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The *Imperata* grasslands of tropical Asia: area, distribution, and typology

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Abstract. The rehabilitation or intensified use of *Imperata* grasslands will require a much better understanding of their area, distribution, and characteristics. We generated estimates of the area of *Imperata* grasslands in tropical Asia, and suggested a typology of *Imperata* grasslands that may be useful to define the pathways toward appropriate land use intensification. We conclude that the area of *Imperata* grasslands in Asia is about 35 million ha. This is about 4% of the total land area. The countries with the largest area of *Imperata* grasslands are Indonesia (8.5 million ha) and India (8.0 million ha). Those with the largest proportion of their surface area covered with *Imperata* are Sri Lanka (23%), the Philippines (17%), and Vietnam (9%). Laos, Thailand, Myanmar, and Bangladesh evidently all have similar proportions of their land area infested with *Imperata* (about 3 to 4%). Malaysia (< 1%), Cambodia (1%), and the southern part of China (2%) have but a minor proportion of their total land area in *Imperata*. The species was found widely distributed on the full range of soil orders. It occupied both fertile (e.g. some of the Inceptisols and Andisols) and infertile soils (Ultisols and Oxisols) across a wide range of climates and elevations. *Imperata* lands fall into four mapping scale-related categories: *Mega-grasslands*, *macro-grasslands*, *meso-grasslands*, and *micro-grasslands*. The mega-grasslands are often referred to as 'sheet *Imperata*'. They are the large contiguous areas of *Imperata* that would appear on small-scale maps of say 1:1,000,000. We propose that this basic typology be supplemented with a number of additional components that have a key influence on intensification pathways: land quality, market access, and the source of power for tillage. The typology was applied in a case study of Indonesian villages in the vicinity of *Imperata* grasslands. We propose an international initiative to map and derive a more complete and uniform picture of the area of the *Imperata* grasslands. This should include selected studies to understand conditions at the local level. These are critical to build the appreciation of change agents for the indigenous systems of resource exploitation, and how they relate to local needs, values, and constraints.

"Before we plow an unfamiliar patch,
It is well to be informed about the winds,
About the variations of the sky,
The native traits and habits of the place,
What each locale permits, and what it denies."
– Virgil (33 B.C.)

Introduction

The *Imperata* grasslands of tropical Asia are a vast underutilized natural resource of common occurance in most countries. Consequently, most nations in the region have focused considerable attention toward making better use of their grasslands, but the efforts have not paid off satisfactorily. Little information is available about the origin, status, and conversion (where appropriate) of *Imperata* grasslands into more intensive production systems. No authoritative estimates exist of just how much area they occupy. Their rehabilitation or intensifed use will require a clearer understanding of their distribution and characteristics.

The objectives of this paper are to generate reasonable estimates of the area of *Imperata* grasslands in Asia, and to suggest a typology of *Imperata* grasslands that may be useful in defining the pathways toward appropriate land use intensification. The paper begins with a discussion of the methodological issues in the estimation of *Imperata* area. We then propose a four-tiered scale of grassland types and discuss how this classification may assist in the estimation of the extent of the grasslands. Available data on *Imperata* area and distribution are presented for the key countries, along with information on the evolution and trends in *Imperata* distribution. This is followed by a regional analysis. The final part of the paper discusses key factors that differentiate various types of *Imperata* grasslands, leading to a proposed grassland typology for practical application.

Imperata distribution in the tropical Asian region

The genus *Imperata* is composed of two sub-genera, *Imperata* and *Eriopogon*. The subgenus *Imperata* has only one species, *I. cylindrica*. Hubbard et al. (1944) classified *I. cylindrica* (L.) Raeuschel into five varieties, based on morphological characters, geographical distribution and ecological forms. They are *major*, *africana*, *europea*, *condensata* and *latifolia* (Tjitrosoedirdjo, 1993). *Major* is predominant in Asia, Australia, East Africa and India; *africana* is found in West Africa; *europa* is found in the Mediterranean region and Central Asia; *condensata* is found in central Chile; and *latifolia* occurs only in northern India (Brook, 1989). Within its area of adaptation in Asia, *I. cylindrica major* (spear grass) exerts a much more dominant role in grassland communities, and influences the ecology and economy of the region more

than do the other varieties in their respective areas. *Imperata* is found in Latin America but it is not an important component of the vast savannas of the continent. The question of why *I. cylindrica major* is so much more important in Asia than elsewhere is intriguing, but has so far not been answered.

Because there are no good aggregate data on the extent of *Imperata cylindrica* grasslands in tropical Asia the available estimates vary widely. To our knowledge a regional area analysis has never before been attempted, probably because of the difficulties in compiling and reconciling such disparate available data. The only estimates made have been at the national level in certain countries. However, these were obtained with variable definitions and procedures. We recognize these drawbacks, but attempt to develop a picture for the region by assembling data on a country-wise basis. This culminates in an aggregate analysis that includes all countries where *Imperata* is presumed important. The exercise is based on very tentative estimates in some cases. In the discussion we employ the local names for *Imperata* as we discuss the situation in the various countries.

Methodological issues

To answer the question of how much *Imperata* area exists in a country, one needs to have a clear definition of what is *Imperata* area, and what mapping scale is being considered. Defining *Imperata* grassland as a mapping unit poses problems. *Imperata* grassland is often envisioned as being a nearly pure sward. In reality it is often associated with other vegetation types, particularly other major grass species and secondary forest vegetation. In many areas it is also associated with various agricultural systems, particularly fallow-rotation cropping in shifting cultivation.

Only by using maps at a very large scale (for example aerial photographs at 1:5,000 scale) is it possible to make a fairly definitive separation of grassland from other vegetation types. When making estimations from satellite images (even SPOT or the Landsat Thematic Mapper with a pixel diameter of 30 to 40 m) the judgment of different interpreters may vary. How much of a given mapping unit must be composed of grassland, or more specifically of *Imperata* cylindrica, in order to qualify as '*Imperata* grassland'? There is no standard answer. Therefore, approaches vary.

Imperata may exist in quite large contiguous areas, or small patches in a vegetation mosaic with shrubs or cropped fields. Most national estimates of *Imperata* area are not based on detailed map sources but rather on quite small-scale maps (often 1:500,000 scale or smaller), due to data limitations. This leads to the exclusion of the smaller-sized *Imperata* areas, which occur at the municipality or village level, even though these are important if aggregated. To cope with this complexity, we may consider *Imperata* as falling into four mapping scale-related categories: *mega-grasslands*, *macro-grasslands*, *meso-grasslands*, and *micro-grasslands*.

The *mega-grasslands* are often referred to as 'sheet *Imperata*'. They are the large contiguous areas of *Imperata* that would appear on small-scale maps of say 1:1,000,000. These grasslands are large enough to span municipality or district-level boundaries. This category is the one featured in discussions of the so-called vast *Imperata* 'wastelands'. Because they are so large, the control of fire is often nearly impossible at the local level. Fires initiated at some distant location sweep across the landscape through numerous political boundaries. Colonization of such grasslands by agriculture or forestry is therefore treacherous due to the ever-present risk of a disastrous fire. Settlement is most successful when it enters the grassland from the edge, although even there the risk of fire damage is still serious.

Macro-grasslands are also large contiguous areas that encompass individual village boundaries. However, these areas are confined within a sub-district or municipality. They exhibit many of the ecological characteristics of the mega-grasslands, but may not be large enough to appear on national land-use maps.

Meso-grasslands are *Imperata* areas more-or-less confined within villages. They are not large enough to be estimated except with quite large-scale maps (say 1:50,000). They are often of major local importance. Fire control is much more feasible in the meso-grasslands through regulations and monitoring at the village level.

