermott (1996) reported that in Southeast Asia, traditional medicine is drawn from at least 560 to 900 indigenous species of the Malay Peninsula, Borneo and New Guinea (4.5 % of indigenous Southeast Asian flora) and that traditional healers in East and Southeast Asia have employed 6000 species. Traditional knowledge of the societies in this region includes an awareness of how the application or ingestion of products extracted from certain types of plants or their parts can induce specific responses in humans. Furthermore, it is known that the response can be reproduced in repeated trials, as exemplified by the use of the anti-malaria drug quinine, antibiotics against fungal infections and reserpine from *Rauvolfia* (Kloppenburg and Balick, 1996). Traditional pharmacologists are remarkably successful and proficient, even though their knowledge is based only in memory and transmitted verbally by special individuals.

To date, the number of plant products used by humans represents a small portion of the actual number of compounds that occur in plants, and only a fraction of the large number of plant compounds already identified have been tested for their possible use in medical treatments (Davidson *et al.*, 1996).

CONSERVATION

Plants are important for the well-being of people, such as in medicine and public health. As noted above, in developing countries up to 80 % of the populations depend on traditional plant-based medicine (Farnsworth *et al.*, 1985). In the United States, the value of plant-based drugs to the economy and to the maintenance of health is considerable (Principe, 1996). Appreciating the potential pharmaceutical value of plants underlines the need to value ecosystems. Thus, conserving biodiversity implies conserving ecosystems, in view of the fact that (1) biodiversity is best conserved in its original habitat; (2) the integrity of an ecosystem is maintained through interactions among the composing species and the interaction of species with environmental factors; (3) the nature of species in an ecosystem, including their pharmaceutical and chemical characteristics, is a product of these interactions; and (4) many species in tropical ecosystems are scientifically still unknown and knowledge about them is minimal, which means that conserving them individually outside their original ecosystems is impossible.

Plants, and in particular their pharmacological properties, offer an especially important indicator of value for biodiversity and ecosystems. But our inability to predict which plants will provide useful drugs makes it necessary to preserve the maximum biodiversity possible (Kloppenburg and Balick, 1996). The value of tropical forests is greater than that of the raw materials currently extracted from them, and products, especially those having medicinal significance yet to be discovered, have far greater value than currently indicated. Conservation strategies, therefore, should not focus on current products, but should adopt a wide perspective to encompass all species that may contain potentially valuable natural products.

It is widely known that in the last four decades or so, plant diversity has decreased rapidly as a result of indiscriminate exploitation of natural ecosystems — in particular forest ecosystems — for short-term economic gain. Disturbances to ecosystems and resulting losses of species will have profound implications for human health and important effects as well on food supply and water quality (Grifo and Rosenthal, 1997). The rapid rate of species loss parallels the growing disappearance of traditional knowledge, with deleterious effects that are negatively synergistic (Cox, 1997). Unless programs to study available biodiversity are undertaken now, these valuable resources may soon be lost forever. There is an urgent need to conduct intensive collection and study of plants, including ethnobotanical investigations.

Other strategies for research may include taxonomic, phytochemical, chemosystematic and random approaches. This last approach is based on the idea that if more plants were studied and evaluated through pharmacological screening, there would be a high likelihood of discovering important new compounds. All these strategies are important in relation to the use and conservation of biodiversity. Another strategy that may prove highly effective in conservation efforts is a holistic and comprehensive approach employed by Prof. D. D. Soejarto at the University of Illinois at Chicago. His so-called ecopharmacognosy method, which integrates ecological, ethnobotanical and phytochemical studies, has been successfully implemented in Indonesia by Chemistry Research Center (*Pusat Penelitian Kimia*) of the Indonesian Institute of Sciences (LIPI), Serpong, Indonesia.

Furthermore, it is vitally important to do large-scale screening for rapid identification of new therapeutically active agents. This can be done in various ways (Davidson *et al.*, 1996; Nunes, 1996), including two main approaches of building on leads provided by folk medicine and herbals, and carrying out larger, more widespread screening. Traditional knowledge about medicinal plants and folk medicine has accumulated over a long period, suggesting that these plants are worthy of further investigation. The combination of traditional knowledge and scientifically based knowledge of botany, taxonomy, ecology, natural products chemistry and screening technology offer strong prospects for the development of new pharmacological agents (Davidson *et al.*, 1996). Indonesia is rich in traditional knowledge, and national scientists have access to this knowledge and to the plant resources found in the country's diversity-rich forests. Integrating these resources with recent scientific analysis and technology, as initiated by the Research Center for Applied Chemistry (P3KT-LIPI) in collaboration with the Herbarium Bogoriense of the Research Center for Biology (Puslit Biologi-LIPI), should lead to the discovery of more and more active compound in plants.

INTELLECTUAL PROPERTY RIGHTS

As the value of all kinds of genetic material increases, there is increasing social pressure to control access to and property rights of those materials. People in developed countries have generally considered genetic materials and biochemical resources a public good and have collected them from local and indigenous peoples mainly in developing countries without providing any compensation. These bio-prospectors have enjoyed bountiful benefits from access to commercially valuable plants and other genetic materials without developing the means to ensure that fair payments flow to the parties that provided the resources and cultural information. Instituting ways of compensating the people who provide, reproduce and maintain valuable genetic, biochemical and information resources would help achieve objectives of biodiversity conservation (Kloppenburg and Balick, 1996). For developed countries, it is a matter of ethics. At the same time, indigenous communities are increasingly demanding that those who arrive to carry away resources must also be willing to give something in return (Shiva, 1990; Suhai, 1992). Arrangements are needed in which the parties concerned — that is, the suppliers (individuals, communities and countries) and recipients (individual scientists, private companies and governments) — can indicate their willingness to accept the principle that access to genetic and biological resources justifies payment. There has, in fact, been a proliferation of measures aimed at securing fair compensation for genetic materials received from indigenous peoples, ranging from legalistic agreements to a treaty-like accord. Yet the issue is complex, involving questions not only of suitable compensation but also of who should receive the compensation, under what condition compensation will be paid and who should have the right to determine the conditions (Kloppenburg and Balick, 1996).

At the international level, a global instrument governing these issues is needed. Some people consider the Convention on Biological Diversity (CBD) to be a suitable framework, but it deals more with the exploitation of the Earth's resources than with their protection. The CBD establishes global control of existing legal measures for the appropriation and patenting of biochemical and genetic materials, but overlooks the situation of materials already secured and deposited in gene banks and indigenous people's rights in regard to such materials.

Recently, Indonesia initiated a number of activities related to the implementation of intellectual property rights for biodiversity. Muhtaman and Zuhud (1997) have discussed a broad range of issues surrounding access to Indonesia's biodiversity, including the integration of economic development and biodiversity conservation; biodiversity policies from regional and international perspectives, with and emphasis on the CBD; bio-prospecting; intellectual property rights; and policy implications and recommendations for the Indonesian government in view of increased poaching of the country's biodiversity by foreigners.

CONCLUSION

Only with awareness and deep commitment, along with a sincere willingness among all concerned parties to sacrifice time, funds and energy, will efforts to conserve medicinal plants produce significant results. A commitment to ensuring the future availability of medicinal plants and other biological resources should be an inherent obligation of us all and not viewed as a responsibility endowed by external forces. If our joint conservation efforts are successful, not only traditional knowledge but also medicinal plants themselves will be available for future generations to inherit. We have yet to prove that we are a responsible generation.

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