Environmental Cooperation Between
the Republic of Indonesia and the Kingdom of Norway
1994-1995

Feasibility Study on:
Reforestation of Degraded Grasslands in Indonesia as a Climate Change Mitigation Option

by

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CICERO Report 1996:5

The Ministry of State
for Environment,
INDONESIA

Center for International Climate
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Cover: *Imperata* (*alang-alang*) grasslands with pine (*Pinus merkusii*)
in West Kalimantan, Indonesia.
All photographs by Lars Otto Næss.

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ISSN: 0804-4562
Printed 1996 in Norway by GAN GRAFISK AS, Oslo.

FOREWORD

Indonesia and Norway are both parties to the United Nations Framework Convention on Climate Change (FCCC). Indonesia ratified the convention on August 1st 1994, through Act No. 6, Year 1994. Both countries are undertaking joint action to fulfil the commitments stipulated in the Convention. In consistence with the concern for climate change issues that could affect adversely small island and archipelagic countries, the Republic of Indonesia and The Kingdom of Norway conducted a project activity titled “Feasibility Study on Sustainable Reforestation of Degraded Grasslands in Indonesia.” This activity is operated under the Memorandum of Understanding of July 14, 1990, which has as objective to establish environmentally sound and sustainable development through bilateral cooperation, based on equality and mutually beneficial cooperation for both countries.

Poor forest management and uncontrolled land use changes in Indonesia contribute a significant share to anthropogenic emissions of greenhouse gases, especially CO_2, and one of many ways to reduce the CO_2 emission is to encourage reforestation and better forest management. The following study focuses on the rehabilitation of degraded grassland areas. It should contribute to the understanding of the importance of reforestation and sustainable management. Based on the results of the study, degraded grassland rehabilitation offers significant potential for yielding benefits both locally and globally. It can provide long term sustainable economic benefits to the country, as well as income generating opportunities and increased welfare for local communities. Therefore, reforestation of degraded grassland areas is very important for Indonesia because it complements ongoing activities to alleviate poverty and could contribute to reduce Indonesia’s anticipated increase in CO_2 emissions.

We hope that this effort will contribute to the global efforts of addressing climate change by undertaking sustainable development. The results of this study will also assist in finding solutions to the problems of degraded grassland in the tropics.

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SUMMARY

1. Deforestation and land use change in the tropics contribute a significant share of the anthropogenic emissions of greenhouse gases, of which the most important is carbon dioxide (CO_2). Increasing the uptake and storage of carbon in the terrestrial biosphere through reforestation has been proposed as one strategy to counteract the atmospheric build-up of greenhouse gases. This study investigates the feasibility of reforestation of degraded *Imperata* (*alang-alang*) grasslands in Indonesia as a climate change mitigation option. A primary objective has been to discuss reforestation in a local perspective, as previous experiences have demonstrated that proper attention to social aspects and issues relevant to the local communities is key to reforestation success. Man-made *Imperata* grasslands in Indonesia cover at least 8.6 million hectares of land of variable production potential. The grasslands have been spreading on former forest lands as a result of logging and slash-and-burn cultivation, and are sustained by regular burning.

2. Imperata grasslands are considered by both the government and the local authorities to provide less benefits to the local people, to the nation, and to the global community, than its potential as a reforested area. However, there are many stakeholders involved in these grasslands, and their aims may be conflicting. Even though grassland rehabilitation in most cases appears to be socially beneficial and economically a 'no-regret' option, there are institutional, economical and social barriers for its implementation. Costs and benefits are distributed unequally in time and space, and the short term financial feasibility for the actors is not obvious. These obstacles make it necessary to give support in the establishment phase, as well as to provide incentives for long-term maintenance.

3. The report contains a brief overview of the issue of *Imperata* grasslands, an outline of the present status, a discussion of potential costs and benefits associated with reforestation, and suggestions of strategies which could be applied to reach the desired goals. Case studies are presented from three locations in Indonesia where fieldwork has been undertaken (one location in Sumatra and two in Kalimantan). The case studies provide baseline data about the sites and the *Imperata* grasslands, experiences from earlier efforts to rehabilitate the grasslands, the common attitude to reforestation among the local communities, a discussion of the feasibility of reforestation, and finally, recommendations for the future.

4. Reforestation of grasslands could contribute considerably to climate change mitigation through increasing the above- and below ground carbon storage, thereby removing carbon from the atmosphere on a long term basis. Furthermore, increasing the productivity of grasslands may in some cases reduce the pressure on natural forests and in turn reduce carbon releases from deforestation and land use change. Producing durable products, replacing fossil fuels with fuelwood, and using wood instead of fossil fuel consuming products, would further increase the carbon storage.

5. Grassland rehabilitation also carries a significant potential for yielding benefits to Indonesia, both on the national and local level. Properly managed it may provide long term sustainable economic benefits to the nation, and income generation and increased welfare for local communities. Furthermore, a forest cover would produce a number of goods and services such as timber and non-timber products, soil and water conservation, and biodiversity benefits.

6. The case study locations differ in terms of population size, density and ethnicity, topography, grassland area and patch size, legal situation, applied management systems, and farming systems. The common attitude among the people in these areas is that grasslands represent a management problem, sometimes small, sometimes large. In all locations the grasslands were claimed and used by local people, mostly for shifting cultivation. Land use within the communities is regulated through customary land rights, but these are in most cases not accepted by the government. Hence, no compensation has been given when farmers have lost land because of governmental reforestation efforts. The *Imperata* grass is used to some extent for animal fodder and roof cover. Despite this, farmers would always welcome reforestation if this would increase their income and welfare.

7. So far, reforestation efforts have been unsuccessful in a high proportion of the cases. The main reason for the failures is uncontrolled fire. Grasslands left to fallow and protected from fire will over time reestablish a forest cover through natural succession. Fires are partly accidental and partly a result of intentional actions to provide cattle fodder, clear lands for cultivation or hunt animals. The problem of man-made fires appears to be due to social constraints rather than technical ones, arising from a lack of support for large-scale reforestation efforts from the local communities. Farmers generally have measures to control burning in their own fields, but have few incentives to protect the plantations. This arises due to several factors, including: (a) inadequate communication and cooperation between the government or the investor and the local farmers; (b) lack of established land tenure rights. Farmers have generally not been compensated for loss of lands, because traditional rights are not respected or legally accepted; and (c) farmers do not know the planted species and often do not believe that they will receive benefits from the plantations. Additional problems are lack of forest plantation maintenance, and inappropriate reforestation techniques and species selection.

8. Reforestation cannot be justified on the basis of carbon sequestration alone, but must be seen in the context of long-term social and economic development. It seems, however, that there exist management options where there are few conflicts between these aims. Efforts that benefit the people and the environment will generally result in increased carbon sequestration. To facilitate reforestation success the local communities should receive adequate benefits from the activities. Reforestation should also be undertaken in a way that facilitates an increase in biodiversity and contributes to reducing pressures on natural forests. Proposed strategies for reforestation include (1) plantations, (2) agroforestry, and (3) natural regeneration. The choice of strategy will depend on economic efficiency criteria, on the preferences of the local communities, and on environmental impacts in the area. It seems clear that reforestation have the greatest chances of being successful when strategies are based on existing agricultural practices on the sites.

9. Priority should be given to the provision of incentives to the local people in order to guarantee their participation in reforestation activities, and to secure proper maintenance. Reforestation should only be attempted when the local communities are in agreement with the reforestation proposal and support the investment. An absolute necessity is that the local people understands and have confidence in the efforts. Existing or potential conflicts that may hinder reforestation, either within communities or between communities and the investor, must be resolved prior to reforestation. Clearly defined, legally accepted and adequately enforced land use rights are fundamental. The economic risk of participating in reforestation schemes should be minimised and priority should be given to strategies with low input and management costs, aiming at diversifying the income sources of the farmers.

10. The main objectives of the next project phase should be to enhance local development, monitor carbon sequestration, and assess the social, economic and environmental impacts linked to reforestation. A major objective will be to facilitate capacity building at the local level. Already established projects for reforestation of *Imperata* grasslands could be good starting points for further work. Specific recommendations for the three case study areas are provided.

SAMMENDRAG

1. Avskoging og endret arealbruk i tropiske strøk er årsak til en betydelig del av de antropogene utslippene av klimagasser, hvorav den viktigste er karbondioksid (CO_2). Skogetablering for økt opptak og lagring av karbon har vært foreslått som en av mange strategier for å motvirke akkumulering av CO_2 i atmosfæren. Denne rapporten diskuterer egnetheten for re-etablering av skog i menneskeskapte grasområder i Indonesia som et klimatiltak. Indonesia har i dag minst 8.6 millioner hektar (86 000 km^2) med slike områder av varierende produksjonspotensiale. Grasområdene har i stor grad blitt dannet som følge av avskoging og svedjebruk (‘slash-and-burn’). Høy brannhyppighet hindrer gjenvekst og holder områdene åpne. Områdene domineres av grasarten *Imperata cylindrica* (lokalt navn: *alang-alang*), som er svært konkurransedyktig under disse forholdene.

2. Det er bred enighet om at *Imperata*-dominerte grasområder gir mindre nytte lokalt, nasjonalt og globalt enn de kunne gjort ved alternativ bruk. Re-etablering av skog, enten i form av plantasjeskogbruk, agroskogbruk eller naturlig gjenvekst, regnes for å være den beste løsningen for å øke den sosio-økonomiske og miljømessige verdien av områdene. Et hovedproblem er imidlertid at nytte og kostnad er ulikt fordelt i tid og rom. Lokalt initierte klimatiltak vil ha en global nytte på lang sikt, mens de umiddelbare kostnadene for en stor del må bæres av nasjonene og lokalsamfunnene. Lønnsomheten for den enkelte aktør kan derfor være usikker. For å gi insentiver til en langsiktig forvaltning synes det nødvendig med støtte som sikrer at de som mottar nytten også er med på å dekke kostnadene på kort og lang sikt.

3. Rapporten gir først en oversikt over ulike problemstillinger knyttet til *Imperata*-grasområder. Dernest diskuteres mulige nytte- og kostnadseffekter ved re-etablering av skog og aktuelle strategier for å oppnå ønskede mål. Videre presenteres studier fra tre områder i Indonesia, ett lokalisert på Sumatra og to på Kalimantan. Feltarbeidet omfattet diskusjoner med lokale myndigheter og intervjuer blant folk som bor nær grasområdene. Rapporten gir bakgrunnsdata om områdene, utbredelse av *Imperata*-områder, og tidligere erfaringer med tiltak for etablering av skog i grasområdene. Den gjennomgår også lokalbefolkningens holdninger til tiltakene, og gir en diskusjon av egnethet for skogreising og anbefalinger for framtiden.

4. Skogreising i grasområdene kan gi betydelig global nytte som klimatiltak. Nytten består primært i binding av CO_2 i vekstfasen, og på lang sikt økt ‘karbonlager’ i vegetasjon og jordsmonn. Primærskog i Indonesia holder en permanent karbonmengde på omkring 150-250 tonn per hektar. Til forskjell fra skog på høyere breddegrader har tropisk skog mer karbon i vegetasjonen enn i jordsmonnet. Det er anslått at mellom 90 og 100% av karbonet i vegetasjonen går tapt ved avskoging og omforming til grasområder. For jordsmonnet regner en med et tap på omkring 10-25%. Det er stor usikkerhet knyttet til disse estimatene, spesielt når det gjelder jordsmonnet. Anslått total karbonmengde i *Imperata*-grasområder er 50-75 tonn per hektar.

Re-etablering av skog vil øke karbonmengden i vegetasjon og jordsmonn for derved å binde en viss andel av den karbonmengden som ble frigjort i avskogingsprosessen. Det er imidlertid en rekke andre faktorer som bestemmer hvor stor den totale karbonbindingen blir. Den kanskje viktigste faktoren i Indonesia er hvordan tiltakene påvirker gjenværende naturskog. Økt produktivitet i grasområdene vil kunne minske etterspørselen etter land, og derved redusere avskogingstakten. Den motsatte effekten vil imidlertid også kunne oppstå: Hvis skogetableringstiltak legger beslag på dyrkingsjord uten å kompensere for tapet vil dette kunne gi økt takt i avskogingen. Levetiden på produktene vil også være avgjørende. Bruk av tømmer til bygningsmateriale vil øke 'karbonlageret'. Ytterligere gevinster oppnås hvis ikke-fornybare energikilder erstattes av bioenergi, og bruk av tømmer til erstatning for materialer som f.eks. sement, hvor produksjonen i dag forbruker store mengder fossilt brensel.

5. På tross av klimagevinstene vil muligheten for vellykkete tiltak i stor grad bestemmes av hvilken nytte skogreisingstiltakene gir lokalt og nasjonalt. Studien har vist at riktig utført vil etablering av et skogdekke kunne gi en rekke gevinster, inkludert 1) sosial og økonomisk nytte som vil komme fattige befolkningsgrupper til gode, 2) bevaring av vannressurser og jordsmonn, og 3) økt artsmangfold.

6. De tre stedene hvor feltarbeidet ble utført var forskjellige m.h.t. befolkningstetthet og etnisk opprinnelse, topografi, grasområdenes totalareal og blokkstørrelse, forvaltnings-status og lokale landbrukssystemer. Et fellestrekk var imidlertid at grasområdene er bebodd og i bruk, hovedsakelig for svedjebruk. *Imperata*-graset brukes i noen grad som dyrefôr og taktekke. Holdningen blant lokalbefolkningen er likevel at *Imperata*-områdene utgjør et problem og at rehabilitering er ønskelig i den grad det kan gi økt inntekt og velferd. Bruken av grasområdene er idag regulert gjennom tradisjonelle rettighetssystemer som i liten grad er akseptert av myndighetene, noe som igjen betyr at det ikke er blitt gitt kompensasjon ved tap av land og rettigheter ved etablering av industrielle tømmer-plantasjer.

7. Tiltak for skogetablering i grasområdene har til nå i stor grad vært mislykket. Det største problemet er ukontrollert brenning. I tørkeperioden er *Imperata*-graset svært utsatt for brann. Svedjebruk i naturskog vil lett antenne tilliggende grasområder, og brannene spres ofte over store områder. De tekniske problemene med å kontrollere brannene synes likevel å være underordnet de sosiale og institusjonelle hindringene. Hovedproblemet er at skogreisingstiltakene ofte mangler støtte i lokalbefolkningen. Mens bøndene har metoder til å kontrollere brann i sine egne jordbruksområder har de få insentiver til å beskytte plantasjene. Viktige årsaker er: a) manglende kommunikasjon og samarbeid mellom myndigheter/skogbruksorganisasjoner og lokalbefolkningen både før skogreisingstiltaket skjer og under gjennomføringen, b) tap av land uten kompensasjon, fordi lokale rettigheter ikke er akseptert eller respektert, og c) bøndene kjenner i mange tilfeller ikke treslagene som blir plantet, og har liten tro på at de vil få noe nytte av tilplantingstiltaket.