The *micro-level grasslands* correspond to grass patches within individual fields. These patches can be managed by the individual farmer or land manager. Because they are 'privately' controlled, and are isolated by surrounding cropland or secondary vegetation, the grass can be managed as a problem of weed control. A major issue at this scale is how the invasion of *Imperata* can be prevented or alleviated in established agricultural or forestry enterprises. Failure to be able to control the grass often ruins the farmer's investment in crops or trees.

From the foregoing discussion, we have a four-tiered classification that may have utility in map interpretation and in determining management implications. The scale of mapped data dictates the inclusion or exclusion of different-sized *Imperata* areas. Thus, any estimate of the area of *Imperata* grassland can only be useful if the mapping scale at which it was made is specified.

The country-level estimates of *Imperata* grassland area tend to refer to analyses done at a mega scale. Macro-level areas may or may not have been detected in such exercises because the map scale was not large enough. Meso and micro grasslands would have definitely been excluded. Thus, if the *Imperata* area in macro, meso, and micro grasslands are sizable amounts, it is expected that the area estimates of *Imperata* for the country are understated. Of course, it is usually impractical to map *Imperata* grasslands at a very detailed scale. In the future we expect that fractal analysis will be a useful tool in obtaining more definitive estimates. Currently, we must work with what data are available, and try to specify as clearly as possible the mapping scale

at which the data are aggregated. The following sections discuss the area and ecology of *Imperata* in each of several countries where it is important. This is followed by an aggregate analysis for tropical Asia as a whole.

Imperata *grasslands in Indonesia*

In Indonesia *Imperata* (known as *alang-alang*) grassland rehabilitation receives intensive attention by government at all levels. The grasslands have been considered a prime target for transmigration schemes that attempt to re-settle rural people to these areas from the over-populated island of Java. Much work has thus been done on how to develop sustainable smallholder farming systems on these lands, and much experience has been accumulated, often at the expense of failed projects. More recently, the grasslands have been looked upon as a resource for establishing large commercial re-forestation projects to supply timber and pulpwood to replace the declining supply from the natural forests.

Early estimates. The earliest estimates of *Imperata* area in Indonesia were made by Wind and Vonk (1937), as cited by Warsopranoto (1968). They estimated that the area of *Imperata* in one major mega-grassland area, Palembang, South Sumatra, was about 1 million ha. Three decades later, Warsopranoto (1968) concluded that the area was 1.6 million ha in Palembang using the previous figures and the estimates of Danhof (1940, cited by Warsopranoto, 1968). He concluded that there were about 16 million ha in the whole of Indonesia. This figure of 16 million ha has been cited frequently ever since (e.g. Soerjani, 1970).

Suryatna and McIntosh (1980) made an estimate of the *Imperata* area in their paper on annual cropping systems for *Imperata* reclamation. They concluded that *Imperata* covered 64.5 million ha, or 34% of the nation's total land area of 191 m ha. This very high figure was arrived at by deduction rather than map inventory. It no doubt had the desired effect of alerting policymakers to the major extent of the grasslands, but unfortunately this estimate was wildly unrealistic. The issue of realistic national estimates could only be clarified by more definitive mapping efforts.

Recent estimates. The most uniform and comprehensive data source for *Imperata* area estimation is that of the Centre for Soils and Agroclimate Research (CSAR) in Bogor. They have developed a national map of *Imperata* distribution at a mega-grassland scale of 1:2,500,000 (M. Soekardi, pers. comm., 1994). The data sources for the *Imperata* grassland distribution map were the land use maps of the Land Registration Office, the Land Use and Forest Classification Maps (Ministry of Transmigration, 1990), and a vegetation map of Sumatra (Biotrop; 1:1,000,000). All data sources were post-1985. Sheet *Imperata* was not sharply delineated; it was often associated with other grass and/or shrub mapping units. The *Imperata* grassland area was

obtained from these maps using the CSAR mainframe geographic information system (GIS).

The CSAR estimate of *Imperata* grassland area in Indonesia was approximately 8.6 million hectares (Table 1). This is approximately 4.5% of the land area of Indonesia. Among the islands Sumatra and Kalimantan have the largest *Imperata* areas (Figures 1 and 2). In Kalimantan the largest areas of *Imperata* are in the provinces of South Kalimantan and West Kalimantan. These provinces have the highest population density in Kalimantan. One of

Table 1. The distribution of *Imperata* grassland in Indonesia by islands and provinces.

Islands/provinces	Area	
	ha	% National land area
Sumatra	2,125,250	1.11
– Aceh	155,625	
– North Sumatra	591,250	
– Riau	176,875	
– West Sumatra	143,125	
– Jambi	83,750	
– South Sumatra	708,375	
– Bengkulu	45,000	
– Lampung	221,250	
Java	195,625	0.10
– West Java	51,250	
– Central Java	12,500	
– East Java	131,875	
Kalimantan	2,193,500	1.14
– West Kalimantan	929,750	
– Central Kalimantan	142,500	
– South Kalimantan	525,000	
– East Kalimantan	596,250	
Sulawesi	1,305,725	0.68
– South Sulawesi	446,375	
– Central Sulawesi	205,600	
– South East Sulawesi	653,750	
– North Sulawesi	*	
Nusa Tenggara	2,030,375	1.06
– Bali	*	
– West Nusatenggara	160,000	
– East Nusatenggara	1,664,750	
– East Timor	205,625	
Maluku	270,000	0.14
Irian Jaya	469,375	0.24
Total	8,589,850	4.47

* Too fragmented and too small to delineate at scale 1:2,500,000.
Source: Soekardi et al. (unpub.) Centre for Soils and Agroclimate Research, Bogor, Indonesia.

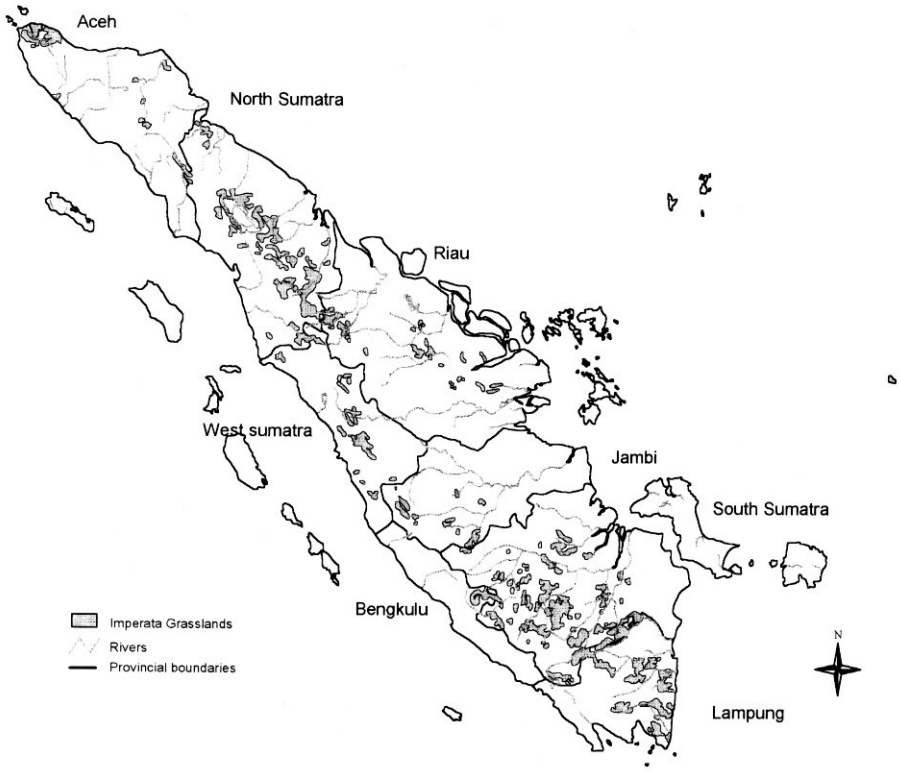

Figure 1. The *Imperata* grasslands of Sumatra, Indonesia.

the most prominent sheet *alang-alang* areas in Kalimantan is in the western foothills of the Meratus Mountains in South Kalimantan (Figure 2). *Alang-alang* extends in a mostly contiguous area about 300 km from north to south. The grass covers 525,000 hectares, or 21% of the entire province. West Kalimantan is the largest province in Kalimantan, and has the largest *alang-alang* area. The province's 929,750 hectares of grassland accounts for 5% of the area of the province.

It is interesting that the total area of *Imperata* in Kalimantan (2.19 million ha) and in Sumatra (2.13 million ha) was found to be about equal. These are some of the most humid parts of the country. The provinces with the most grassland in Sumatra (Table 1) are South Sumatra (708,000 ha) and North Sumatra (591,000 ha). The total grassland area in Nusa Tenggara, a group of many smaller islands comprising the more subhumid to semiarid region of Indonesia, is 2.03 million ha. This aggregate area is also quite similar in size to that of each of the two largest islands. In these parts of the country, however, the savannas are often composed of grass species other than *Imperata.*

The researchers compiling these estimates assumed a 20% margin of error for their figures. They attributed this to several potential sources of error in the analysis:

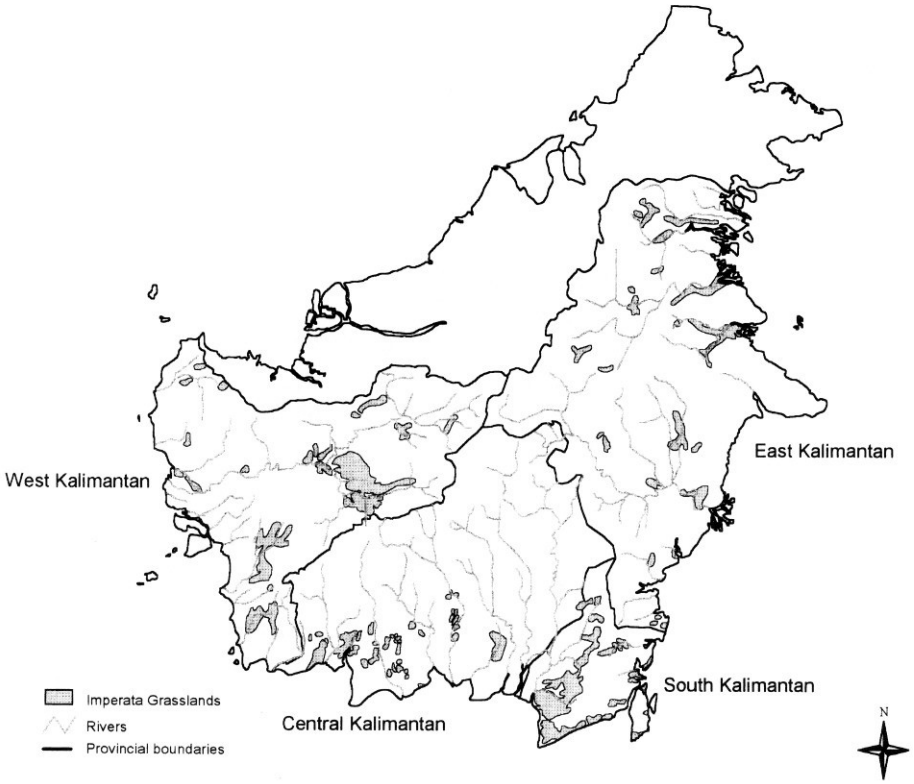

Figure 2. The *Imperata* grasslands of Kalimantan, Indonesia.

1) the source maps varied in scale, with some distortion introduced in standardizing the mapping scale;
2) the definition of *Imperata* grasslands for the map legend is subject to confusion, as the category '*Imperata*' as classified includes all grasslands and areas with a mixture of *Imperata* and shrubby vegetation (*Chromolaena* sp., *Melastoma* sp., and *Lantana* sp., and ferns); and
3) on some source maps the category 'semak' or 'belukar' (shrubs) was subsumed within *Imperata* grasslands.

These distortions would tend to result in a net overestimate of *Imperata* grasslands. However, a countervailing factor is that since the map was drawn at a small scale, many smaller areas of *Imperata* were not included. Thus, the two effects therefore tend to cancel each other, lending strength to the overall figure. The national map produced by CSAR only reveals the distribution pattern of the large concentrations of sheet *Imperata.*

Tjitrosoedirdjo (1993) contains an estimate of the area of Indonesian grasslands of 10.2 million ha, which is about 2.7 million ha higher than that of Soekardi et al. (unpub.). These estimates are directly from the data of the surveys of the Ministry of Transmigration (1990), known as RePPProT. These

maps were also one of the data sources of the CSAR exercise, but the data were revised based on the other sources of information mentioned above. The major discrepancy between these estimates and those developed by Soekardi et al. (unpub.) occurred in the estimate of *Imperata* area in the province of Irian Jaya. This province has a large area of what is considered natural (not anthropogenically-produced) climax savanna. The RePPProT estimate is that 3.21 million ha of *Imperata* grassland occurs in this province (31% of the Indonesian total). Soekardi (unpub.) estimated only 0.47 million ha. The difference (2.7 million ha) is equal to the difference in the Indonesian total between the two sources. A re-examination of the RePPProT maps suggests that their figures for Irian Jaya are an overestimate. We have therefore used the Soekardi (unpub.) national estimates as more definitive.

An additional 18.9 million ha in the RePPProT analysis was classified as bush or shrubland. This land category also contains a significant fraction of *Imperata* grassland area. There is also cause for assuming that a part of the area that was classified as being under shifting cultivation (11.7 million ha) is also in a state of *Imperata* fallow.

The national mapping agency (BAKOSURTANAL) has also recently attempted a separate inventory of *Imperata* grasslands (Sumardiyono et al., 1993). Their work did not cover all provinces, but did include a number of important ones in Sumatra, Kalimantan, and eastern Indonesia. This work was based on maps produced at a 1:500,000 scale produced from satellite imagery (Landsat, SPOT) and aerial photo imageries, and supported by the national land use map (Ministry of Transmigration, 1990).

CSAR is currently collaborating with ICRAF to reconcile the BAKOSURTANAL maps with their previous analysis. A map of mega-grasslands of Indonesia will be published from the GIS database. All the current national analyses are at a small mapping scale, which limits the map coverage of *Imperata* to the mega-environments of massive sheet *alang-alang*. At such scales, even macro *Imperata* areas covering adjacent villages would be too small to be represented. The large contiguous areas of *Imperata* as seen on the map and on the ground may give the impression that these areas are uninhabited. This is not the case, as discussed by Potter (this issue) and by Tomich et al. (this issue). Thus, land use changes in even the mega-grasslands must consider the participation of the local populations, who often have valid usufruct claims to the land that are recognized locally.

Is the Imperata area in Indonesia expanding or contracting? There is much debate about this issue. The data available does not lend itself to a clear conclusion. In some areas of the country, for example in East Kalimantan, many observers assume that the area is definitely increasing. The large-scale fires of 1983 were observed to dramatically expand the *Imperata* grasslands in that province. More recently, during the drought of 1994 some five million hectares were estimated to have been burned countrywide. It is reasonable to assume that much of this land will revert to *Imperata* grassland. When highly destructive logging is practiced, large amounts of debris are left behind. These

provide a favorable source of tinder during exceptionally dry seasons. Once burned-over, the land is often invaded by *Imperata*, and if fires occur periodically thereafter, *Imperata* dominance becomes permanent. This process has greatly expanded the sheet grassland areas around the Bukit Baka/Bukit Raya National Park on the border between Central and West Kalimantan (D. Taylor, pers. comm., 1996).