8. Re-etablering av skog i grasområder kan ikke begrunnes bare ut fra at det har nytte som klimatiltak, men må sees i sammenheng med langsiktige sosiale, økonomiske og miljømessige utviklingsmål. Riktig utført synes det likevel å være relativt få konflikter mellom disse målene: Tiltak som er bra for lokalbefolkningen og for bevaring av jordsmonn, vannressurser og artsrikdom vil også binde store mengder karbon. Strategier som har vært diskutert i rapporten er 1) plantasjeskogbruk, 2) agroskogbruk, og 3) naturlig gjenvekst. I vurderingen vil lokale jordbrukssystemer måtte stå sentralt. En kombinasjon av ovennevnte systemer kan i mange tilfeller være hensiktsmessig.

9. En hovedkonklusjon er at hensynet til lokale forhold må være rettesnoren for tiltakene. Å involvere lokalbefolkningen i planlegging og gjennomføring vil være helt avgjørende for å kunne lykkes på lang sikt. Eksisterende eller potensielle konflikter, både innen lokalsamfunnene, og mellom lokalsamfunn og myndigheter, må avklares før eventuelle tiltak kan påbegynnes. Mangel på definerte, lovfestede og håndhevete eiendomsrettigheter er et hovedproblem, som nevnt over. Det må videre gis støtte for å minske den økonomiske risikoen for bøndene ved å delta i prosjektene. Tiltak med lave investerings- og vedlikeholdskostnader bør prioriteres, og tiltakene må ta sikte på å gi økt fleksibilitet for lokalbefolkningen.

10. Hovedmål for den neste prosjektfasen bør være å utvikle tiltak som kan støtte opp under utvikling på lokalt nivå, måle karbonbinding, og å vurdere hvilken nytteeffekt tiltakene har sosialt, økonomisk og miljømessig. Et samarbeid med eksisterende institusjoner vil være et godt utgangspunkt for videre arbeid. Rapporten gir avslutningsvis anbefalinger for hvert av de tre områdene som ble studert.

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ABBREVIATIONS AND GLOSSARY

ADB	Asian Development Bank
BAPPEDA	Regional Development Planning Board (*Badan Perencanaan Pembangunan Daerah)*
BTR	Reforestation Technology Institute (*Balai Teknologi Reboisasi*)
Belukar	Shrub, thicket, underbrush.
Bupati	A Government Official appointed as head of Kabupaten (District Head)
CIFOR	Center for International Forestry Research
CH_4	Methane
CO_2	Carbon dioxide
Dinas	Local government service department, responsible to the provincial governor, and with indirect links to the relevant central government departments
DN	Directorate for Nature Management, Norway (*Direktoratet for Naturforvaltning*)
EFI	European Forest Institute
ENSO	El Niño / Southern Oscillation
Enso	Enso Forest Development Ltd.
FRDC	Forest Research and Development Center (*Pusat Penelitian dan Pengembangan Hutan*)
FAO	The Food and Agriculture Organisation of the United Nations
FINNIDA	Finnish Agency for International Development
GEF	Global Environmental Facility
Hak Ulayat	"Right of Disposal", ownership over lands held by communities
HPH	Natural Forest Logging (Forest Concession Rights, *Hak Pengusahaan Hutan)*
HTI	Industrial Timber Estate (*Hutan Tanaman Industri*)
Hukum adat	Traditional or customary laws (*adat* = custom)
HWL	High Water Level
ICRAF	International Centre for Research in Agroforestry
Inhutani	PT. (Persero) Inhutani; a state-owned forestry company
Inpres	Presidental Instruction (Instruksi Presiden)
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal rate of return
Kanwil	Provincial level office of a central government department (*Kantor Wilayah*)
KSNP	Kerinci-Seblat National Park
Ladang	Arable lands, commonly used as the cultivated fields in the shifting cultivation practice
LWL	Low Water Level
MPTS	Multi Purpose Tree Species
MSE	Ministry of State for Environment, Indonesia
N_2O	Nitrous oxide

OECF	Overseas Economic Corporation Fund
pH	Measure of soil acidity
PHPA	Directorate General of Forest Protection and Nature Conservation, Ministry of Forestry (*Direktorat Jenderal Perlindungan Hutan dan Pelestarian Alam, Departemen Kehutanan*)
Sawah	Wet ricefield
Semak	Annual weeds, bush
Semak Belukar	Bushlands
TGHK	Forest Consensus Boundary (*Tata Guna Hutan Kesepakatan*)
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WAHLI	Indonesian Forum for the Environment (*Wahana Lingkungan Hidup Indonesia*)
WWF	World Wide Fund for Nature
YLBHI	Indonesian Legal Aid Foundation (*Yayasan Lembaga Bantuan Hukum Indonesia*)

1 km^2	= 100 ha = 1000 da
rp.	= rupiah (November 1995: 1 US$ ≈ 2200 rp.)
t	= tonne
C	= carbon
°C	= degrees Celsius

ACKNOWLEDGEMENTS

This feasibility study is the result of a collaborative effort between The Ministry of State for Environment (MSE) in Indonesia and the Center for International Climate and Environmental Research - Oslo (CICERO) in Norway. The fieldwork was coordinated by MSE through Assistant Minister for Environment Mr. Ir. Aca Sugandy, Dr. RTM. Sutamihardja, Mr. Dadang Hilman, Mr. Gunardi, and Mr. Hasoloan Panjaitan, with the support of Forest Research and Development Center (FRDC) in Bogor: Dr. Ngaloken Gintings, Ms. Sri Suharti and Ms. Risna Girsang. The CICERO team included Mr. Arne Dalfelt, Mr. Lars Otto Næss, Mr. Rolf Selrod, and Dr. Asbjørn Torvanger. Funding for the project has been provided by the Ministry of Environment through the Directorate for Nature Management, Norway.

A significant number of other Indonesians and Norwegians contributed to the success of this project. The authors would like to acknowledge this support in mentioning the following individuals and institutions who contributed in one way or another:

In Jambi:

Mr. H. Bambang Sukowinarno, Bupati Kerinci
Mr. Ahmad Nur, Bappeda Sungai Penuh
Mr. Hasvia, Bappeda Jambi
Mr. Sempirin, Plantation department, Sungai Penuh
Ms. Linda, Agricultural department, Sungai Penuh
Mr. Rico Prihatono, Dinas Perhutanan dan Konservasi Tanah, Sungai Penuh
Ms. Rinna Syawal, University of Jambi
Mr. Wahyudi Zainir, University of Jambi
Mr. Sefrizal, STTP Padang
Ms. Nova, Jambi
Ms. Leli Rina, World Wide Fund for Nature, Sungai Penuh
Sub-district Office, Sungai Penuh
Sub-district Office, Air Hangat

In West Kalimantan:

Province Governor, Pontianak
Bappeda, Pontianak
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District Head (Bupati), Sintang
Bappeda Sintang
Mr. Iwan Setiadi, Bappeda Sintang
Ms. Desti, Researcher, PT. Inhutani III, Blonti, Kayan Hilir
Mr. Hendromono, M.Sc., Researcher, Pusat Litbang Hutan, Bogor
Mr. Catur Margono, PT. Inhutani III, Nanga Pinoh.
Sub-district Office, Nanga Pinoh
PT. Rimba Equator Permai, Pontianak

PT. (Persero) Inhutani III, Pontianak
Mr. Leo B. Sekti, PT. Adhimulia Aneka Consult, Jakarta
Mr. Langgeng Wiharto, PT. Adhimulia Aneka Consult, Jakarta

In Riam Kanan:

Mr. Arif P.S. Sagala, BTR Banjarbaru
Mr. Acep Akbar, BTR Banjarbaru
Mr. Sudin Panjaitan, BTR Banjarbaru
Mr. Baginda, BTR Banjarbaru
Mr. Antti Otsamo, Enso Forest Development Ltd. Banjarbaru
Province Governor, Banjarmasin
Bappeda, Banjarmasin
District Forest Office, Banjarbaru
Sub-district Office in Aranio, Drs. Agus Prabowo

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Mr. Sjur Kasa
Dr. Jan S. Fuglestvedt
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Ms. Elisabeth Meze

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Dr. John W. Turnbull

At EFI:

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At ICRAF:

Dr. Thomas P. Tomich

1. INTRODUCTION

1.1 BACKGROUND

The 1995 report of the Intergovernmental Panel on Climate Change (IPCC 1995) concludes that anthropogenic emissions of greenhouse gases[1] (GHGs) and the corresponding increase in atmospheric GHG concentrations[2], together with anthropogenic aerosols, have an influence on the global climate. Analyses of patterns of climate change give strong indications of a man-made impact on the global climate. Since the late 19th century, global mean surface temperature has increased by between about 0.3 and 0.6°C, a warming that according to IPCC (1995) is "unlikely to be entirely natural in origin". The current 'best estimate' predicts an increase in global mean surface temperature relative to 1990 of about 2°C by 2100 (IPCC *op.cit.*). On the regional level, there are still large uncertainties concerning the magnitude of climatic changes.

Carbon dioxide (CO_2) is the most important of the anthropogenically enhanced greenhouse gases. Annual emissions from fossil fuel combustion and cement production are around 5.5±0.5 gigatonnes of carbon (GtC) (IPCC 1994). The terrestrial biosphere plays a significant role in the carbon cycle. As a result of deforestation and changes in land use, tropical forests are assumed to be a net source of CO_2 emissions (1.6±1.0 GtC / year). Mid- and high-latitude forests are found to be a net sink of 0.5±0.5 GtC / year. In Indonesia, land use change is the largest source of CO_2 emissions (Table 2:3). Reforestation of degraded grasslands has been proposed as one of many strategies to counteract CO_2 build-up in the atmosphere. This report investigates the feasibility of efforts for mitigation of climate change through reforestation of *Imperata* (*alang-alang*) grasslands in Indonesia.

1.2 PROJECT HISTORY

This project is a continuation of the finalised project "Eco-strategies for terrestrial CO_2 fixation in Indonesia" (DN / MSE[3] 1994), which emphasised the biological potential of CO_2 fixation in the country. It is one out of five projects included in the second work period of the bilateral agreement on Environmental Cooperation between the Republic of Indonesia and the Kingdom of Norway, signed on October 29th, 1993.

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[1] The most important are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), CFC-12, HCFC-22, and CF_4.

[2] Since pre-industrial times (around 1750) the level of CO_2, CH_4 and N_2O have grown by about 30%, 145%, and 15%, respectively (IPCC 1995). The level of atmospheric CO_2 has increased from about 280 ppmv in 1800 to about 358 ppmv in 1994 (IPCC 1995).

[3] DN = Directorate for Nature Management, Norway; MSE = Ministry of State for Environment, Indonesia

DN / MSE (1994) consider reforestation of *Imperata* grasslands to be of particular interest for the following reasons:

1. *CO_2 fixation:* There is a considerable potential for relatively immediate CO_2 fixation through reforestation of grasslands. The potential is regarded as being largest in a 50 years perspective.
2. *Social and economic gains:* Most management strategies were found to be profitable, even without considering CO_2 fixation benefits ("no-regret options"). The internal rate of return (IRR) varied between 10 and 29% p.a.
3. *Environmental benefits:* By using a mix of indigenous tree species, the efforts would give substantial environmental benefits such as decreased erosion, improved watershed conservation, and biodiversity benefits.
4. *Low opportunity costs and low conflict potential:* The study regards *Imperata* grasslands as having generally low environmental and economic value, and that reforestation of these lands will have a lower potential for conflicts than similar efforts in other land categories in the country.
5. *Large potential area for implementation:* The DN / MSE study considered the maximum area for tree planting to be 3.16 million ha, 40% of the estimated grassland area.

The recommended strategies for plantations on grasslands in a 10, 30 and 60 years perspective are summarised in Table 1:1 below.

10-year perspective: The suggested reforestation strategy involves plantations with mixed species and *Paraserianthes falcataria* as the main production tree (G4). This method was found to have the largest carbon accumulation potential among the acceptable strategies, but with lower internal rate of return than monoculture with *Paraserianthes* (G2). Strategy G4 is favoured due to lower environmental problems.

30-year perspective: A monocultural plantation with *Pinus merkusii* on grassland (G3) was found to be the only 30-year strategy with acceptable environmental impacts. All monoculture plantations have problems of low biodiversity, nutrient degradation and erosion. It was therefore recommended to run three 10-year rotations with the mixed species plantation strategy G4 (see above). This strategy would, compared to G3, result in higher IRR, better environmental conditions and about the same carbon accumulation after 30 years.

60-year perspective: A plantation with *Shorea spp.* or *Tectona grandis* on grassland gives high CO_2 accumulation potential, high internal rate of return and moderate environmental impacts. Secondary forest development would give the highest environmental value to the area, but was found to have relatively low carbon sequestration potential and limited financial return.

Table 1:1. The DN / MSE (1994) ranking of the management strategies for grasslands concerning area potential, cost-efficiency and environmental assessment.

Management strategy 10 years	Total accum.pot. in 10^6 tonnes CO_2 max 40%	min 10%	Cost efficiency IRR % p.a.	Environmental disturbance
(G2) Monoculture plantation; *Paraserianthes*	986	246	29	medium
(G4) Mixed plantation; *Paraserianthes, Eucalyptus, Acacia*	1,235	309	14	medium
Management strategy 30 years	Total accum.pot. in 10^6 tonnes CO_2 max 40%	min 10%	Cost efficiency IRR % p.a.	Environmental disturbance
(G3) Monoculture plantation; *Pinus*	1,292	323	10	high
Management strategy 60 years	Total accum.pot. in 10^6 tonnes CO_2 max 40%	min 10%	Cost efficiency IRR % p.a.	Environmental disturbance
(G1) Secondary forest development	711	178	-	low
(G5) Monoculture plantation; *Shorea*	3,751	938	20	medium
(G6) Monoculture plantation; Teak	3,666	917	17	medium

1.3 OBJECTIVES

The primary objective of this study is to investigate the feasibility of management alternatives for climate change mitigation through reforestation of grassland, when taking into account environmental values, social impacts, national development objectives and economic benefits. Specific goals are:

- Assessment of ecological and socio-economic aspects of reforestation alternatives.
- Assessment of potential conflict areas.
- Assessment of areas suitable for reforestation.
- Discussion of costs and benefits.
- Discussion of institutional and organisational issues relevant to reforestation projects.

1.4 THE SOCIAL CONTEXT

The social context will be of central concern in this study. Particular emphasis will be given to the local communities; their potential role in the rehabilitation efforts and how incentives could be provided for reforestation in accordance with local needs and priorities. There is a general consensus among scientists that too little attention has been given to the interests of the small farmers. DN / MSE (1994) point out that grasslands may be used by local people for several purposes which could give rise to management conflicts. Other reports (e.g. Turvey 1994) argue that *Imperata* grasslands are not “wastelands” but for the most part occupied lands with several important uses for the local communities, and where utilisation is regulated through informal land tenure arrangements.

The DN / MSE study (presented above) is partly used as a theoretical background on economic and environmental issues. Case studies have been undertaken in three separate areas in 1) South Kalimantan, 2) West Kalimantan, and 3) Jambi province, Sumatra. The case studies have been undertaken in collaboration with the Division of Policy Formulation on Environmental Management, the Ministry of State for Environment in Indonesia.

2. OUTLINE OF SUBJECT AND PRESENTATION OF PROBLEMS

2.1 GRASSLANDS IN INDONESIA

The majority of the grasslands in Indonesia and Asia as a whole are considered to be human-made (Dove 1986, Banerjee 1995). Large areas of tropical forests in Indonesia have been converted to grasslands as a result of logging and frequent burning. This section gives a brief overview of such human-induced *Imperata* (*alang-alang*) grasslands, describing its origin, biology and ecology, area coverage, and management issues. Natural grasslands caused by climatic or edaphic conditions, as the climax savanna found in Nusa Tenggara and Irian Jaya (Tjitrosoedirdjo 1993), are beyond the scope of this report.

2.1.1 Origin of grasslands

Human-induced grasslands in Indonesia have been described in the literature from the middle of the 19th century (Potter 1995). Grasslands are formed in deforested areas where establishment of secondary tree vegetation is hindered by a high fire frequency. Generally, the conversion from forest to grassland occurs through: (a) logging, (b) slash-and-burn cultivation, and (c) continued frequent burning. It must be noted, however, that slash-and-burn cultivation is not the only cause for grassland formation. Historically, cash crop plantations introduced in the colonial period have been important for the creation and spread of *Imperata*. Land clearing for pastoralism and deer hunting involving regular burning, has also been a major factor (Potter 1995, Dove 1986:169). It is also important to separate between traditional systems of shifting cultivation and the modern slash-and-burn practices (see appendix 5). It seems clear that traditional systems of swidden cultivation, evolved over a long time period and in times of low population pressures on land, can exist without threatening the resource base, nor create permanent grasslands (cf. e.g. Hurst 1990, Whitten *et al.* 1987). Migrants, on the other hand, tend to use non-sustainable practices because they lack indigenous knowledge about traditional farming in the areas where they settle.

(a). Logging in natural forests is undertaken through concession agreements between the Indonesian government and forestry companies. It often starts with the government establishing a general land claim in rainforest areas, in many cases rejecting traditional land claims of people living in the forests. These nationalised areas are subsequently leased out to private forest logging companies as logging concessions for a fixed time period, currently 20 years. After 20 years, concessions may be renewed. The renewal process give opportunities for the authorities to investigate whether the concession regulations and demands have been fulfilled by the timber companies (World Bank 1993). Logging is mainly selective, as a relatively small proportion of the tree species is commercially valuable. Thus, logging affects large areas, and the remaining vegetation is substantially

damaged (cf. DN / MSE 1994, Whitten *et al.* 1987).
(b). After the forests have been logged over, subsistence farmers often move in, using slash-and-burn technology. Roads created for forestry open up large forest areas which were previously inaccessible. The new settlers are either poor farmers moving spontaneously in search for livelihood at the forest frontiers, or people migrating through governmental transmigration schemes (Turvey 1994). The newcomers often displace the indigenous people, who are forced to move further into the forests.

Land clearing and burning give high initial crop yields. Repeated cultivation for a few years will, however, lead to a rapid decline in soil productivity. The plots are likely to be invaded by aggressive weeds, the most infamous of them being *Imperata cylindrica*. The cultivation plots are then abandoned for a fallow period of 15-30 years (Calub *et al.* 1995). The proportion of time used for cultivation in comparison to the period of fallow will differ with soil conditions, the ability to control *Imperata* growth, and existence of alternative land for shifting cultivation. Shortage of land for cultivation will force the farmers to reduce the fallow period and continue cultivation for a longer time period (cf. Potter 1987). The long term effect, lowering of soil fertility and weed invasion, make cultivation too costly for most farmers. Better-off farmers may add fertilisers and use animal ploughing for weed control, and some (indigenous) communities are reported to have developed techniques to overcome the problem of degrading conditions (Potter 1995).

(c). The development of the deforested lands will be largely determined by the fire regime (Suharti *et al.* 1995). If fire is excluded for a certain time period, and if the soils are not too degraded and the seeds are available from the soil or nearby forests, woody species will re-colonise and secondary vegetation will re-establish (Turvey 1994). The time of fire prevention needed for trees to establish is normally 2-7 years (DN / MSE 1994).

A common situation is however that the lands are used as components in various systems of extensive agriculture involving frequent burning (Turvey 1994). Frequent burning prevents natural secondary succession of forest (Eussen and Wirjahardja 1973) and favours fire tolerant grasses. The most common species in Indonesia is *Imperata cylindrica*. *Imperata* does not form stable climax communities (Dove 1986), but may rather be considered as sub-climax communities, stabilised by regular burning (cf. Blasco 1983). Turvey (1994:12) points out that “shifting cultivation is only associated with *Imperata* colonisation if a source of *Imperata* is in close proximity; sites of shifting cultivation well within closed forest will recolonise to forest species”. *Imperata* is not very common in secondary forest, and is virtually absent in primary forests (Eussen and Wirjahardja 1973). *Imperata* can form single stands or associations with other grass species.

Fire is used intentionally as a management tool, but it may also be accidental due to high flammability of the grasses, especially during the dry season. The main purposes of intentional burning are: 1) provision of fodder for livestock, 2) hunting, either because some game animals are attracted by the *Imperata* fields (Dove 1986) or because it chases out small games, and 3) suppression of pests and diseases. Hunting of deer is reported to be one of the causes for creation of grasslands in historic Java (Dove *op.cit.*). Generally, grasslands are burned at the end of the dry season. Fire is also used as a way of showing social protest (see e.g. Suharti *et al.* 1995). Moreover, excessive forest exploitation increases fire risk, as the forest becomes more exposed to wind and sunlight and dries out in certain periods. (Suharti *et al.* 1995). In a case study from the Riam Kiwa Valley, South Kalimantan, Potter (1995) reports that burning is likely to be particularly widespread during periodic droughts which occur in association with the ENSO (El Niño-Southern Oscillation) events. A recent work by Salafsky (1994) from West Kalimantan suggests that dry periods linked to the ENSO phenomenon have increased over the past two or three decades.

Frequent fire is considered to be the key constraint for reforestation of grasslands. It is a problem as it often gets out of control and spreads over wide areas. Fires starting in grasslands may burn adjacent forest, thus trees planted by the government may suffer from fires (Dove 1986:175). Turvey (1994:12) argues that the problem of fire management is more related to problems concerning land tenure, ownership of trees and their products, and community attitudes, than the flammability of the grass. It is reported that prevention of fire through legal arrangements and sanctions is hindered by a lack of personnel, equipment and organisation systems of fire fighting (cf. Suharti *et al.* 1995). Fire management, including possible strategies for fire control, will be further elaborated in later chapters.

2.1.2 Biology and ecology

The dominating species in Indonesian grasslands is *alang-alang* or *Imperata cylindrica* (L.) Beauv. var. *major*[4]. *Imperata cylindrica* is a pioneer grass species that has obtained its widespread occurrence due to its great competitiveness under the circumstances described above. An ability to tolerate frequent fire is the most important factor, but *Imperata* also has a number of other biological characteristics which contribute to its success. These include rapid spreading habit, drought resistance, allelopathy, and adaptability to a wide range of environments.

For the most part, *Imperata* is considered as a problem weed with significant negative impacts on agriculture and forestry. It is ranked among the ten worst weeds globally (Holm *et al.* 1977). At the same time, it is widely known that the grass has several important uses for the communities living near the *Imperata* fields (cf. Potter 1995).

Imperata cylindrica is a perennial grass with a height ranging from 50 to 150 cm (Hafliger and Scholz 1980, cited by Turvey 1994). It is a "root grass" with a dense mat of underground stems or *rhizomes*, forming an extensive network 15-40[5] cm below the soil surface (Van So 1995; Potter 1995; Banerjee 1995). The rhizomes have a great productivity and spread rapidly. They are capable of remaining dormant for an extensive period and provide a reservoir of nutrients and water for the plant (Terry *et al.* 1995, Van So 1995,

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[4] The genus *Imperata* is divided into two sub-genera, *Imperata* and *Eripogon*. *Imperata cylindrica*, the only species in the *Imperata* sub-genera, consists of five varieties: *major, africana, europea, condensata* and *latifolia*. In Indonesia, *major* is the predominant variety (Tjitrosoedirdjo 1993). In the following, the terms *Imperata*, *Imperata cylindrica* and *alang-alang* will be used for the same species, namely *Imperata cylindrica* var. *major*.

[5] Terry *et al.* (1995) reports that the rhizomes are concentrated in the upper 20 cm of the soil (based on previous findings of Soerjani (1970) and Tjitrosemito (1991), cited by Terry *et al.* (1995))

Turvey 1994). This gives *Imperata* a high tolerance towards drought and fire.

The regenerative capacity of the rhizomes increases with age (Ayeni and Duke 1985, cited by Terry *et al.* 1995). The extensive occurrence of endomychorriza gives the plant another competitive advantage by increasing the availability of phosphate[6] (Terry *et al.* 1995). *Imperata* has an allelopathic effect through the release of toxic substances, mainly from the rhizomes, which delay germination and inhibit growth of other plants (Eussen *et al.* 1976; Tjitrosoedirdjo 1993).

Over longer distances, *Imperata* spreads by seeds. Seed productivity is large and the seeds spread easily. The effectiveness of regeneration by seeds is disputed. Santiago (1965), cited by Terry *et al.* (1995) reports that seeds can germinate rapidly and retain viability for one year, while Ivens (1983), cited by Banerjee (1995), reports that seed viability is low and that *Imperata* has a slow seedling growth at the outset.

Imperata adapts easily to different conditions in climate, topography and soils (cf. Van So 1995; Turvey 1994; Terry *et al.* 1995). *Imperata* is a C_4 plant, which means that it utilises high light intensities effectively while it at the same time cannot withstand prolonged shade (Banerjee 1995, Terry *et al.* 1995). The grass does not tolerate indundated soils (Turvey 1994). *Imperata* is likely to be outcompeted by other grasses when grasslands are subject to heavy grazing (Dove 1986, Banerjee 1995).

Generally, a dry season is required for the existence of grasslands. It is reported that *Imperata* is not a significant problem in the province of Sarawak, Malaysia, because continuous rain throughout the year reduces the prevalence of fire (Shim 1993, cited by Potter 1995).

In humid climates, *Imperata* forms single stands when fire is frequent. At higher altitudes with more seasonal climates *Imperata* is commonly associated with other grasses and herbaceous species such as *Themada gigantea, Sorghum serratum* and *Arrundinella setosa* (Blasco 1983). Banerjee (1995) notes that *Imperata* may be replaced by *Arundo madagascarenas* at elevations above 700 metres altitude. The competitiveness of trees to *Imperata* differs among species (Turvey 1994).

Fire prevention is a prerequisite for permanent eradication of *Imperata*. Other means of controlling *Imperata* include herbicides, mechanical cultivation (hoeing and ploughing)[7], pressing, shading with trees, and long fallow periods[8] (Turvey 1994). There exists a large amount of literature dealing with the technical aspects of rehabilitation of *Imperata* grasslands. Kuusipalo and Hadi (1995) conclude that reclamation of grasslands is

[6] Potter (1987) observed that the phosphorus content of the topsoil were much lower in grasslands than in nearby forests and scrublands.
[7] According to Dove (1986), it is well documented that *Imperata* can be readily tilled by hoe or plough. The author observed the expression “Hoed once, it is gone” (*Pacul sekali, habis)* among transmigrants, in sharp contrast to the view of the transmigration officials.
[8] See *e.g.* following authors for a discussion of different strategies for *Imperata* control: Drilling (1995), Terry *et al.* (1995), and Akobundu and Anoka (1995).

technically relatively simple, provided that the required investment for the use of effective establishment methods is done, and intensive fire protection during the establishment phase is taken care of. Banerjee (1995) notes that *Imperata* is most vulnerable to control measures at the end of the dry season, before it can replenish its carbohydrate reserve with new growth. Mechanical control should be at least 30 cm deep (Banerjee *op.cit.*). Because many of above-mentioned techniques require capital investments, it is likely to be a large difference between rich and poor farmers in the ability to control *Imperata*.

2.1.3 Area covered by grasslands

Imperata grasslands are difficult to define as a single species mapping unit because they are commonly associated with other vegetation types and agricultural systems (Suharti *et al.* 1995; Blasco 1983). Soekardi *et al.* (1992) report that area coverage of *Imperata* grasslands in Indonesia is about 8.6 million ha, or 4.5% of the total land area. All recent estimates of *Imperata* areas are however limited to massive 'sheet *alang-alang*' (cf. Table 2:1). This means that smaller areas, e.g. small patches in a mosaic with fallow croplands, will not be included. Therefore, it is reasonable to believe that the real area of grassland-covered lands is considerably higher. Estimates of 20 million ha (Vandenbeldt 1993) and 12 million ha (Banerjee 1995) have also been presented. It is unclear how much of these estimates refer to human-made grasslands. An estimate presented by Tjitrosoedirdjo (1993) showed that one third of the total grassland area of 10.2 million ha was found in Irian Jaya, which has a large area considered as natural climax savanna.

Table 2:1. *Imperata* grasslands classified by scale of measurement.

Type	Description
1. Mega Scale	Large scale sheet *Imperata* grasslands spanning district boundaries, patch size more than 10 000 ha.
2. Macro Scale	Inter village *Imperata* grasslands, span more than one community
3. Meso Scale	*Imperata* patches within a single community
4. Micro Scale	*Imperata* infested individual field

Source: Van Noordwijk et al. (1995b)

It is uncertain whether the area of *Imperata* grasslands in Indonesia is expanding today. Grassland formation due to deforestation is counteracted by conversion of grasslands to permanent farmlands and forest plantations. The forces behind conversion of grasslands to other land types include governmentally sponsored settlements (transmigration), plantation establishment programs, and spontaneous settlement of farming communities. Factors determining contraction or expansion include (1) Land availability, (2) Population growth, (3) Timber prices, (4) Infrastructure condition, (5) Capital availability for investments, (6) Access to technology, and (7) Other socio-economic factors. A decrease in the area of grasslands through farmers' efforts is most likely where land is scarce and market links are good (Van Noordwijk *et al.* 1995b). Conversion of grasslands to other uses by farmers has been documented in Java, Sumatra and Kalimantan (Van Noordwijk *et al. op.cit.*). In areas with high population density, such as Java, pressure on lands for small farming has resulted in a gradual intensification of cultivation and in turn eradication of

Imperata (Potter 1995).
Many efforts are currently undertaken to establish plantations on grasslands, implemented by private or state-owned forestry companies and financially assisted by the reforestation fund (Turvey 1994). The success of plantation establishment on grasslands has been limited so far, as a result of social and technical constraints (see section 2.5.1). It is a national goal for Indonesia to become one of the world's top ten paper producers, which would imply that 10% of Indonesia's land area will be converted to plantations (WAHLI and YLBHI 1992).