Davies (1995) did a pilot study that examined eight areas in various parts of Sumatra where he compared the area of *Imperata* grassland as shown on the RePPProT maps with that contained on more recent (early 1990s) satellite images. He found that in virtually all cases there was extensive deforestation, and that the area of *Imperata* grassland had significantly increased. Other parts of the deforested lands had been converted to bushland or shifting cultivation that had a very high potential for further subsequent conversion to *Imperata.*

Elsewhere in Indonesia, there exist *Imperata* grasslands that have evidently existed for a long period of time, perhaps more than a century in some areas. The large sweep of grassland in South Kalimantan are an example (see Potter, this issue). Land use intensification is evidently occurring in some of these areas, as smallholder agriculture and tree crop plantations expand gradually into the sheet *alang-alang*. These changes suggest that, at least in some localities, the area of *alang-alang* is declining. One-third of the island of Java was estimated to be covered with *Imperata* at the beginning of the 20th century, but the area is now less than two percent. This process is underway in parts of the outer islands as well, in areas where extensive land use is being intensified as population density increases. Hundreds of thousands of hectares of small-holder and larger-scale rubber, oil palm, and other agroforestry systems have been established during past decade, some of which has been in grassland areas. Reforestation by large-scale timber estates may also be contributing to this process to a minor extent. One example is the sizable plantation reforestation during the past decade around Benakat, South Sumatra.

Determining the net effect of all these changes on the aggregate area of *Imperata* will await a thorough re-analysis of the country's current vegetative cover. On balance, however, it appears reasonable that the very rapid rate of grassland creation as a result of deforestation during the past two decades has exceeded the rate by which previous grasslands were being converted to other land uses.

Imperata *grasslands in the Philippines*

The most common form of vegetation in the Philippine uplands is grassland, predominantly *Imperata cylindrica* (known locally as *cogon*) or *Themeda triandra.* At higher elevations a common species is *Miscanthus japonicus.* A small portion of the grassland area may be a result of natural disturbances, but the overwhelming majority is derived from the repeated occurrence of fire (Bartlett, 1956). At the turn of the 20th century, 40% of Luzon island, and

extensive areas of other Philippine islands were covered with grassland. The land classification of 1919 estimated that grassland covered 19% of the entire country, a figure that stayed roughly constant through 1957 (Roth, 1983).

A satellite data analysis (Swedish Space Corporation, 1988) of Philippine land use estimated the area of pure grassland to be 1.8 million ha, with an additional 10.8 million ha or 33% of the country's land surface in extensive cultivation mixed with grasslands and brushlands (Table 2). This suggests that as much as 20% (or more) of the country is currently covered by grasslands.

Figure 3 shows the general land use distribution in the Philippines. Public lands administered by the Department of Environment and Natural Resources cover slightly more than half of the country's land area. Settlement is dense and agriculture is intensive on the coastal plains and interior river valleys. On most islands the grasslands (along with brushlands) are typically found in the belt of land in the foothills at an intermediate elevation below the remnant forests on the steep mountain terrain. Historically, permanent agriculture has moved gradually upward into the grasslands, while the frontier of cultivation continually extends the grasslands ever further into the remaining forest.

The grasslands have thus served as an intermediate zone: A portion of them are continually being transformed into permanent croplands or plantations

Table 2. Land cover of the Philippines as of December 1988 (000 ha) (excluding forest and intensively cultivated land).

Region	Grassland	Extensive land use	Other[a]	Lake
North				
Ilocos	172.9	469.9	524.8	3.7
Cagayan Valley	263.4	590.3	689.7	4.1
Central Luzon	281.3	374.3	858.3	6.8
So Tagalog	179.8	1,559.3	1,694.8	124.6
Metro Manila	274.5	697.0	121.9	1.8
Bicol	100.4	460.1	1,089.1	5.6
Central				
Western Visayas	78.2	954.7	861.0	1.7
Central Visayas	75.8	806.0	511.0	1.0
Eastern Visayas	11.1	1,108.9	546.2	0.0
South				
N. Mindanao	7.7	636.7	722.1	1.0
C. Mindanao	161.1	1,065.2	717.6	17.7
E. Mindanao	98.9	1,122.6	971.9	1.2
S.E. Mindanao	21.3	477.9	578.9	3.0
S.W. Mindanao	46.0	475.5	396.0	46.2
Total	1772.4	10,798.4	10,283.3	218.4

[a] Includes mixed grasslands, brush, and plantation or other crops, and open areas of forest land.

Source: Swedish Space Corporation (1988).

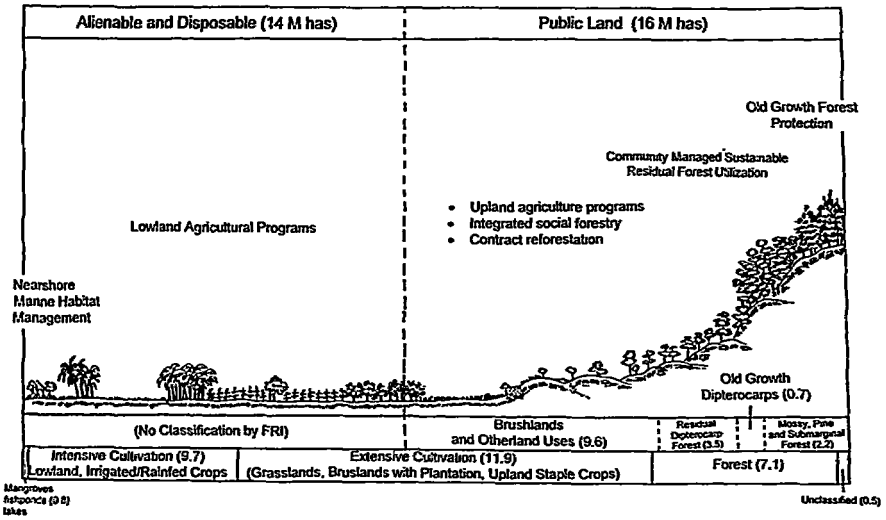

Figure 3. Land classification of the Philippines, actual land use, and emerging problems. Areas in parentheses are millions of hectares. From Queblatin (1992).

over a long period of time, whereas new *Imperata* lands are created as the forest is destroyed through logging and/or smallholder farming . In some intensive grass-fallow rotation systems, fire climax savanna is used indefinitely as the fallow species (for example, see Barker, 1984).

Extensive areas of the *Imperata* (*cogon* in Filipino) grasslands have commonly been used as pasture for cattle ranching. Range management by private ranchers was generally poor, leading to estimates that the grasslands are the leading source of soil erosion in the country (World Bank, 1989). During the past 15 years, however, land pressure and insurgency have resulted in a precipitous decline in ranching. This resulted in a 50% decline in the size of the national cattle population. Currently, the Philippines imports hundreds of thousands of live cattle from Australia to meet the needs of the beef industry.

The grasslands have long functioned as a strong migratory sink for the settlement of landless and jobless families. This is exemplified by the historical evolution of land use over a 40-year period in the uplands of a town in northern Mindanao which illustrates the transition into *cogon* grassland, and its conversion into permanent upland farming (Garrity and Agustin, 1995; Garrity and Mercado, 1994). The land was primarily under dense tropical dipterocarp forest until the early twentieth century, with swidden agriculture practiced on a small portion of the area. Commercial logging removed much of the old growth timber in the early decades of the century. Migrant smallholders from the Visayan islands followed the logging operations, practiced swidden farming, and displaced the indigenous Higa-onon population, which

retreated to higher elevations. Cattle ranchers gained control of extensive areas through government leases and completed the transformation of the area into *cogon* grasslands.

Aerial photos taken in 1949 show that natural *cogon* grassland occupied 85% of the non-forested land. Smallholder food crop farming was concentrated in contiguous patches in the grasslands (rather than the forested areas). These locations later developed into the major villages. The 1967 photo-analysis showed a 20% decrease in the grassland area as food crop cultivation intensified (Figure 4). Between 1967 and 1988 the grassland area declined sharply to 18%, while the cropped area doubled. Forest had nearly disappeared.