2.1.4 Land use rights

Generally, there exists informal land allocation between the members of the communities living in or nearby the *Imperata* grasslands. This happens even if the lands are newly converted from closed forests (Turvey 1994). It is difficult to find large blocks of grassland areas that are not receiving some use or being claimed (Van Noordwijk *et al.* 1995b). The traditional land rights (*hukum adat*) in Indonesia are of three main types (Ministry of Forestry and FAO 1990):

1. Rights on specific trees, both tended and growing wild, and other forest resources (e.g. hunting and fishing rights)
2. Use rights in land utilised currently or in the past for long-fallow rotational (shifting) cultivation, and
3. Communal "right of disposal" (*hak ulayat*) over land held as homeland and property of a particular group or community. This is the strongest traditional right to land in Indonesia.

Despite general statements mentioned in the laws which recognise traditional rights of local people, forestry policy has broadly speaking not yet taken any of the positive aspects of indigenous resource management regimes into consideration. The official view on communal rights (*hak ulayat*) is that they have faded away and are no longer relevant to Indonesian land law (Evers 1995). Only customary (*adat*) land rights which were formally established before the Basic Agrarian Law was declared in 1960, are accepted by the Government. Both communal and individual rights are recognised, but there is an emphasis on the latter. The main problem is that traditional customary land rights have been inherited without any formal documentation. Without evidence and registered rights, the lands are considered as State land.

Land rights in shifting cultivation systems are often more loosely defined than for communal rights (*hak ulayat*), but the rights are still established and recognised within the communities. In Kalimantan, land claims are sometimes confirmed by growing rattan or fruit trees in the fields. However, as the official policy is to replace shifting cultivation with other practices, these rights are not accepted by the Government (Ministry and Forestry and FAO 1990, Evers 1995).

For *Imperata* grasslands, even large blocks of grasslands are claimed by the local communities. Van Noordwijk *et al.* (1995a) report that in one case in Kalimantan, a grassland area of 300 000 ha believed to be 'empty' was designated for an industrial timber plantation, but after the project started it was found that the entire block was claimed and managed by local villagers. A similar situation is found in South Sumatra (Cossalter pers.comm.). Such overlapping claims represent a major problem for reforestation of grasslands, because they "create tenure insecurity for local people and forestry companies [and] undermine incentives for sustainable resource management on both sides" (Van Noordwijk *et al. op.cit.*).

Compensation is sometimes paid for *ulayat* rights, and for standing trees. Compensation is not for the loss of ownership (which does not exist legally), but for the loss of (future) right to dispose. The payment is not sanctioned by any law, but is a matter of practical necessity, in view of the potential costs of hostile relations with the surrounding community (Ministry of Forestry and FAO 1990).

For the forests which are part of the protected area system (see Appendix 1), no specific guidelines or legal basis on zoning, buffer zones etc., as well as on their integration with development in surrounding areas have been developed. The lack of implementing regulations, particularly of the Law on the Conservation of Living Natural Resources and Their Ecosystems (Law No.5 of 1990), has rendered the work at ground level difficult. Particularly the issue of participation of local communities, traditional resource rights and the involvement of the private sector in the management of conservation areas.

At present, local communities do not participate in planning and mangement of protected areas. Community participation is specifically called for by Law No. 5, 1990 (see above), article 37. However, in the absence of implementing regulations no guidance (e.g. methodology) is provided to institutionalise the involvement of local people. There seems to be considerable ambiguity in people's rights to utilise forest resources in and around protected areas. In essence, no provision has been made by law for indigenous resource management and forest utilisation. The only category of protected areas for which traditional community rights have been explicitly mentioned in Law No.5/1990 (Article 32) is national parks, where the so-called "*zona pemanfaatan tradisional*" or traditional use zone is feasible as a part of the "*zona lain*".

In areas under legal concession agreements, the concessionaires are supposed to reforest their own concession lands after logging. Experience shows that they rarely do so as long as there are other rainforest concession areas they could move to and log. In some cases when concessionaires have replanted the grasslands, the local population often put fire to the plantations in protest against the nationalisation or company occupation of what they consider as their land.

2.2 GRASSLANDS AS PROBLEM AREAS: A CRITICAL REVIEW

The dominating view on *Imperata* (*alang-alang*) grasslands is that they are degraded problem areas or 'critical lands' representing a constraint to development (cf. Turvey 1994, Potter 1995, Dove 1986, Hurst 1990): "At its present state, *alang-alang* is useless wasteland, with value neither for farmers nor cattle-keepers." (Kuusipalo 1995b, p.27). On the other hand, many authors claim that the fact that grasslands generally have a low productivity does not necessarily mean that the lands are degraded from a social point of view. Grasslands produce a number of goods and services that are locally very important (see e.g. Dove 1986, Banerjee 1995, Potter 1995). For a historical review of the attitudes toward *Imperata* grasslands, see e.g. Potter (*op.cit.*). This chapter gives a brief discussion of the "wasteland" attitude towards *Imperata* grasslands, including some of the strategies that have been suggested for rehabilitation.

Programs for rehabilitation of *Imperata* grasslands were started in the 1960s, but large-scale efforts were not implemented until 1976 (Tjitrosoedirdjo 1993). The discussion below will include both current and potential grasslands. The term 'potential grasslands' are used to describe successional stages, commonly referred to as *semak belukar* or only *belukar*[9], which contains some *alang-alang*, which will spread if lands are reopened by cutting and/or burning (Eussen and Wirjahardja 1973).

2.2.1 Environmental values and productivity

DN/MSE (1994) assessed grasslands according to 9 criteria for environmental soundness (Table 2:2). For each of the criteria a relative value from 1 (lowest) to 6 (highest) was given. As seen in Table 2:2, grasslands were given the lowest values (1-2) for all criteria except use of chemicals and erosion (value 6 for both). Consequently, permanent grasslands were considered as an unacceptable management strategy concerning environmental soundness. The largest size classes of *Imperata* (cf. Table 2:1) are likely to have the lowest environmental values. Of the development strategies with relevance to grasslands, natural regeneration with establishment of secondary vegetation scored highest. Mixed plantations, as well as various monoculture plantations, were judged as acceptable rehabilitation strategies for *Imperata* grasslands.

Table 2:2. Criteria for evaluation of environmental soundness and evaluation of grasslands.

Criterion	Evaluation of grasslands (1=low, 6=high)
1. Occurrence and stability of a tree cover	1
2. Canopy structure and height in mature stands	1
3. Species composition of tree layer	1
4. Forest biodiversity	1
5. Erosion	6
6. Hydrology	1
7. Soil properties, nutrient cycling and sustainability of timber production	1
8. Effect on local climate	2
9. Actual and probable use of chemicals	6

Source: DN/MSE (1994)

Productivity will generally depend on the original vegetation form and the time period the grasslands have been sustained. Frequent fire adversely affects the environmental value by killing seeds and young seedlings, hampering establishment of trees, and removing soil

[9] *semak* = annual weeds and *belukar* = shrubs (van Noordwijk *et al.* 1995b). Eussen and Wirjahardja (1973) uses the term *belukar* for all successional stages from grasslands to secondary forest.

organic matter. The loss of soil organic matter lowers the nutrient content, soil moisture,

biological activity and species diversity, and degrades the soil physical properties through loss of structure, increased compaction and reduced water infiltration (Turvey 1994:12). It is clear that *Imperata cylindrica* is a menace to crops, and the species has been found to reduce yields in cultivated plots and tree plantations with e.g. rubber and *Tectona* (Banerjee 1995, Van Noordwijk *et al.* 1995a). Moreover, experiments in Africa demonstrated that *Imperata* caused 70-80% yield losses in maize, sorghum and cassava plots (Akobundu and Anoka 1995). *Imperata* can however be beneficial as fallow crop for erosion control, and possibly contribute to build up of VA mychorrizal inoculum (Van Noordwijk *et al.* 1995a).

Soil fertility. Even though the occurrence of *Imperata* is not necessarily an indicator of low soil fertility (ICRAF 1995), lands subject to repeated shifting cultivation and frequent burning will over time experience a degradation of soil properties (Turvey 1994, Sangalang 1995, Potter 1987). The effects are likely to be more severe the longer fire has been used to sustain the grasslands. For top-soil studies, Potter (1987) found a general trend of a lower pH level as well as lower levels of organic carbon, nitrogen, phosphorus and total exchangeable bases in grassland tops than in forest- and scrub-covered soils around.

Soil carbon. Under constant inputs, soil carbon content will tend towards an equilibrium level. When forest is converted to grasslands, a significant amount of carbon is released to the atmosphere. The equilibrium level is lowered, both because grasslands have lower density of above-ground vegetation than forests, and as a result of frequent burning. Thus, it is assumed that appropriate management systems could increase the potential for carbon sequestration and storage in areas currently under grasslands (see e.g. DN/MSE 1994, Young 1989, Fisher *et al.* 1994, Bolin 1986). This issue is also discussed in chapter 2.3 below.

Absence of a tree cover means a loss of the wealth of goods and services which trees provide: Trees improve and maintain soil fertility and soil physical properties, conserve watersheds, give windbreaks and shade, and provide habitats for fauna and flora. In addition, trees produces a number of economic and non-economic goods such as timber, fuelwood, animal fodder, building material, fruits and medicines. (Turvey 1994, Young 1989).

Biodiversity is low in grasslands, as the habitats are open, hot and simple, containing few but widespread secondary species with broad niches and great reproductive potential (Whitten *et al.* 1987; DN/MSE 1994). For plants, frequent fires will lead to a progressive lowering of species diversity by killing young shoots and seeds buried in the soils of domesticated as well as wild plants (cf. Kuusipalo 1995a). Generally, both soil biological activity and species diversity are significantly reduced (Turvey 1994, Chinene and Dynoodt 1994). A long term study by Harrison (1968), cited by Whitten *et al.* (1987), demonstrated that the total number of non-flying mammal species were reduced from about 30 species in primary forest to some 10 species in grasslands, all of which were introduced species.

Erosion. Land conversion of forest to grassland is likely to cause substantial erosion, both through soil exposure and building of logging roads. Erosion in permanent grasslands is however low due to the dense growth and the extensive root system of *Imperata* (cf. DN/MSE 1994). Young (1989) states that ground cover is far more important for erosion control than tree canopy. If ground cover is lost, a high tree canopy will increase soil erosion compared to open grasslands. Raindrops reach over 95% of their terminal velocity in a free-fall distance of 8m, and drop size may increase through accumulation on leaf surfaces. A forest with several canopy layers will thus result in lower erosivity (Young *op.cit.*). Van Noordwijk *et al.* (1995a) suggests that maintaining strips of *Imperata* in cropping areas could be a more cost-effective way of preventing erosion than using labour to introduce new grass species or trees. Erosion is likely to increase if grasslands are used intensively as pastures.

Hydrology and climate. Hydrology will be affected as forest is converted to open grassland. This is expected to increase surface water flow, decrease soil moisture, and, consequently, lower groundwater recharge. As a result, grasslands will have a low value for watershed conservation as the water-holding capacity is significantly reduced. The low vegetation cover in grasslands will likely affect both rainfall and temperature. Rainfall is expected to decrease, while temperature variations during the day may increase (DN / MSE 1994). Increases in soil and air temperatures during daytimes will have particularly negative effects on soil structure, soil biodiversity and biomass production (DN / MSE 1994).

The *use of chemicals* is low in grasslands. Rehabilitation efforts may on the other hand involve the use of pesticides and chemical fertilisers (site preparation for planting, weed and pest control, etc.), and thus give negative environmental effects.

2.2.2 Socio-economic value

The authorities generally view *Imperata* grasslands as degraded lands (see e.g. Dove 1986:175, Potter 1995). The official strategy has been to rehabilitate the grasslands by tree planting and / or planting of so-called "superior" grasses[10]. The perceptions of local communities towards *Imperata* have been observed to show great variations, from those using *Imperata* as an integrated part of the agricultural system, to those viewing *Imperata* as "an enemy" (Dove 1986, Potter 1987, 1995).

The main uses of *Imperata* grasslands are:

- Animal fodder. Either cattle graze on the young shoots, or *Imperata* is converted into cattle fodder by protein enrichment. Grazing occurs mainly when *Imperata* is in the early stages of development (Soewardi *et al.* 1974), i.e. shortly after burning. With advancing maturity, the nutritive value of the grass gets lower. It is often necessary to supplement with other forages, salt and minerals (Calub *et al.* 1995, Turvey 1994).
- Low-quality paper, although this depends on processing and technological facilities (Turvey 1994).
- Roof thatch. The market value of roof thatch may in some cases be high. In areas where cultivation is too intensive to allow for any growth of grasses during fallow periods, it has been observed that land has been taken out of food production to grow *Imperata* on it (see Dove 1986:166, Turvey 1994).

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[10] According to Dove (1986:176), experience has shown that the "superior" grasses are either not more nutritious than *Imperata*, or they require so many more capital and labour inputs that they do not offer any net benefit to the villagers.

- Ritual usage (Dove 1986).
- Hunting. Dove (1986) reports that fire is used to hunt *menjangan* (rusa deer, *Cervus timorensis*). The main purposes of fire are to eliminate brush before the hunt, and to stimulate growth of new grass to attract the browsing deer to the area. Fire is also used during the hunting to flush the deer from cover or drive them in a certain direction.
- Grasslands also have a social function as landless people often settle on these lands when migrating from Java to the outer islands. The pressure on remaining forests (as well as the political pressure) may be lower than if these groups were forced to settle and find jobs elsewhere.

The total value of the use of grasslands is low, as the use is not very intensive (cf. Turvey 1994:12; Van Noordwijk *et al.* 1995b). Furthermore, a large proportion of the use value of grasslands originate from non-market goods and services. However, the importance of grasslands for many local communities is often underlined (e.g. Potter 1995; Minister of Forestry 1995:4; Turvey 1994; Van Noordwijk *et al.* 1995), although, as mentioned above, the perceptions vary greatly (Dove 1986, Potter 1987). Although *Imperata* grasslands may be located in remote areas far away from roads and markets, and have low population density, even mega-scale sheet grasslands are populated and the use is often underestimated (Van Noordwijk *et al.* 1995b, Potter 1995). Local perceptions will be crucial for the long term success of reforestation efforts. It is clear that recognising local, informal land tenure arrangements is necessary if serious conflicts are to be avoided.

There is a general consensus among scientists that the social aspects related to reforestation of grassland, especially those dealing with local needs and priorities, have been neglected. It is clear that grassland rehabilitation cannot succeed unless local communities are involved in the process of developing an appropriate management system. National objectives and the local needs should be integrated in the same management strategy. The users must be given incentives for sound management practices; whether they are local people, private enterprises or government institutions.

The ability of small-scale farmers to cultivate grasslands depends to a large extent on access to animals or tractors for tillage. Opening of grasslands only by using hoe is very costly. Potter (1987, 1995) reports that only in cases with serious land scarcity the grasslands are tilled manually. Dove (1986) found that only those farmers who owned cattle themselves or could afford to rent cattle or hire Javanese ploughing teams were able to open lands dominated by *Imperata*. Other farmers left the lands to fallow when *Imperata* invaded, and did not open them until *Chromolaena* and/or shrubs and trees had replaced *Imperata*. In response to these difficulties, new settlers (transmigrants) in grasslands have been observed to adapt cropping practices which enable 2 or 3 successive harvests per year with only one primary tillage operation (Suryatna and McIntosh 1980).

2.2.3 Concluding remark

Imperata grasslands include a variety of land types where the total value and the local value vary greatly. Any strategy for rehabilitation should primarily be seen in relation to those communities living adjacent to the grasslands. Even if physical and financial characteristics may suit a definition of degraded lands, the lands are not necessarily degraded from the local communities' point of view. Planning of reforestation should include an analysis of gross value and how different community levels (local, national, global) and groups (rich vs. poor farmers) are affected. Even if the total value is increased through reforestation, there may be groups losing sources of income and subsistence.

2.3 GRASSLANDS AND CLIMATE CHANGE

Deforestation and land use conversion currently contribute about 20% of the global emissions of carbon dioxide (CO_2), the most important of the anthropogenically enhanced GHGs[11] (IPCC 1994). In Indonesia, around 78% of the estimated CO_2 emissions and roughly 10% of the methane (CH_4) emissions stem from these processes (Table 2:3). Carbon is released through biomass burning and decay and oxidation in exposed soils. The long term effects on the carbon cycle depend on the ability of vegetation regrowth to capture the released carbon. As mentioned above, a large area of converted lands have developed into more or less permanent grasslands. This chapter investigates how management of grasslands affects carbon flux and storage. It is also discussed how grassland management could affect other terrestrial carbon sources and sinks, such as natural forests and combustion of fossil fuels (cf. Sedjo and Ley 1995).

2.3.1 Climate change issues in Indonesia

The latest IPCC predictions for global mean surface temperature increases are between 1 and 3.5°C by the year 2100. Regional temperature changes could differ substantially from the global mean. Temperature increases are expected to be largest at high latitudes (IPCC 1995). Considerable changes in precipitation patterns are also projected. Earlier analyses have suggested that the South Asian monsoon will strengthen due to global warming. Recent model predictions indicate that the cooling effect of aerosols would be significant, and may even result in a weaker monsoon in some areas (Mudur 1995). Generally, a global warming will lead to a more vigorous hydrological cycle, and several models indicate an increase in precipitation intensity and more extreme rainfall events (IPCC 1995). Globally, sea level is expected to rise in the range of 15 to 95 cm by 2100, depending on emission scenario, assumed climate sensitivity to warming and ice melting sensitivity. The "best estimate" is a sea level rise of about 50 cm from the present to 2100. The main causes for sea level rise will be thermal expansion and melting of glaciers. The sea level is expected to

[11] Since pre-industrial time, CO_2 has contributed about 64% of the radiative forcing due to the human-induced increase in well-mixed GHGs (IPCC 1994). *Radiative forcing* describes changes in the earths's energy balance and is thus a simple measure of the importance of a potential climate change mechanism.

continue to rise at a similar rate for several centuries after 2100, even if concentrations of GHGs in the atmosphere were stabilised by that time, and would continue to do so even beyond the time of stabilisation of global mean temperature (IPCC *op.cit.*).

Table 2:3. Emissions of GHGs in Indonesia, by sector.

Sector	CO_2 (Ktons-C)	CO (Ktons-C)	CH_4 (Ktons)	N_2O (Ktons)
Energy	32 889	905	408	6
Industry (Cement)	1 665	NA	NA	NA
Agriculture	NA	NA	4 775	NA
Forestry/land use conversion	124 260	4 578	610	NA
Land fills	NA	NA	511	NA
TOTAL	158 814	5 483	6 304	6

Source: ADB (1994)
NA=Not Applicable

Potential impacts of climate change in Indonesia are discussed by ADB (1994) and Parry *et al.* (1992). Natural resources and activities located at the coast will likely be most vulnerable. Freshwater supply and hydropower generation could also be severely affected. Possible indirect socio-economic impacts, such as health effects, should receive careful attention as well. Generally, the poorest parts of the society will be most vulnerable and will have the least resources to adapt to the changes.

Changes in climatic conditions would affect natural ecosystems as well as domesticated crop and livestock systems. Both structure and function of ecosystems are expected to change as species respond different to changes in physical conditions. Adaptation to climatic change will depend on several species characteristics. Characteristics that will be favourable are high mobility, large populations, high dispersal rates, and ability to colonise a wide range of habitats. Endemic species and species living at the limit of their environmental range would hence be particularly threatened. The impacts on fisheries would depend on how fish populations would be able to adapt to changes, and the ability of fishermen to move in response to shifts in fish stocks.

It has been suggested that the increase in atmospheric CO_2 levels will be retarded by an increase in plant growth, the so-called ‘fertilisation effect’. This effect is highly uncertain, especially for natural ecosystems. There are great interspecific differences in the growth response to increased CO_2 levels, and nutrient availability may be a more limiting factor for plant growth than CO_2 (cf. IPCC 1994).

Changes in climate could mean that present crop and livestock genetic resources become less appropriate to the environmental conditions, which in turn will affect farmer’s income and food basis. Model predictions for a doubling of atmospheric CO_2 levels (‘2 x CO_2’) suggest severe impacts on yields of major food crops such as rice, soybean and maize (Parry *et al.* 1992). New technologies and improved crop varieties could mitigate some of these effects. It is likely that the poorest farmers will have the least opportunities to invest in new varieties.

Indonesia is among the most vulnerable countries regarding effects of sea level rise (Parry 1990, UNEP / Delft Hydraulics 1989). Indonesia's coastline is 80 000 km long, the longest of any country in the world. Costs of improving coastal defences against a sea-level rise of 20 cm have been estimated to be 4 million US$ per km (UNEP 1993). Loss of land for settlement and agriculture, and salt intrusion in freshwater aquifers represents serious threats to the 110 million people (of a total population of 179 millions) in Indonesia living in coastal areas (ADB 1994). Sea level rise would come in addition to local subsidence due to heavy constructions and excessive water withdrawal from aquifers, especially in urban centres, and tectonic movements. In Jakarta, a conservative estimate for relative sea level rise due to these factors (including a climate change induced sea level rise of only 15 cm) is 2.0 metres by the year 2070 (ADB 1994).

Indonesia signed the Framework Convention on Climate Change (UNFCCC) the 5th of June 1992. On August 1st of 1994, the President of the Republic of Indonesia approved an Act of Ratification of U.N. Framework Convention on Climate Change Number: 6 / 1994 (*Undang-undang tentang Pengesahan Konvensi Kerangka Kerja PBB tentang Perubahan Iklim Nomor: 6/1994*). On August 23rd of 1994, the document of ratification was deposited to the Secretary General of U.N. At that time Indonesia was included legally as a Party of the Conference which imply that Indonesia will be bound to the rights and obligations stipulated in the Convention. One of the obligations is to communicate actions taken to mitigate climate change.

The complexity of the climate change issue and the uncertainties involved imply that one is likely to focus primarily on 'no regret' options. Further, it is expected that the main efforts will be on adaptation to climate change rather than on decreasing emissions, even though the seriousness of the problem recommends a risk-averse approach. In case of Indonesia, two points should be emphasised:

1. Indonesia is very vulnerable to the effects of climate change, and has limited institutional and economic ability to adapt to changes or implement mitigation measures. The high discount rate used is an important constraint for investing now for climate change mitigation ("discount barrier"), of which potential benefits would not be apparent in maybe 50 years. Additionally the problems of valuing the climate effects in economic terms arise. The issue of cost and benefit distribution also need consideration: While climate change mitigation actions carry local investment costs, the benefits will accrue and be distributed globally.
2. According to two greenhouse index rankings presented by WRI (1992), the GHG emissions from Indonesia rank as number 10 and number 13 globally. Although the total emissions are significant, per capita emissions are low, and a large part of emissions from land use changes stem from 'life-sustaining activities' such as slash-and-burn cultivation. Reductions in emissions may thus on short term reduce the welfare of poor subsistence farmers or put restrictions on national development goals. Reduction of GHG emissions in Indonesia will have to be considered as a part of a global co-operative effort. The primary focus should be on options with the least conflicts between climate change response strategies and general development aims.

One of the realistic measures that could be taken by a country like Indonesia is to enhance the role of tropical forests as a sink of carbon dioxide. Sustainable forest management is the only way to increase the role of natural forests in an environmentally sound development, either nationally or globally. The increasing demand for forest products could not be met by the natural forests alone, as this would lead to overexploitation of the resources. One of the ways of increasing the supply is reforestation of degraded lands. In the following, reforestation of *Imperata* grasslands is discussed in relation to carbon sequestration, environmental goods and services, and social profitability.

2.3.2 Grasslands and the carbon cycle

In the long term, the most important issue is whether the carbon storage capacity of the lands is reduced through the conversion from forest to grassland. In short term, it is important to know which management system gives the most efficient sequestration of carbon. Sedjo and Ley (1995) suggest that carbon sequestration by afforestation should be considered as a temporary measure, i.e. to mitigate climate change until actions are taken to reduce the GHG emissions to an acceptable level. In this situation, the most effective would be to establish vegetation with rapid growth and high CO_2 fixation rate (Schroeder and Ladd 1991).

The net carbon releases from land conversion depends on the rate of conversion, total area converted, carbon density per ha in the forest, the fate of the converted lands and the ecosystem processes that control the carbon fluxes (cf. Watson *et al.* 1992). Conversion of natural forests involve biomass burning and soil exposure. It is estimated that 12.5 million tons of carbon are released annually from biomass burning in Indonesia, in addition to 7.8 million tons from exposed soils[12] (ADB 1994). Burning releases carbon mainly as carbon dioxide (CO_2), in addition to methane (CH_4), carbon monoxide (CO) and small amounts of elemental carbon (charcoal). Carbon monoxide (CO) is not a greenhouse gas *per se*, but has indirect effects through atmospheric chemistry contributing to an enhanced greenhouse effect. Elemental carbon could be considered as permanently sequestered, as it is an extremely resistant form. For African savanna fires, Justice *et al.* (1994) suggest that the long term global effect would be to remove carbon from the biosphere and atmosphere through formation of such elemental carbon. The significance of this process is however uncertain (see also Bolin 1986; Goudriaan 1995).

Even though CO_2 accounts for the largest share of the carbon release from land conversion, emissions of methane (CH_4) is also important. Methane has a radiative effect per molecule 21 times the effect of CO_2, as well as climatically important chemical feedbacks in the atmosphere. Globally, biomass burning accounts for around 40 (20-80) Tg[13] of the 375 Tg

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[12] When using an annual deforestation rate of 1,2 million ha. Corresponding to 45.7 and 28.6 tons of CO_2, respectively.
[13] $Tg = 10^{12}$ g

annual anthropogenic CH_4 emissions. Apart from atmospheric removal, a significant sink of CH_4 is microbial uptake in soils, about 15-45 Tg/year (IPCC 1995). For temperate soils, disturbance (cultivation and fertilising) has shown to reduce the effectiveness of the soil sink (IPCC *op.cit.*). In Indonesia, forested upland soils are assumed to be a sink of methane, at least in the dry season (Van Noordwijk *et al.* 1995b). The authors *op.cit.* suggest that this sink, which is important for offsetting methane emissions from wetland rice fields, could be significantly reduced by forest conversion.

Figure 2:1. Schematic diagrams of carbon content of living vegetation (upper graph) and soils following harvest in forests transferred into farm land which later is abandoned. *Source: Moore et al. (1981), cited by Bolin (1986).*

Vegetation removal leaves the land vulnerable to soil erosion. Loss of organic matter lowers the content of carbon, in addition to reducing fertility and damaging soil physical properties, including the water holding capacity. Cultivation of forest soils will increase CO_2 emissions due to increased decomposition and oxidation of carbon (Schimel *et al.* 1995). The magnitude of the potential carbon sequestration over time will vary according to the vegetation system, the physical conditions on the site, and the fate of the products. Some of the important factors are:

- Amount of carbon stored in soils: Soil carbon storage is generally large in soils with high fertility, neutral pH, low temperature, high moisture content and balanced exposure (cf. Dixon *et al.* 1994a; Chinene and Dynoodt 1994). Organic carbon is assumed to make up 58% of the soil organic matter (Young 1989).
- Amount of carbon stored in above-ground biomass: Generally, carbon stock increases with increasing biomass, which in turn is determined by the soil fertility on the site (cf.

Turvey 1994:12). In contrast to mid- and high-latitude forests, tropical forests hold more carbon in vegetation than in soils (Houghton 1991). Organic carbon makes up around 50% of the dry-matter plant material (Young 1989; Nye and Greenland 1960).

- Carbon sequestration will be higher the longer the durability of the forest products. Dixon *et al.* (1994a) regard carbon storage in durable wood products to be an insignificant component of the global total.
- Substitution of fuelwood for fossil fuels will reduce net CO_2 emissions, provided that CO_2 from fuelwood burning is captured in forest regrowth.
- Substitution of forest products for other materials that give CO_2 emissions when produced (e.g. concrete) will lower the net CO_2 emissions.
- Trees are used for shading and windbreaks, which in turn reduces energy usage (Sedjo and Ley 1995).
- Impacts on natural forests will be of major importance, as standing forests represents a large carbon storage.
- Climate change may have an impact on carbon storage potential by affecting biomass productivity and decomposition rates.

It seems clear that carbon density is considerably reduced when forests are converted to *Imperata* grasslands. Conversion from forest to grassland will lower the carbon stock by reducing above ground biomass (absence of tree cover), while continued and frequent fire will lead to reductions in soil carbon content. Estimates of the magnitude of this change show large variations. Some of the variations may be explained by local differences as mentioned above. Another factor is that the two main approaches for estimating carbon stocks, which are (a) converting volumes of biomass to carbon, and (b) direct weighing of biomass, may give different results (Houghton 1991, 1995).

Primary tropical forests are considered to be in a steady state concerning CO_2 releases and uptake, and thus holding a permanent carbon stock[14]. The same will hold true for all vegetation systems, although the equilibrium level varies depending on management and vegetation density. The carbon density of natural forests in Indonesia is by Trexler and Haugen (1995) estimated to be between 125 tC/ha (low estimate) and 225 tC/ha (high estimate), while Iverson *et al.* (1993) report that forests in Indonesia and Malaysia may hold more than 250 tC/ha. Other estimates are 283 tC/ha for tropical wet and moist forest and 125 tC/ha for tropical dry forest (Olson *et al.* 1983 and Post *et al.* 1982, cited by Houghton 1993). The carbon stock in primary forests in Sabah, Malaysia, is estimated at 348 tC/ha (Putz and Pinard 1993). In contrast to forests at mid- and high latitudes, mature tropical forests hold more carbon in vegetation than in soils (Houghton 1993, Swischer 1991).