The processes elucidated for one frontier municipality are evident in data for the country as a whole. Between 1980 and 1987 the area of cultivated land in the Philippines increased by more than 1.6 million ha, an annual increment of 229,000 ha per year. The annual rate of deforestation during this period was 157,000 ha. It appears, therefore, that large areas of grasslands were being converted to agricultural uses and that the net area of grassland is declining (Garrity et al., 1993).

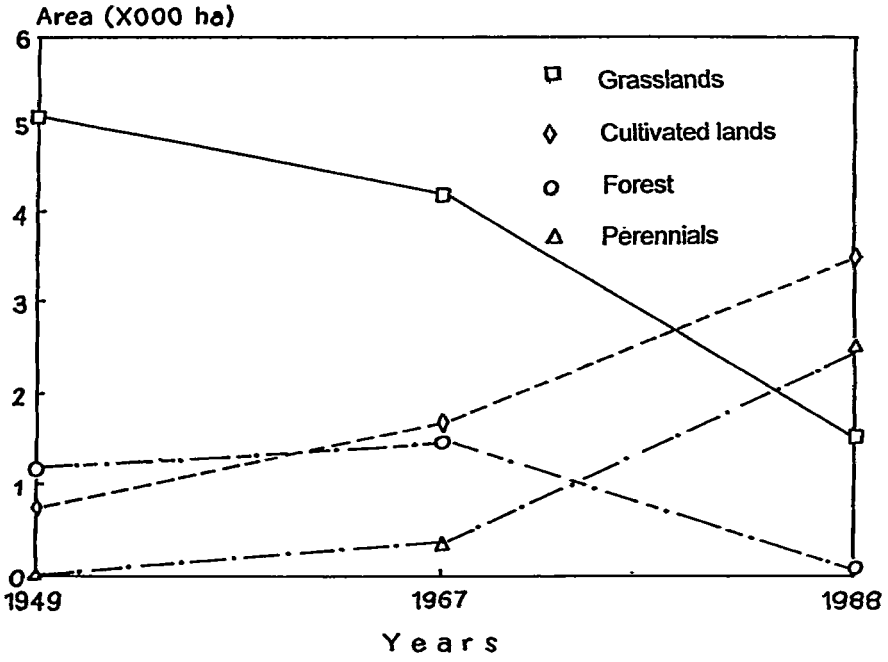

Figure 4. Changes in land use between 1949 and 1987, Claveria, Misamis Oriental (Mindanao), Philippines. From Garrity and Agustin (1994).

Imperata *grasslands in Malaysia*

Known as *'lalang'* in Malaysia, *Imperata* is widely distributed in the country. But, in comparison with Indonesia and the Philippines, its area of coverage is remarkably less: Perhaps no more than 200,000 ha or 0.6% of the country's area of 33 million ha. Shim (1993) reports that the largest contiguous blocks of sheet *lalang* in Malaysia are in northwest Sabah. The only estimates available (from 1970) indicate a grassland area for Sabah of 155,400 ha. Potter's (1994) examination of recent maps of Sabah indicate that much of this land has been reforested with *Acacia mangium*. According to Shim (1993), the need for pasturage for ruminants is a major factor in the persistence of grassland in Sabah. The firing of *lalang* for browse is an integral tradition that has not been susceptible to change.

In Sarawak, Hatch (1982) estimated that there were 72,000 ha of *Imperata* grassland, or 0.3% of the total land area. But this figure also includes some scrubland. Shim (1993) believes that the actual figure is even smaller than this. He relates that there are no large tracts of sheet *lalang* reported in Sarawak. He attributes this to the year-round rains, which reduce the prevalence of fires. In contrast to the small area of grasslands, the area covered by shifting cultivation was estimated at 3.5 million ha (29% of total area). Thus, shifting cultivation covers nearly 50 times more area than *Imperata* grassland. Recent efforts to encourage shifting cultivators to establish fast-growing tree species for timber and pulp production on land fallowed after food cropping appear to have had a significant effect on reducing the area of newly-derived *Imperata* land.

In Peninsular Malaysia, there are apparently no significant areas of sheet *Imperata*. But there are large areas of 'idle' land that could potentially be invaded by *Imperata*. Recent estimates [National Agriculture Policy 1992–2000, cited by Shim (1993)] indicated that there were 725,000 ha of idle land. The bulk of this was on rubber smallholdings. The remainder is unutilized rice land.

Imperata *in mainland Southeast Asia*

Vietnam has experienced very rapid deforestation. Since 1943, when about 67% of the country was forested, the forest cover has declined to approximately 29% (Do, 1996). The greatest reduction has occurred in the Northern Mountainous Region, where forest cover has declined from 95% in 1943 to 17% in 1991. Almost two-thirds of the Northern Mountainous Region was considered barren land in 1991 (Table 3). Other regions with a large proportion of barren lands occur on the North Central Coast (40–44%) and the South Central Coast (42–49%). The amount of these lands covered by *Imperata* is not known. We estimate that from 1 to 5 million ha of this land is *Imperata* grassland, with a most-likely expected coverage of about 3 million ha.

Imperata is common in southern China in the lowlands and highlands, and

Table 3. Forest cover, deforestation and unused land in Vietnam.

Region	Land area (000 ha) 1991	Forest cover (% of land area)		Annual rate of deforestation (% of total forest cover)			Baren land (% of area)
		1943	1991	1943–73	1973–85	1985–91	
1. Northern Mountains	7,645	95	17	2.4	3.9	(0.3)	60–65
2. Northern Midlands	3,982	55	29	1.0	4.5	(0.3)	27–33
3. Red River Delta	1,030	3	3	0.9	6.7	0.2	5–14
4. North Central Coast	4,002	66	35	0.7	2.3	(0.4)	40–44
5. South Central Coast	4,582	62	32	1.4	2.3	(0.1)	42–49
6. Central Highlands	5,557	93	60	1.4	0.1	0.3	25–32
7. N.E. of Mekong	2,348	54	24	0.7	3.7	1.4	23–34
8. Mekong Delta	3,957	23	9	1.8	3.0	(0.1)	12–21
Total	33,107	67	29	1.6	2.5	0.0	35–42

Source: Ministry of Agriculture and Rural Development, Hanoi.
Note: Numbers in parentheses indicate net reforestation.

extends into the subtropical/temperate areas. In Yunnan province it is the major weed across all the province's climatic zones. It is one of the most important invasive weed species in plantations, particularly in the rubber and fruit tree-growing areas. We estimate that the area of *Imperata* grassland in the southern provinces ranges from 1 to 5 million ha, with an expected area of 3 million ha. This would amount to about 2% of the land area of the southern one-fifth of the country.

In Laos upland agriculture is dominated by slash-and-burn farming. Logging is now proceeding at a rapid pace. *Chromolaena odorata* is the dominant species in the fallows, but in areas that have been under intensified slash-and-burn *Imperata* becomes a dominant cover. We estimate that *Imperata* may occupy from 0.5 to 2 million ha, with an expected coverage of about 1 million ha.

Imperata is a dominant cover in many upland areas under shifting cultivation in Thailand. In Chiangrai and adjoining provinces it is a common vegetation in watershed areas with high population densities. Remote sensing analyses could provide good estimates of *Imperata* coverage nationwide. We estimate that *Imperata* grasslands occupy from 1 to 4 million ha, with an expected area of about 2 million ha. In Cambodia *Imperata* does not appear to occupy a very significant area (H. Nesbitt, 1994, pers. comm.).