When forests are cleared and converted into grasslands, the lands may lose between 90 and 100% of the initial carbon (C) in vegetation and 10-25% of soil carbon (Houghton *op.cit.*). Most of the carbon in grasslands is stored in soils (cf. Parton *et al.* 1995). According to Brown and Lugo (1988), cited by Swischer (1991), conversion of forests to pasture lands reduces the soil carbon content by 25%, and only 5 tC/ha will remain in biomass.

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[14] A recent study from the Brazilian Amazon (Grace *et al.* 1995), suggests however that carbon uptake and release in undisturbed tropical forests may vary considerably from one year to another.

Kuusipalo (1995a) estimates that *Imperata* grasslands contain around 5tC/ha in above ground vegetation and 5 tC/ha in roots, while soil humus will be approximately the same as forests the first years after conversion (65 tC/ha), and then diminish gradually over time if the lands are burned regularly. A recent study by ICRAF (Van Noordwijk *et al.* 1995b) found carbon stocks in *Imperata* grasslands of around 2 tC/ha above ground and 50-60 tC/ha below ground. For African savannas, Justice *et al.* (1994) state that as much as three-quarters of the carbon is stored in the soil organic matter. Faeth *et al.* (1994) report that forests and forest soils store 20 to 100 times more carbon per ha than pastures or croplands do. Young (1989) states that soil humus would be reduced to the half after conversion.

Fisher *et al.* (1994) suggest that productivity in grasslands may be considerably larger than these estimates. The authors found an initial carbon storage in South American savannas of around 190-200 tC/ha, which could be increased to roughly 230-270 tC/ha by introduction of deep rooted grasses. These results, i.e. the potential for pasture soils to act as carbon sinks, were however questioned by Davidson *et al.* (1995). The authors *op.cit.* also pointed out that introduction of exotic grasses, as in this example, could have deleterious ecological effects.

Fire affects the carbon cycle by reducing input of organic material as well as the above ground biomass. It also removes carbon from soil humus. If there is no regrowth to capture the released carbon, the carbon stock will decline, at least in the upper soil layers (Turvey 1994, Potter 1987). Jones *et al.* (1992), cited by Fisher *et al.* (1994), discussed the role of fire in determining whether native savannas become a net source or sink of carbon in the tropics (see also Justice *et al.* 1994). It is reasonable to believe that steady state carbon storage in grasslands is considerably lower with regular burning. Scholes and Hall (1994) estimate that the carbon stored in *savannas* probably would double if fires are excluded, and it would take about 50 years to reach a new steady state situation. Some of the carbon from incomplete biomass burning will however be returned to the soil as elemental carbon (charcoal) which is a resistant form of carbon (Bolin 1986, Justice *et al.* 1994).

Permanent cultivation with annual crops has probably a lower carbon storage potential than grasslands. This arises due to more biomass removal and soil disturbance, which produce higher decomposition and carbon emission rates. Reduced tillage and covering of the ground by plant residues (mulching) could reduce these losses significantly. Shifting cultivation and long fallow systems have generally higher above-ground biomass than annual cropping because of the tree component in the fallow period. At the same time soil carbon is conserved through organic material inputs and a low level of soil disturbance during the fallow period.

Trees play a major role for the carbon storage potential of lands. The tree component increases standing biomass while increasing inputs and reducing losses of organic matter. Soil decomposition is reduced by reduced temperature and exposure while soil moisture is increased. Thus, the carbon equilibrium level is increased, although carbon buildup takes more time than the release during the conversion process, particularly for soil carbon (cf. Figure 2:1) (Turvey 1994; Potter 1987).

Natural regeneration, plantations and agroforestry represent reforestation strategies where both above- and below ground carbon storage potential is expected to be considerably higher than that of regularly burned *Imperata* grasslands. It is assumed that regrowth after land clearing and burning of primary forest has a lower carbon storage potential than primary forest (Schimel *et al.* 1995, Bolin 1986). For plantations and agroforestry, the average carbon content over time will be determined by factors such as how much of the produced biomass is removed, the durability of products (e.g. fuelwood vs. furniture) and rotation length. Carbon sequestration rates are expected to be highest in plantations with fast-growing species, while secondary forests and agroforestry systems are considered to have the highest long-term carbon storage potential. These strategies are further elaborated in following sections.

The effect on natural forests should also be considered when choosing a strategy for grassland reforestation. Hall and House (1994) state that halting deforestation should have priority over all other options for CO_2-emission reductions. Plantations may reduce deforestation if they are able to supply timber that can replace timber from natural forests. The effect of plantations may also be opposite: Successful and profitable plantations may induce clearcutting of natural forests for establishment of more plantations (Turvey 1995). Further, if plantations are established on agricultural lands, they may force farmers to clear more forest land for cultivation. This is most likely where population density is high. This issue is also discussed below in chapter 2.5.1. A point that also has been raised is that reduced deforestation rates in one location could affect forest utilisation in other regions, which also should be taken into account when calculating the total carbon benefits (cf. Sedjo *et al.* 1995).

One hypothesis is that intensification of land use can reduce pressure on land and thus decrease deforestation rates. Several studies argue that agroforestry in this way could give opportunities for reducing carbon emissions. Unruh *et al.* (1993) consider agroforestry systems to have the greatest potential for halting deforestation, because they “may enhance agricultural productivity rather than compete with it”. The authors suggest that these secondary effects may be more important than the primary effect of carbon storage *per se*. Kuersten and Burschl (1993) claim that the additional carbon sequestration effect of agroforestry, including protection of natural forests, may amount to 20 times the quantity of the sequestered carbon of 60 tC/ha. In Peru it is estimated that 1 ha agroforestry could save 5-10 ha of tropical forests from clearing (Sanchez and Bandy 1992). An example from Thailand shows similar results (Dixon *et al.* 1993).

At the same time, experiences from Indonesia show that for conditions where the hypothesis do not apply, intensification may accelerate deforestation rather than reducing it (Tomich and van Noordwijk 1995). Successful systems may lead to an inflow of jobless people and in turn increase the pressure on the forest margins. Tomich and van Noordwijk (*op.cit.*: 6) outline three necessary conditions for the ‘intensification hypothesis’ to be valid: (1) Field level: the intensification techniques must be ecologically and agronomically sound, socially acceptable, and financially profitable for smallholders. (2) At the community level, there must be effective monitoring and enforcement of the boundaries of the forest that is to be saved from conversion to other uses. (3) At the benchmark/national level, attention must be given to reducing the broader forces that drive deforestation. In particular, an inflow of migrants driven by lack of economic opportunity elsewhere can swamp the effects of field level and community level interventions.

The potential impact of climate change on the carbon cycle is complex and much debated. *Global warming* would increase respiration and decomposition rates, thus increasing carbon releases. Recent studies using model predictions indicate that climate change would lead to reduced soil carbon storage in grasslands and savannas, by increasing respiration (Schimel *et al.* 1995, Parton *et al.* 1995). *Elevated CO_2 levels* could on the other hand increase CO_2 assimilation, and reduce water losses and respiration. As a result, grasslands could potentially become net sinks of carbon (Parton *et al.* 1994, 1995; Smith *et al.* 1992). Nutrients (phosphorus, potassium) are however often more limiting factors for growth than CO_2, and although a CO_2 stimulus may lead to better soil exploration (Goudriaan 1995), the significance of the so-called "CO_2 fertilisation effect" is still uncertain. For a recent review on this topic, see e.g. Culotta (1995).

2.4 THE RATIONALE FOR CHOOSING REFORESTATION OF GRASSLANDS AS AN OPTION FOR CLIMATE CHANGE MITIGATION

2.4.1 Social profitability and cost-benefit analyses

The term *social profitability* can be defined as the society's surplus, whether positive or negative, which results from a given project. This implies that all effects of a project which directly or indirectly affect human welfare should be included. In contrast to private profitability, assessments of social profitability require that factors that are not reflected in the market are taken into account. The most important are *externalities*[15] and *public goods*[16]. The aim is to *identify*, and to the extent possible to *evaluate* relevant factors. In a climate change perspective, the main challenges will be to find the value of carbon sequestration, i.e. the value of the avoided climate change damage. Further, it will be essential to evaluate additional costs and benefits arising at different times as a result of reforestation efforts. For all rehabilitation efforts, one needs to know the potential value of alternative land use systems compared to the present system (the reference case), and the costs of change. This involves all user groups, both present and future ones.

A *cost-benefit analysis* (CBA) is one of the tools for evaluating the outcome of projects. CBA provides "an analytical framework for comparing of consequences of alternative policy actions on a quantitative rather than qualitative basis" (Munasinghe *et al.* 1995). Generally, CBA involve discounting of marginal costs and benefits in order to find the project with the highest net present value. The usefulness of CBA clearly depends on the extent of assessing

[15] Externalities are positive or negative effects that will affect other than those creating the effect, and where these effects are not reflected in the market. Thus, in case of negative externalities (e.g. air pollution) in a free market situation, the polluters will not have to pay for the losses they inflict on others.
[16] Normally defined as goods that once produced are available to all on a nonexclusive basis. A good that is nonrival and nonexclusive will not be efficiently supplied by the market.

costs and benefits. Nilsson (1995) claims that the considerable uncertainties in evaluating effects of global afforestation programs as well as the choice of discount rate may give misleading results. Hoen and Solberg (1995) oppose this view and represent a more optimistic position of the use of cost-benefit analyses for this purpose.

Key challenges when using economic analysis on carbon sequestration include (1) large uncertainties concerning the effects of CO_2 accumulation in the atmosphere, (2) difficulties in valuing the effects now and in the future, as carbon sequestration is a public good (see below), (3) the long time perspective needed for the climate change issue, which means that the choice of discount rate will be critical, and (4) the global characteristics of CO_2 emissions and abatement, i.e. how costs and benefits should be distributed between various groups or countries.

Cost-effectiveness is the variant of CBA that has been most widely used for the climate change problem. A cost-effectiveness approach allows the decision makers to focus on the "least-cost" option to reach a desired level of CO_2 emissions, or the cheapest way of sequestering a given amount of carbon. (Munasinghe *et al.* 1995). This approach is useful in situations with 1) strict budget limitations, which is particularly important in developing countries, and 2) the difficulties of explicitly valuing the benefits of GHG emission reduction[17]. However, the cost-effectiveness criterion has been subject to criticism (Gupta 1995). One potential negative effect of the criterion is that it leads to a focus on large projects instead of small ones, because cost-effectiveness encourages minimising of the middle persons involved per project and optimising the economies of scale. Furthermore, the criterion tend to favour a short-term view on technology efficiency, while long-term aspects such as education and institution-building become less important. It also lead to a 'project' approach, which in turn may result in a lop-sided growth in the communities where projects are based. Finally, as minimising of costs is a main objective, information disclosure and public discussion are often given low priority (Gupta *op.cit.*).

A CBA which evaluates economic efficiency cannot answer how costs and benefits should be *distributed* among the involved groups, e.g. between the global community and the local people. For political decision-making, these aspects need to be taken into account. Economic instruments can also be applied in order to deal with issues concerning distribution of costs and benefits. As a supplement to CBA, one might apply a *multicriteria analysis*, which is designed to identify possible trade-offs between equity objectives and economic efficiency. A *decision analysis* deals with uncertainty and irreversibility, two key characteristics of the climate change issue (cf. Munasinghe *et al.* 1995).

[17] It has been discussed whether the carbon sequestration benefits should be discounted at all (see Sampson *et al.* 1995).

A main problem for "production" of carbon sequestration is that it is a pure public good (non-rival and non-excludable), and that there is no market demand for carbon storage. Carbon sequestration is a market externality which is produced jointly with other commodities (wood products, biodiversity, soil and water conservation). In a free market, the supply would thus be too low (cf. Ley and Sedjo 1995b). Additionally there is a problem of valuing the benefits of carbon sequestration due to the effects of CO_2 accumulation in the atmosphere.

When using CBA, the choice of discount factor will be crucial for the distribution of costs and benefits between present and future generations. Costs and benefits occurring at different times will be judged very differently when changing the discount factor. See e.g. Nilsson (1995) for a discussion of discount rates in afforestation projects.

The global marginal benefits of abatement of CO_2 emissions will be considerably higher than the benefits for Indonesia as a nation. This creates problems for implementation of projects that would otherwise be in the "no-regrets" zone. The Global Environment Facility (GEF) mechanism is a tool designed to make the global community pay for the benefits they receive, thus enabling implementation of projects that would otherwise be uneconomical on a national scale.

A division must be made between national reforestation programs and the individual projects by using economic analysis or financial analysis. Large programs may affect markets, prices, and the behaviour of the producers, in addition to other potential social impacts. These impacts also need to be quantified and factored into the final result (Sampson *et al.* 1995).

Costs:

The *direct* costs of reforestation include forest establishment (site preparation/weeding), infrastructure, future management and maintenance, transport, labour and capital costs, and land rent (royalties/fees). Investment costs are often considered to represent a major constraint for the small-scale farmers' possibilities to invest in reforestation, e.g. fertilisers, livestock for ploughing, seeds, etc. (Potter 1987). Still, there have been observed initiatives for woodlot establishment among poor farmers even without subsidies (Garrity and Mercado 1993). Investment costs are considered to be minor to the costs of transport and marketing of timber. For small scale farmers growing their own woodlots, it is assumed to be desirable to market the products on a stumpage sale basis (Kuusipalo and Hadi 1995).

Indirectly, reforestation of grasslands could affect the utilisation of other ecosystems, e.g. influence the pressure on remaining forest land (see e.g. Turvey 1995). This effect must also be taken into account when determining the social profitability of a strategy. (1) In some cases it has been observed that present land tenure arrangements are ignored and the users expelled from the *Imperata* plots. In addition to the social costs from loss of income for the individual farmers, pressure on remaining forest is likely to increase as people would be forced to move to recently deforested areas for slash-and-burn cultivation. (2) In other cases, these costs may be only temporary, as new income opportunities could be provided (when farmers are employed as labourers on plantations, or they are given support for investing in intensification of cultivation, e.g. fertilisers, livestock for ploughing etc.). The costs of changing from one system to another may in either case be significant. If products from plantations or agroforestry systems can substitute products from indigenous forests, pressure on the latter may be reduced. Whether this is possible is debated among scientists.

Benefits:

Carbon sequestration is clearly a global benefit, as carbon sequestered in Indonesia will contribute to reducing the anthropogenically enhanced greenhouse effect. Thus, the benefits of carbon sequestration are the avoided costs of global climate change. Nordhaus (1993), cited by Sedjo and Ley (1995), found that marginal damage from carbon emissions is generally in the range of US$ 5-20 per ton.