Imperata *in India*

India has five major complexes of grass cover (Figure 5). *Imperata* is a component of the *Phragmites-Saccharum-Imperata* complex, a cover type that occupies a very sizable area: Approximately 28 million ha in the Gangetic and Brahmaputra river watersheds of northern India. This grass complex is

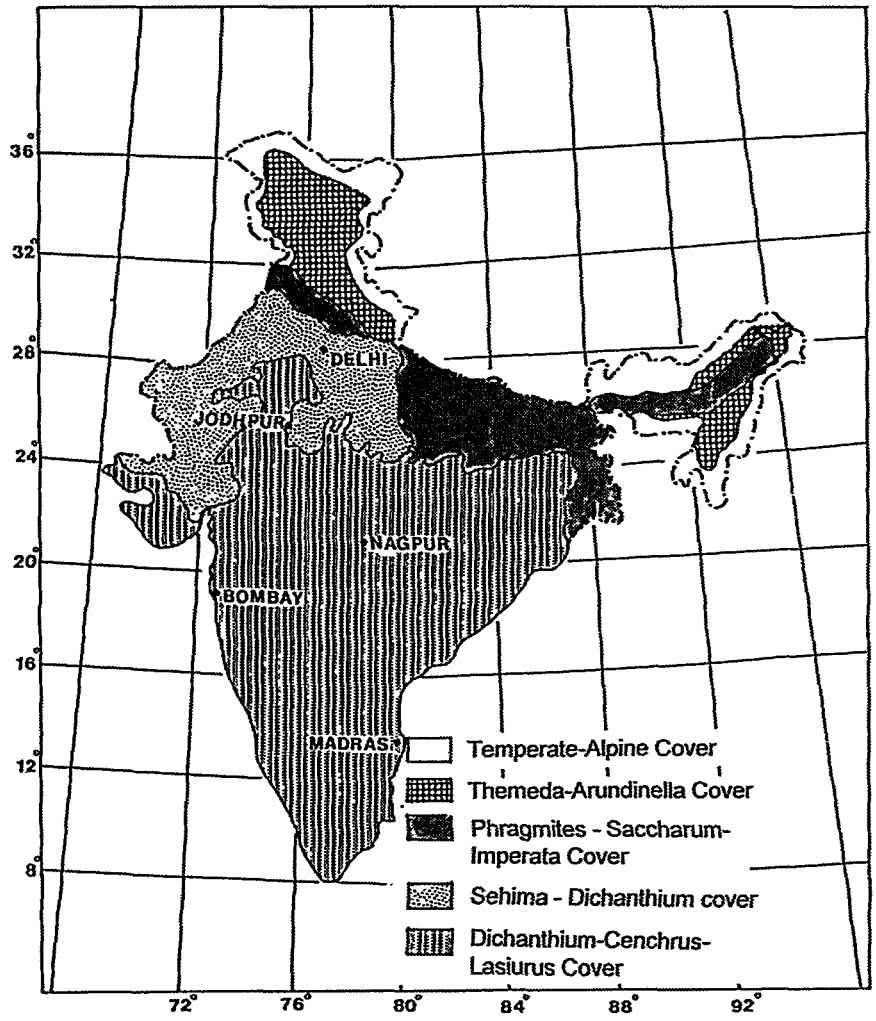

Figure 5. The distribution of grass cover types in India.

found between 26 and 32 degrees North, from the plains of Punjab, Uttar Pradesh, Bihar, and West Bengal to the hills of Assam, Manipur, and Tripura in the northeast (see Figure 5). *Imperata* is observed on the margins of moist or swampy areas as well as on steep drought-prone slopes, and on low phosphate soils that range in pH from 4.0 to 7.5. The elevation range of this grassland complex is up to 2000 m.

Imperata tends to dominate when the land is subjected to repeated burning and cutting, in which case it assumes a depauperate form. The young regrowth provides tender foliage and can stand considerable grazing pressure. The ecologically well-developed stage of this cover type favors the presence of

tall, coarse, and unpalatable species. It is only when the grassland condition deteriorates to a *Desmostachya-Imperata* depauperate stage that the grass vegetation can be used for grazing. With increasing grazing pressure, however, other grasses of even lower value tend to outcompete *Imperata*. In the north-eastern hill zone, where slash-and-burn agriculture predominates, *Imperata* colonizes sloping fallowed fields. On river banks it assumes a compact stand in response to grazing and high moisture. *Imperata* in this region is not found in extensive open grasslands. There are no published national estimates of the land area of India specifically covered by *Imperata*-dominated grasslands. We estimate that the *Imperata* occupies about 30% of the total domain of the grassland complex in which it is a major species, for a total area of approximately 8.0 million ha.

Imperata *in Sri Lanka*

Imperata (*illuk* in the local language) is the most common vegetation in the dry zone highlands of Sri Lanka. The total coverage including both the northern and southern dry zone areas is 0.6 to 0.72 million ha. Shifting cultivation is a common land use in these areas. Patches of *Imperata* are burned for cultivation and after several cycles the land becomes highly degraded. The *Imperata*-occupied lands are mostly state-owned.

In the intermediate zone (300 to 500 meters elevation) the grass occupies 0.7 to 1.0 million ha within the mid-country tea lands. In the tea lands at high elevations (300 to 2,000 meters) *Imperata* is found scattered in unplanted areas. Here the foliage of *Imperata* is used for mulching young tea gardens to prevent soil erosion and conserve moisture. In the rubber- and coconut-growing areas of the lowlands, *Imperata* infestation is localized. *Imperata* roots are observed to penetrate and grow along the interior of the roots of the perennials, wounding and killing them, thereby suppressing tree growth.

Aggregate *Imperata* area in tropical Asia

Table 3 presents our estimates for the area occupied by *Imperata* in tropical Asia. Among the countries for which some data were available, few had data quality sufficient for high confidence estimates. Therefore, we developed three estimates: 1) a conservative estimate, 2) an estimate of the expected area of sheet *Imperata*, and 3) an estimate that assumed a larger figure to include macro and meso level *Imperata* areas that would not have been distinguishable at the mapping scales at which most of the work was done. This estimate assumed that reports of national *Imperata* area were lower than the 'actual' total area of the grass.

Our best estimate is that the total area of *Imperata* grassland in tropical Asia is 34.7 million ha. The sum of our conservative estimates for all countries is 20.8 million ha. Our estimate for sum of the total area of *Imperata*

Table 4. Estimates of the area of *Imperata* grasslands for tropical Asia by country.

Country	Mega-grassland area (Sheet *Imperata*)		Sum of mega, macro, and meso grasslands	% Area of country[a]	Source
	Conservative estimate	Expected			
Southeast Asia					
Indonesia	7.5	8.5	13.5	4	Soekardi et al. (1993)
Philippines	4.0	5.0	6.0	17	SSC (1988)
Malaysia	0.1	0.2	0.5	< 1	Shim (1993)
Vietnam	1.0	3.0	5.0	9	*
S. China[b]	1.5	3.0	5.0	2	*
Laos	0.5	1.0	2.0	4	*
Cambodia	0.1 0.2		0.3	1	*
Thailand	1.0	2.0	4.0	4	*
Myanmar	1.0	2.0	3.0	3	*
South Asia					
Bangladesh	0.1	0.3	0.5	3	*
India	3.0	8.0	12.0	3	*
Sri Lanka	1.0	1.5	2.0	23	*
Total	20.8	34.7	57.2	4	*

[a] Expected area of mega-grassland as % age of the total area of the country.
[b] Southern China (1/5 of the country).
* Estimates by the authors of this paper.

including mega, macro, meso grasslands over all countries is 57.2 million ha. For practical purposes we consider that the *area of Imperata grasslands in Asia is about 35 million ha.* This is about 4% of the land area. [Sanford and Wangari (1985) have reported that for the Asia as a whole, the grassland cover is estimated at 6–12%. This figure includes much area that is outside the humid tropics (e.g. the temperate steppes).]

Our analysis indicates that the countries with the largest area of *Imperata* grasslands are Indonesia (8.5 million ha) and India (8.0 million ha). However, the countries with the largest proportion of their surface area covered with *Imperata* are Sri Lanka (23%), the Philippines (17%), and Vietnam (9%). Laos, Thailand, Myanmar, and Bangladesh evidently all have similar proportions of their land area infested with *Imperata*: All are in the range of 3 to 4%. The countries that evidently have quite minor areas of *Imperata* as a proportion of their total land area are Malaysia (< 1%), Cambodia (1%), and the southern part of China (2%).

We need to emphasize that empirical data sources for the estimates shown for all countries other than Indonesia, the Philippines, and Malaysia, were either unavailable or very sketchy. Thus, the figures are educated guesses. The

literature abounds with many wild guesses about the land area coverage of *Imperata* in the region. Our purpose here was to assemble some reasonable expected numbers that may put the issue in some degree of perspective. They are based on the contributions of a team of individuals coming from most of the countries covered. We readily acknowledge the need for more empirical study of *Imperata* coverage in every country, particularly those on the continental mainland. We are confident that such studies will reveal significant improvements.

Development of an *Imperata* grassland typology

The focus of this workshop is on the analysis of the opportunities for intensifying land use in *Imperata* grasslands (particularly those related to agroforestry) and the factors influencing the appropriateness of the various options. Intensification refers to the application of greater levels of management, labor, and capital to increase the productive use of land, water, and biotic resources. Figure 6 illustrates the flow of land use change from *Imperata* to any of a number of more intensive land use systems. They are identified as 'reclamation' pathways. Their success is partially dependent upon effective practices (technologies) that reduce costs or increase output, and thereby make more intensive land use attractive enough to warrant investment of scarce resources.

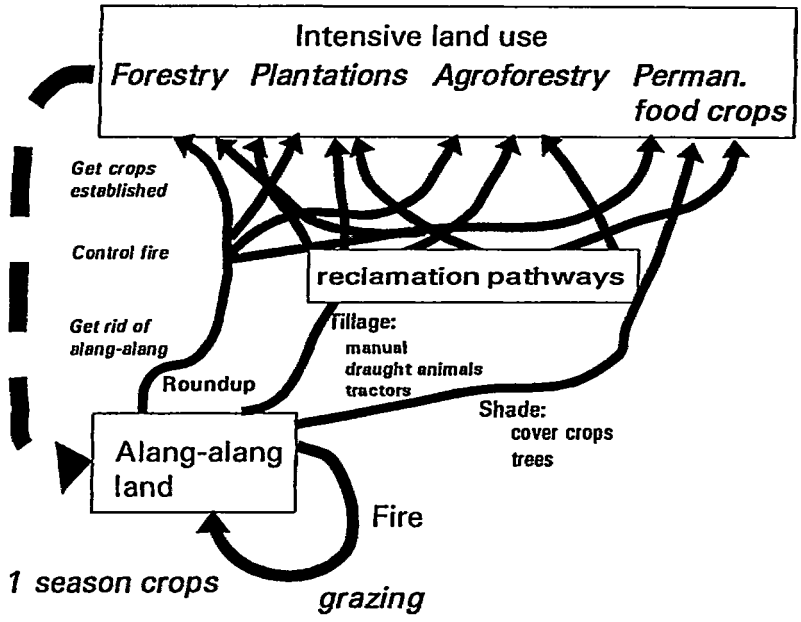

Figure 6. Pathways in reclaiming *Imperata* grasslands.

A mere compendium of alternative practices and technologies is of little use to development planners and workers. The characteristics of an optimal mix of species and practices in highly structured systems are extremely environment-specific. One needs a typology that categorizes systems and technologies and relates them to the realities of specific real-world situations and the evolutionary pathways that these systems are following. This enables identification of relevant policies and resource allocation strategies.

First, we return to the typology based on the size of the grassland area that was outlined at the beginning of the paper. We then propose a number of additional components that have a key influence on intensification pathways: land quality, market access, and the source of power for tillage. These factors enrich the typology as we move toward specific applications.

Size of the grassland. Earlier we discussed how the size of grassland area impacts on the development of useful area estimates of *Imperata* lands. Four size classes of grassland were identified (Table 5), ranging from the huge expanses of sheet *Imperata* (mega-grasslands) to individual, isolated fields populated by the grass (micro-scale). The patch size also has dominant effects on the land management potential of a site. Most important is its influence on the risk of fire.

Extreme flammability is a characteristic of *Imperata*. As the size of the grassland increases, the risk of periodic fires increases. This is due both to natural causes (greater availability of contiguous flammable material) and human factors (organizational control mechanisms become less feasible).

Patch size may also be related to land quality indicators. The very large contiguous areas of *Imperata* (mega-grasslands) tend to be associated with relatively more severe deficiencies in productive potential: Low inherent soil fertility, rough topography, and/or proneness to drought. They also tend to have existed as 'stable' fire climaxes for longer periods of time than grass-

Table 5. Typology of *Imperata* grasslands.

Type	Specification
1. *Mega scale:* large scale sheet *Imperata* grasslands spanning district boundaries	1.1. Sheet grasslands on poor quality land with low population density
2. *Macro scale:* inter village *Imperata* grasslands	2.1. Intermediate elevation. Transition zone between intensive agriculture and mountain forest margins
3. *Meso scale:* intra-village *Imperata* patches	3.1. Zone of *Imperata* between intensively managed cropland near settlement and the forest margin
4. *Micro scale: Imperata* invested individual field	4.1. Fallowed field maintained for grazing 4.2. Perennial tree-crops

lands of other patch sizes, often subjecting them to longer periods of biodiversity reduction, constraining their ecological potential for conversion to woody vegetation. Smaller patches (meso- and micro-level) tend to have been derived more recently, and in closer proximity to other vegetation types and sources of recolonization propagules.

Patch size is also related to land tenure. Sheet grasslands are vastly predominant on public forest lands throughout the countries of tropical Asia, areas where sizable populations often reside. Local systems of land tenure may operate, but tenure is ultimately insecure because the national government claims ownership of the land. It is apparent that effective intensification of such areas will usually depend upon the development of stronger community or household tenurial security (see Tomich, this issue, for a deeper treatment of this issue).

Land quality. It is often assumed that the presence of *Imperata* is an indicator that land is degraded, and of poor quality. This may or may not be true. Although *Imperata* is found on some very degraded sites, it is also observed on a wide range of soils with moderate to high fertility: It has a very wide range of adaptability. The real distinguishing factor for its persistence is the intermittent occurrence of fire. This is evident from the macro-analysis of the distribution of *Imperata* by soil type in Indonesia (Soekardi et al., 1993). They amply illustrate the very wide ecological adaptability of *Imperata*. The CSAR national map of *Imperata* grassland was overlaid on the national soils map (US Soil Taxonomy) and the area of *Imperata* on the various soil types was tabulated (Table 6).

Imperata was found widely distributed on the full range of soil orders. It occupies both fertile (e.g. some of the Inceptisols and Andisols) and infertile soils (Ultisols and Oxisols). It was also distributed on a wide range of physiographic land units, from karst to alluvial lands. The data indicate that

Table 6. Distribution of *Imperata* grassland in Indonesia by soil order.

Soil order	Area	
	ha	% of total
Inceptisols	5,835,350	67.9
Ultisols	1,265,410	14.7
Entisols	518,265	6.0
Andisols	319,580	3.7
Oxisols	246,590	2.9
Mollisols	205,495	2.4
Alfisols	98,660	1.1
Vertisols	69,830	0.8
Histosols	30,670	0.4
Total	8,589,850	100

Table 7. The distribution of *Imperata* grassland in Indonesia by climatic type.