In addition to carbon sequestration, reforestation will produce other marketable and non-marketable goods. Two main categories of these goods are (1) "Products" (timber, other forest products), and (2) "Services" (biodiversity, soil and water conservation). The potential benefits of reforestation through reducing the pressure on indigenous forests was mentioned above. According to Munasinghe *et al.* (1995), most estimates lie in the range of 1 to 10 US$ additional benefits for every dollar of benefit from GHG emission reduction. Haeruman (1995) states that turning *Imperata* grasslands into productive forests is totally justified and economically feasible as such, even without any industrial targets. This arises because of the benefits provided for CO_2 fixation, biodiversity, and conservation of soil and water. The extent of these benefits will vary with the chosen strategies, which will be briefly discussed in the next chapter.

According to Kuusipalo (1995b), degradation of one ha natural dipterocarp forest into *Imperata* grassland results in emissions of 400 tonnes (80%) of carbon in the form of CO_2. Full restocking of one hectare of grassland by *Acacia mangium* plantation will remove 200 tonnes of carbon from the atmosphere to the organic carbon stock. The author assumes an environmental benefit of restocking *Imperata* grasslands by *Acacia mangium* of about US$ 10/tonne of carbon. Thus, the environmental benefit of restocking grassland by *Acacia mangium* = US$ (10 x 200) = US$ 2000/ha, which is expected to exceed the establishment costs of an *A.mangium* plantation considerably.

Discussion:

Rehabilitation of grasslands should involve all relevant natural resource sectors. Impacts of reforestation on e.g. agriculture and food production will be crucial for the feasibility of projects (cf. e.g. Sampson *et al.* 1995). The key factors for reforestation strategies are to secure an economically efficient allocation of the input resources when considering carbon sequestration, and a socially desirable distribution of the outputs (costs and benefits)[18]. Identification (and evaluation) of non-financial effects are equally important as the financial costs and benefits for the evaluation of reforestation. It appears that costs of reforestation

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[18] See also Tomich *et al.* (1995)

are generally easier to identify and evaluate than the benefits (Sampson *et al.* 1995). In situations with low net benefits, carbon sequestration efforts may be acceptable if they reduce uncertainty, i.e. the actions can be seen as a "risk premium" (Munasinghe *et al.* 1995).

Experience has shown that many so-called "win-win" solutions are not implemented. This may be due to several factors, including market failures, influence of powerful vested interests, high transaction costs, or, particularly in the case of developing countries, budgetary limitations (Munasinghe *et al.* 1995). Access to the international credit markets may be a major national constraint. Where market mechanisms are unable to reflect the whole range of costs and benefits, taxes and subsidies are justified in order to adjust the market. The design of a system for optimal subsidies for carbon sequestration is discussed by Ley and Sedjo (1995b). As carbon sequestration is a "global good", the global community should pay for its share of the benefits through, for example, the GEF mechanism. An important issue is whether only the incremental cost should be paid for, or all the costs. See also next section (2.4.2).

2.4.2 Policy issues and institutional framework

The most challenging issues for reforestation efforts are probably those dealing with policy issues and institutional aspects (See e.g. Sumitro 1995):

> "...the main problems of reforestation in the *Imperata* grasslands are not technical, but socio-economic. Success depends on the right policies, control of fire, fertiliser availability, land tenure solutions, markets for plantation wood, etc."
>
> *Dr. Neil Byron, head of the CIFOR program on forest policies*

It is clear that management efforts will not succeed unless the groups depending on resource utilisation are given incentives for sound management behaviour. This implies first and foremost to identify the various social groups and their needs and priorities. These groups should be involved in all stages of planning, maintenance, and evaluation of the management system. The roles and rights of various groups must be clearly defined and secured on a long term basis. Moreover, there should be an equitable distribution of costs and benefits resulting from the investments. These general policy aims are well established in Indonesian forestry policy documents, see e.g. ITFAP (1992).

The role of the local communities living in or adjacent to the grasslands is of particular importance. There is a general consensus that these groups have not been given enough attention in grassland rehabilitation efforts so far (Potter 1995). Addressing the role of the local people gives opportunities for combining sustainable resource utilisation with social policy goals such as employment, poverty alleviation and income distribution (cf. World Bank 1992). Furthermore, it creates better conditions for the people to continue to use their traditional knowledge about farming and forestry.

Faeth *et al.* (1994) use "active local support and participation" as one of four main criteria for evaluating carbon sequestration projects in developing countries. On basis of six case studies, the authors argue that there is a direct connection between the welfare of the local people and conservation of the surrounding environment. They conclude that project activities that benefit local people also tend to sequester carbon. Stibbe and Lubbers (1993) use similar criteria for afforestation projects for climate change mitigation. The projects should be the result of a national or regional policy, have a strong economic or ecological function in the region, and contribute to improving the socio-economic position of the local inhabitants. Control and responsibility for the resources on which they depend is considered to be a basic requirement for development.

People will only invest in long term planning when they believe they will receive benefits from the investments, i.e. that there exist secure, long term land tenure arrangements. There are often informal land use arrangements in local communities utilising *Imperata* grasslands (Turvey 1994), but there are few formal instruments to secure long term land tenure. This is a major constraint towards reforestation of grasslands on a permanent basis. As mentioned above, even large 'sheet *alang-alang*' lands are claimed by the local people, but these *adat* rights are generally not accepted by the Government.

Fire control is a prerequisite for reforestation. At the same time fire is used as a management tool, and fires are often difficult and expensive to control once started. Hence, control of fire will only be achieved when the local people believe that fire exclusion will yield higher net benefits from the fields, or if there are regulations for fire control that are not undermining the farmers' interests. Gintings and Byron (1995) present a case study indicating that successful fire protection may be achieved at village level by giving the people appropriate incentives. It was observed that the existing informal regulations of the tribe did not function, so an attempt was made to make a new regulation on the basis of a discussion between people in adjacent villages. The authors *op.cit.* conclude that three basic requirements for success are that (1) people have knowledge about the disadvantages of fire, (2) the regulation is developed among the local people themselves, and (3) there is a sanction applied if there is somebody that does not respect the regulation.

The actual arrangement for local involvement may differ due to several environmental, social and economic factors. The main point is that the arrangement is adjusted to the specific site, and established only after an on-site investigation. One important problem connected to industrial forest plantations on grasslands is that local uses of grasslands and informal land tenure arrangements are ignored (cf., e.g., WAHLI and YLBHI 1992, Van Noordwijk *et al.* 1995a). In some cases the people are expelled from the area and must seek new forest areas for slash-and-burn cultivation. However, some forest plantation concession holders have succeeded in dealing with the people by paying "compensating money" for the land they claim (Sumitro 1995).

Tampubolon *et al.* (1995:141) conclude that the involvement of smallholders in agroforestry may increase their prosperity due to the attractive market for fast-growing timber species. Small scale farmers in the Philippines have independently begun farming timber trees on infertile grassland in response to increasing timber prices (Garrity and Mercado 1993). High timber prices and increased profitability in growing trees as crop commodities can be seen as a spin-off from forest destruction (Garrity 1995).

Garrity (*op.cit.*) suggests that the government's role should be to create infrastructure as an incentive for reforestation, but not get involved in business as such. On the international level, the role of the global community should be to pay for the global benefits from carbon sequestration, and furthermore to encourage sustainable policies while avoiding projects with negative environmental and social impacts. The GEF mechanism is designed to finance the incremental costs[19] of projects which generate global benefits, thus contribute to climate change mitigation. The controversies around the GEF mechanism as a tool for development are analysed by Gupta (1995). Other means of compensation are technology transfer and debt adjustment schemes (WAHLI and YLBHI 1992).

2.5 STRATEGIES FOR REFORESTATION OF DEGRADED GRASSLANDS

Suggested reforestation options for degraded grasslands fall into three main groups:

1. Plantations, both monocultures and mixed-species.
2. Agroforestry systems, including crop and livestock systems.
3. Natural regeneration.

This list is neither exhaustive or exclusive. As pointed out by Potter (1995), there may exist appropriate local agricultural (crop) systems. Furthermore, strategies may occur in combination. It is also clear that mega-scale blocks of *Imperata* grasslands (sheet *alang-alang*) will require different rehabilitation strategies than smaller patches, e.g. at the level of village or farmers' fields. In the following, the strategies are discussed in relation to carbon sequestration, environmental soundness, and social profitablity. Emphasis will be given to the social aspects, including community participation and land tenure arrangements. The description below will repeat many of the points raised in earlier chapters.

2.5.1 Plantations

Plantation establishment has been the main strategy for rehabilitation of *Imperata* grasslands in Indonesia. Plantations are established for production of timber and pulp, and for conservation of soil and water resources. The Ministry of Forestry's target for production plantations is 6.2 million ha by the year 2000, implemented through the HTI program[20] (Kuusipalo 1995b). Plantations include a variety of systems; from large-scale, industrial plantations (such as HTI) to small-scale, community based plantations. The systems could be monoculture or mixed-species, and differ concerning the rotation time and the species composition over time. For community based plantations, there are differences regarding the extent of local involvement. In some systems, locals are used only as labour, while in others the communities play a more integrated role.

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[19] Incremental costs are the additional costs incurred if global environmental aspects are taken into account (Gupta 1995).
[20] HTI = Industrial Timber Estate (*Hutan Tanaman Industri*). See Appendix 2

Carbon sequestration

Plantations are assumed to have a large carbon sequestration potential (cf. Sedjo and Solomon 1989; DN/MSE 1994; Sampson *et al.* 1995). Carbon sequestration will differ with the initial state of the grassland (carbon in soil, productivity), species selection, rotation length (financial or carbon-optimal), the durability of the products, the extent of use of plantation wood instead of fossil fuels, and whether timber replace fossil fuel consuming products (e.g. concrete or steel). In addition, the net carbon sequestration will depend on the impact of plantations on other major carbon sources and sinks, particularly natural forests.

A review of CO_2 fixation and cost efficiency of plantations on grasslands is given by DN/MSE (1994). Houghton (1993) reports that of the initial carbon stocks, 30-50% of the carbon in vegetation and up to 10% of the carbon in soils are lost to the atmosphere when natural forests are converted to plantations. Although plantations may hold as much or more carbon than natural forests, the average carbon stock is reduced because of the harvesting. According to Kuusipalo (1995a), grassland conversion into plantations will increase the carbon stock from 50-75 tC/ha to 200 tC/ha. The environmental benefit is estimated to be 10-30 US$ per ton sequestered carbon.

Plantations on grasslands could increase the supply of wood products (timber, firewood), thus reduce the pressure on natural forests and in turn reduce carbon emissions (cf. Nilsson 1995). Other authors are less optimistic regarding the ability of plantations to substitute for high value timber from natural forests (e.g. Turvey 1995). The *Shorea* plantations examined by DN/MSE (1994) may however have such a potential, as *Shorea* is indigenous to Indonesia, and also the species most commonly extracted from primary production forests. Still, if plantations take up agricultural lands for food production the pressure on indigenous forest may increase. Potter (1995) reports that after plantations were introduced, the local people need to go further from the villages to find patches to cut swiddens.

Environmental value

Because of the tree component, the environmental value is expected to be higher in plantations than in permanent *Imperata* grasslands. Tree establishment will be positive regarding conservation of water resources by reducing evaporation and wind speed. Kuusipalo and Hadi (1995) claim that forest plantations are not “ecological deserts”, but support a variety of natural regrowth and biological diversity. According to the authors *op.cit.*, plantations create favourable conditions for natural regeneration by decreasing fire risk, providing shelter and suitable microclimate to flora and fauna, and by improving soil condition.

On the other hand, all plantation systems examined by DN/MSE (1994) were found to produce a considerably lower species diversity than secondary forest. Biodiversity is lowest in single-species plantations, and will increase with diversification of tree species and canopy structure. Longer rotational cycles will also increase the environmental values because of a more stable ecosystem (DN/MSE *op.cit.*). Single-species plantations may increase the risk of pest and disease attacks. Plantations with exotic species have often failed because the trees are not adapted to the local climate and face new stresses and pests (Evans 1982). For suppressing the grass, herbicides and insecticides may be necessary during the initial phase of plantation establishment, though to a varying extent depending on species composition, density of *Imperata* and availability of local techniques to eradicate the grass.

Soil erosion is low in grasslands, and it may in fact increase after plantation establishment (Young 1989, DN/MSE 1994). Soil loss will be considerable if soils are laid bare prior to planting. Furthermore, a tree canopy alone does not reduce rainfall erosivity (Young *op.cit.*). Ground covering is crucial, either by using plant residues, or by having low trees or shrubs in mixed-species plantations with multiple canopy layers. It is also important to protect the plantations from grazing. If erosion is checked, plantations may increase soil fertility and improve soil physical properties.

It has been suggested that while monoculture plantations may be necessary for an efficient elimination of *Imperata* grass, the second rotation gives opportunities to increase species diversity by the introduction of native tree species, agroforestry systems, or assisted natural regeneration (Tampubolon *et al.* 1995). Kuusipalo *et al.* (1995) suggest that natural forest cover could be reclaimed with the help of a shade cover crop of fast-growing exotic plantation trees. Plantations outshade the grass and create favourable conditions for colonising by indigenous tree species, and could in this way act as the initial steps in secondary succession of grasslands. The most suitable species were found to be *Acacia mangium*. Turvey (1995), on the other hand, judges it unrealistic to expect that plantations will be returned to other uses once they have become productive. Successful plantations may in fact stimulate further plantation establishment, e.g. by clearfelling natural forest areas. Therefore, the possibility of plantations to reduce pressure on natural forests is uncertain.

Social profitability

Plantations are considered to be a cost-effective way of reducing net CO_2 emissions (Sampson *et al.* 1995, Ley and Sedjo 1995a, DN/MSE 1994). Besides prices, yield per ha is the most important factor determining financial returns. Economic performance of plantations is discussed by Kuusipalo (1995a,b). According to the author, yields should be at least 25 m^3/ha/year in order to rely on commercial financing. This is judged to be realistic due to results from earlier projects. The first 1-2 years are particularly important for the success of plantation establishment, while the overall financial results are only moderately sensitive to these investment costs. Key factors for the operation chain needed through the initial phase include (1) appropriate tree species and provenance, (2) good seed quality, (3) site preparation, (4) spacing, (5) fire protection, (6) initial fertilisation, (7) careful plantation management, and (8) weeding. Transport costs will constitute a major expenditure, and even small changes in these will have significant impact on the internal rate of return (IRR) (Kuusipalo and Hadi 1995). If small scale farmers grow own woodlots, it is preferable to market the wood on the stumpage sale basis.

Plantations are regarded as being necessary for supplying timber and other forest products for the growing demands in the domestic markets (Haeruman 1995, World Bank 1993). In a climate change perspective, the absence of a market for 'carbon storage' will produce too little planting. Carbon sequestration is likely to be lower when rotation length is optimised for timber production instead of CO_2 fixation (Ley and Sedjo 1995a).