Climatic type	No. of dry months / No. of wet months	Area	
		ha	% of total
A	0–0.14	4,084,925	47.6
B	0.14–0.33	2,317,745	27.0
C	0.33–0.60	282,305	3.3
D	0.60–1.00	592,425	6.9
E	1.00–1.67	908,605	10.6
F	1.67–3.00	403,845	4.7
Total		8,589,850	100

there is no basis for the proposition that *Imperata* is necessarily an indicator species for poor soils.

Soil quality and topography are key land qualities to characterize *Imperata* environments. The third is climate. Soekardi et al. (1993) analyzed the distribution of *Imperata* in Indonesia based on an index (Q) which was calculated as the average length of the dry period of the year (number of months when rainfall is < 60 mm/month) divided by the average length of the wet period (months when rainfall is > 100 mm/month). *Imperata* was associated with all climatic classes, but tended to be most strongly associated with the wettest climates (Table 7).

Population density and market access. Imperata grasslands tend to be remote to roads and markets, and population density is much lower than in intensive agricultural areas. But even mega-scale sheet *Imperata* grasslands are seldom uninhabited 'wastelands'. Villages often exist throughout these grasslands, and although land use appears to be of low intensity, this is often misjudged (Potter, 1994; Dove, 1986). Improvements in road infrastructure can be expected to have dramatic effects on land use intensity.

Access to markets for the sale of crop, livestock, and tree products tends to increase household capital accumulation and the availability of credit. This leads to greater use of fertilizer inputs. Application of external nutrients is critical on virtually all *Imperata*-infested areas to ward off fertility decline and land degradation. Garrity (1995) emphasized how access to fertilizers dominates the intensification pathways chosen by smallholder households.

Source of tillage. The tillage of grassland soils requires considerable draft power. A great contrast exists is the ability of smallholders to manage grassland farming systems depending on whether they have access to animal or tractor tillage, or they must rely on manual cultivation. Cultivation of forest fallows, however, is possible without tillage. Potter's (1987, 1994) studies of villages in a watershed of the Riam Kiwa river, South Kalimantan, illustrate this. Within a village, those families that had access to a draft animal rou-

tinely cultivated the grassland in fallow rotation. Only those (poorer) families that lacked animal-draft exclusively practiced slash-and-burn farming in the forest. Those with animal power had little or no propensity to encroach onto forested lands.

It is often observed that smallholders depending solely on manual cultivation avoid farming on *Imperata* grasslands. Rather, they select or migrate to areas of woody growth. This preference is attributed to the higher labor use efficiency of slash-and-burn compared to the serious labor requirements in hoeing *Imperata* land by hand. Nevertheless, there are documented cases where indigenous cultures have taken to manually cultivating grasslands. An example is the laborious manual grassland cultivation systems of the Batak in North Sumatra described by Sherman (1980). The enormous group effort that the community expends in spading the grassland to prepare fallowed fields for food or cash crops suggests an adaptation to a serious condition of land scarcity. They often had ruminant animals, whose manure was husbanded to maintain the fertility of the grassland fields: an illustration of complementarity between raising livestock and farming grassland (Potter, 1994; Sherman, 1980).

Spontaneous and project-sponsored settlers in many of the Indonesian government's transmigrant schemes were settled in grasslands, and adapted elaborate inter- and relay-cropping practices of upland rice, maize, grain legumes and cassava, to enable 2–3 successive harvests per year with only one primary tillage operation (Suryatna and McIntosh, 1980). In the Philippines, large numbers of farmers are settling open grassland areas using animal power (Garrity et al., 1993; Garrity and Agustin, 1994). The evidence indicates that the availability of draft animals in grassland communities is one of the most effective incentives to farm the grasslands more intensively, and to reduce the need to abandon *Imperata*-infested land to practice slash-and-burn in the forest.

The typology applied

We recently conducted a study to elucidate smallholder management strategies to cope with *Imperata* in three contrasting parts of Indonesia: South Kalimantan, West Sumatra, and Timor. Table 8 shows the typology as applied to a range of villages in the vicinity of *Imperata* grasslands. The table also shows the range of farmer land use strategies employed. The villages ranged from mega-grassland locations (Riam Kiwa and Rantau) to dominantly forested areas where *Imperata* occurred only in small patches (Kintap). Most villages were in macro-grasslands, which extended to neighboring settlements. Tillage of the grassland soils was done by hand in most of the villages. Where animal power was available the area planted to field crops was larger, although a fallow rotation system was still used in which the land reverted to grassland for several years between cropping cycles.

Table 8. Tentative typology of smallholder villages at various locations in Indonesia.

Village	Grassland typology[a]	Land quality	Power sources	Current farmer strategy
South Kalimantan				
1. Kintap				
– javanese	(4) Micro scattered plots	Moderate	Manual	Food crops-mixed perennials
2. Riam Kanan				
– banjarese	(2) Macro	Low	Manual	Annual cash crops and grazing
3. Riam Kiwa				
– javanese	(1) Mega	Low	Manual	Food crops-mixed perennial
– banjarese	(1) Mega	Low	Animal and manual	Food crops
4. Rantau				
– spontaneous migrant javanese	(1) Mega	Low	Animal	Food crops-mixed perennials
5. Pleihari				
– transmigrant	(2) Macro	Very low	Animal	Food crops-rubber
West Sumatra				
1. Saning Bakar				
– minang kabau	(2) Macro	Very low	Manual	Annual cash crops and grazing
2. Rambatan				
– minang kabau	(2) Macro	Very low	Manual	Mixed cash and food crops
Timor				
1. Kotabes	(4) Micro	Very low	Manual	Annual-mixed perennials and grazing
2. Netpala	(2) Macro	Very low	Manual	Annual-mixed perennials and grazing

[a] Numbers refer to Table 5.

A range of important adaptive strategies were identified by which households farmed the grasslands. Key farmer-developed technologies were also identified that may have relevance on a wider scale. We are currently interpreting the case studies in their wider context. If further efforts are successful in building a workable typology, change agents will be better equipped to cope with the complexities of assisting diverse communities to intensify their land use systems.

Conclusions

This paper attempted to present some reasonable estimates of the area of *Imperata* grasslands in tropical Asia. Such information is critical to the debate on what public sector effort might or ought to be directed to their conversion to more productive uses. The exercise highlighted the lack of standard methods in deriving useful area estimates, and the need for more map analyses that would enable a clearer picture of their importance. The progress that has been achieved in some countries in using remotely-sensed data to derive useful area estimates, notably Indonesia and the Philippines, exemplifies the potential for deriving reasonable estimates on the extent of *Imperata* for the region as a whole.

We propose that an international initiative be implemented to map and derive a more complete and uniform estimate of the area of these grasslands. The first level of activity for such an effort should be to support a national team in each country to conduct map analyses relevant to that country's planners, backed up by common methods determined by the international project. However, decisionmakers are not solely interested in the area of *Imperata* grasslands. They also need historical analyses to understand how these areas have changed during recent years or decades. Fortunately, satellite imagery is now available for time-series comparisons in most countries. Thus, a second part of the international effort should be to elucidate the time trends in the spread or shrinkage of the *Imperata* grasslands.

Third, decisionmakers need to know what is really going on in the grasslands. Interventions to foster more intensive and productive use of the grasslands will rely heavily on a realistic understanding of the social and economic conditions on-the-ground in each specific area. The failure of so many top-down initiatives that seek to reforest or otherwise change land use is clear evidence that local conditions are critical. Sensitivity to the experience and livelihood needs of the people who inhabit them is essential.

The main problem is the failure of outsiders to appreciate the indigenous systems of resource exploitation and how they relate to local needs, values, and constraints. The international effort could provide a vehicle to collate and synthesize knowledge about local circumstances in a number of key *Imperata* areas. This will also enable a typology of grasslands to be refined into a practical tool for analyzing intervention strategies that truly serve the

needs of the *de facto* resource managers in *Imperata* grasslands, who are usually smallholder farmers.

Acknowledgments

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