Turvey (1995) considers it as possible that plantation timber will be able to replace the use of trees from natural forests for pulp production, but argues that one cannot yet expect plantation grown timbersd to substitute for high value timber from indigenous forests. Nilsson (1995) notes that large scale carbon plantations may lead to oversupply of wood products, and in turn lower prices. The impact on markets will depend on the market access, i.e. the distance and the infrastructure conditions, as well as how the demand for wood products develops in Indonesia. Hoen and Solberg (1995) argue that wood production in any case is likely to give increased flexibility for the future because of the many ways of utilising wood products.

Plantations may provide job opportunities for the local people, but may have other negative impacts on the local level. Gintings and Byron (1995) discuss smallholder timber-based plantations. There is relatively little research or field experience on this issue in Indonesia. Smallholder-based rehabilitation approaches are assumed to have advantages over large-scale, estate-based schemes, both concerning profitability and fire control (Tomich *et al.* 1995, Gintings and Byron 1995, Garrity and Mercado 1993). (see 2.5.2.). Many of the arguments in disfavour of plantations relate to the negative impacts on the local level, including:

- Lack of adequate attention to the needs and priorities of the local people (Potter 1995). One of the main constraints for the large-scale governmental reforestation efforts (plantations) has been lack of fire control, which in turn arises partly due to lack of local support (Garrity and Mercado 1993).
- Introduction of plantations may lead to more pressure on shifting cultivators, as fires are forbidden and more land is occupied by the plantation companies. In turn, the villagers must go further from the villages to find patches to cut swiddens (Potter 1995).
- Conflicts and insecurity of land tenure arise because plantations often have been established on lands claimed by local communities (Van Noordwijk *et al.* 1995a).
- Plantations may not provide all the services which the locals need, and may compete with agricultural lands, thereby increasing pressure on remaining natural forests.
- Other strategies than plantations could be more effective for rehabilitation of degraded grasslands. Experience has shown that locals may have techniques to overcome the problems of *Imperata*, thus it may be better to build upon indigenous systems and existing land rights than introducing new systems (Potter 1995).
- The benefits of development in the forest industry sector are not reaching the people who carry the economic, ecological and social costs (WAHLI and YLBHI 1992).

Plantation establishment for rehabilitation of *Imperata* grasslands in Indonesia has up to now been largely unsuccessful. It is clear that lack of attention to the local conditions is a major reason for the failure. Medium term survival rate for plantations on grasslands in Indonesia has been estimated at 57%, but long term survival may be much lower (Pandley

1992, cited by Kuusipalo and Hadi 1995). In addition to above mentioned socio-economic constraints, major technical problems have been impoverished and acid soils, strong competition with grasses and frequency of fires (Otsamo 1995). Experiences from the Philippines showed a survival rate of the reforestation plantations of as low as 26%, due to 1) fire, drought and animal damage, 2) poor seedling quality and pests and diseases, 3) insufficient care and maintenance in the initial phase, and 4) extremely poor soils with aluminium saturation in subsoil and/or excessively low phosphorus and nitrogen (FMB 1988, cited by Calub *et al.* 1995).

2.5.2 Agroforestry systems

Young (1989) describes agroforestry as “land use systems in which trees or shrubs are grown in association with agricultural crops, pastures or livestock, and in which there are both ecological and economic interactions between the trees and other components”. Shifting cultivation is the simplest form of agroforestry. It can be seen as the initial, low population density stage in a development towards intensive multicropping systems which are driven by increasing population pressure on lands (Raintree and Warner 1986). Spatially mixed multistorey tree gardens (home gardens) are examples of intensive agroforestry systems which can support a high population density. Richards and Flint (1993), cited by van Noordwijk *et al.* (1995b), studied how shifting cultivation has been replaced by permanent agriculture in different parts of Indonesia. While this transformation in Java and Bali took place before 1880, it is still in its early stages in parts of Kalimantan and Irian Jaya.

Agroforestry systems differ with regard to temporal and spatial overlap. Trees may be grown simultaneously with other crops or pastures or in sequence (rotational systems). For non-rotational systems, trees and other components may be spatially zoned or spatially mixed. Animal husbandry is often an integrated part of agroforestry systems. Traditional agroforestry systems are mainly rotational or spatially mixed, while modern agroforestry systems are commonly spatially zoned (Young 1989). Agroforestry systems are generally small-scale and oriented towards villages or individual peasants, although agroforestry may also include large-scale systems, as when crops are grown between the rows in tree plantations.

Carbon sequestration

The tree component will generally produce higher above ground carbon density in agroforestry systems than in grasslands (e.g. Kuusipalo 1995a, Young 1989). In low-latitude areas, one estimate of carbon density in agroforestry systems is 50-125 tC/ha (Trexler and Haugen 1994). Dixon *et al.* (1993) report a median above-ground carbon stock in agroforestry of 100 tC/ha compared to natural forests with 220 tC/ha. Carbon sequestration and storage per ha is lower in agroforestry systems than in tree plantations (Unruh *et al.* 1993). For a west-Javanese home garden, Jensen (1993) found a total biomass of 126 t/ha, equalling a carbon storage of around 63 tC/ha. Schroeder (1994) found a median carbon storage of agroforestry practices of 9 tC/ha in semiarid ecozones, 21 tC/ha in subhumid and 50 tC/ha in humid ecozones.

According to the 'intensification hypothesis', establishment of agroforestry on *Imperata* grasslands could be a way of reducing deforestation and in turn carbon emissions. As agroforestry systems does not compete with agricultural lands, the potential for reducing deforestation is assumed to be higher than for plantations. Kuersten and Burschl (1993) found that agroforestry systems can sequester up to 60 tC/ha, while the additional CO_2 mitigation effects may achieve more than 20 times this quantity, through protection of existing forests, conservation of soil productivity, replacing energy-intensive raw materials by wood, and using fuelwood instead of fossil fuels. According to Dixon *et al.* (1993), 1 ha of agroforestry could offset 5-10 ha of deforestation. An example from Thailand showed that agroforestry in combination with plantations was successful in slowing deforestation. At the same time, there are conditions when the hypothesis will not hold true (Tomich and van Noordwijk 1995). (See chapter 2.3.2 above). In these cases, intensification could speed up rather than slow down deforestation, especially because successful systems attract an inflow of migrants.

Environmental value

Trees or woody perennials have a number of characteristics that make them beneficial for improvements in environmental conditions of grasslands as well as monoculture croplands. Soils are improved through increased additions of organic material, reduced losses from nutrient leaching and soil erosion, better physical and chemical properties and increased biological activity. Shade from trees reduces evapotranspiration and stabilises the local climate. Furthermore, mixing of crops with multiple canopy layers provides a more diverse environment in terms of habitats for plants and animals.

The environmental value will strongly depend on the design of agroforestry systems. Studies of home gardens at Java show that their ecological characteristics resemble those of natural forests, with an overall species diversity comparable to deciduous subtropical systems (Dover and Talbot 1987). De Foresta and Michon (1994) found a close structural similarity between natural forests and 'damar' agroforests in Sumatra. Other agroforestry practices may have less or even negative impacts on the environment. The Taungya practice, where crops are either grown in rotation with commercial timber trees or interplanted with trees in the early plantation stage, is considered to be negative for soil fertility and normally suffers high erosion after tree felling (Young 1989, DN/MSE 1994).

Social profitability

It is only recently that agroforestry solutions involving small scale farmers are considered as important alternatives to plantations for rehabilitation of grasslands (Sangalang 1995). Van Noordwijk *et al.* (1995a) suggest that for rehabilitation of grasslands, one should focus on combined systems such as e.g. rotational hedgerow intercropping, instead of pure crop-based production systems. Agroforestry is recommended because the tree component provides a number of goods and services while increasing the land productivity for agricultural products and other commodities. It is also assumed that agroforestry involves a "bottom-up" approach, thus focusing more on the local needs and priorities. This may

mitigate potential conflicts of reforestation schemes and traditional land use patterns. However, Potter (1995) argues that even if agroforestry often intends to be a “bottom-up” strategy, local agricultural practices are often overlooked.

Furthermore, intensification of shifting cultivation requires increased input of labour and capital. Even though growing of trees in the long term may provide considerable soil productivity and cash income, lack of capital for investments (fertilisers, herbicides, seedlings) and maintenance are major constraints for smallholders. The above-mentioned Taungya systems (*tumpangsari*) have been tried in connection with plantation establishment, both in order to give farmers alternatives to shifting cultivation, and to provide cheap labour for development of timber estates. In two cases in South Kalimantan the systems failed due to unclear and too short contracts (1-2 years), and negative impacts of trees on crop growth (Suharti 1993, Potter 1995).

Garrity and Mercado (1993) identify three competitive advantages of smallholder timber plantations within an agroforestry context compared to large scale timber estates: 1) Initial costs are charged to the annual crops, 2) The cropped alleyways provide fire breaks, and 3) more intensive management may better ensure that the trees reach harvestable age. Tomich *et al.* (1995) suggest that smallholder-based rehabilitation has better prospects for fire control, and that there are no economies of scale in rehabilitation or subsequent production activities. Sangalang (1995:3-4) investigates tree crop based systems, and found that annual income at farm level for a simple agroforestry system involving coconuts, sparsely intercropped with coffee and few lanzones trees, was US$ 1,560. This is equivalent to the salary of an ordinary office worker. The author concludes that there is a lot of room for improvement in this system.

Rubber Agroforestry Systems (RAS) have been examined by Bagnall-Oakeley (1995:18) as an alternative to *Imperata* grasslands in West Kalimantan. Higher productivity RAS allow a certain flexibility and suit a strategy of farmer’s income diversification. These systems were found to be sustainable alternatives to shifting cultivation, with low to medium cost and labour input. They also represent reliable sources of cash for farmers from rubber. Additional sources of income could be fruits, and in the long term, timber. The system is based on existing, well-known agroforestry practices and methodologies. For a discussion of smallholder rubber agroforestry, see also Van Noordwijk *et al.* (1995b).

Kuusipalo and Hadi (1995) propose a model involving a central agroforestry element, supported and strengthened by a peripheral element involving integrated hill rice and plantation forests. In this system, natural fallows were replaced by plantation rotations, and burning of swidden plots replaced by mechanical ploughing.

2.5.3 Natural regeneration and secondary forest

Generally, natural regeneration occurs in grasslands provided that fire is prevented for a sufficient number of years and intensive grazing is excluded. The time needed for forest regeneration will vary due to nutrient status of the soils and availability of tree seeds in soils or from nearby forests. Grasslands which have been maintained by fire for a long time period will have less ability to regenerate than recently cleared lands. Similarly, smaller patches surrounded by forests will normally regenerate faster than large blocks of grasslands. Suppression of *Imperata* grass and establishment of trees will normally take 2-7 years, while establishment of a forest cover may take at least 30 years (DN/MSE 1994, Banerjee 1995).

The successional stages from *Imperata* grasslands to secondary forests are described by Eussen and Wirjahardja (1973). More general descriptions of the dynamics of secondary succession in tropical forests are given by Bruenig (1989) and Moran *et al.* (1994a,b). Eussen and Wirjahardja (*op.cit.*) studied succession in dry areas and identified four main stages:

1. *Imperata* formation: 90-100% *Imperata cylindrica*
2. *Imperata/Chromolaena* formation: Equal amounts of *Imperata cylindrica* and *C. odoratum* (shrub species). The formation has a two-layer pattern, with the canopy of *Chromolaena* above *Imperata*.
3. *Chromolaena* formation. Mainly *Chromolaena*, with some *Imperata* in between. This phase will be less pronounced in wetter climates and if fire is totally excluded.
4. Post-*Chromolaena* formation. The amount of *Chromolaena* decreases and trees and shrubs with higher canopies take over. From this formation secondary forests develop.

Carbon sequestration

It is generally assumed that regrowth after land clearing and burning of primary forest has a lower carbon storage potential than primary forest (Schimel *et al.* 1995, Bolin 1986). Dixon *et al.* (1993) report that the potential for carbon sequestration of secondary forest establishment is higher than for agroforestry systems and plantations. DN/MSE (1994) found a total accumulated CO_2 amount over 60 years to be 225 t/ha, equalling a carbon amount of 61 tC/ha. AFRD (1995) measured above-ground biomass of shifting cultivation fallow by cutting, fractioning and weighing of the plant material. After one year of fallow, the above-ground biomass ranged from 1 to 2.5 tC/ha[21]. In 5-year-old forest above-ground carbon stock ranged from 11.5 to 13.5 tC/ha and 10-year-old forest from 22.5 to 34 tC/ha.

Environmental value

Biodiversity will depend on the existence of seeds in the soil or immigration of species from primary forest. Pioneer species are likely to dominate for a long time. Therefore one may need enrichment planting to achieve preferred species composition. It will generally take a long time (200 years or more) until the forest achieves the characteristics of a primary forest. Many factors may influence the end structure of the forest (DN/MSE 1994, Whitten *et al.* 1987). Secondary forests will generally support a higher biodiversity than plantations and most agroforestry strategies. They also have a higher share of indigenous species. The environmental value of secondary forest is considered to be high according to most criteria used by DN/MSE (1994). Kuusipalo *et al.* (1995) found a high proportion of indigenous

[21] Conversion factor from biomass to carbon = 0.5

plant species under plantations with a fast-growing exotic species of *Acacia mangium*. They propose that *Acacia* or other species may be used as an initial step for natural regeneration of degraded *Imperata* grasslands (see also section 2.5.1).

Social profitability

The appropriateness of natural regeneration will be determined by factors such as land demand. Natural regeneration is likely to be best suited where population density is low and the land use extensive. Natural regeneration is a relatively slow process, and tree species appearing by natural succession are often of secondary importance for commercial exploitation. In areas with high demand for land resources for either agriculture or production of commercial wood products, natural regeneration will probably be less suited.

However, in some areas it is known that local people may protect natural forests because of their value for provision of fruits and other goods. In a study from central West-Kalimantan, De Jong (1995) found that the local *Dayak* people protect areas of natural forests and may even establish new forests on former agricultural lands. Even though actively exploited and managed, these forests showed a great similarity with natural forests on the site.

Several methods are used to speed up or direct the succession towards a preferred species composition. These are e.g. enrichment planting and assisted natural regeneration. Kartawinata (1994) discusses the use of secondary forest species for rehabilitation efforts and concludes that assisted natural regeneration is a potentially rapid, efficient, and cost-effective means of reforestation.

Natural regeneration will probably have the lowest investment costs of the strategies. In addition to fire control, site preparation or initial fertilisation for enrichment planting may be necessary to get trees established. The resulting forests would yield relatively low financial returns, but may give opportunities for a sustainable yield of timber. In addition, the forests could provide a number of non-economic goods and services such as fruits, soil conservation, watershed protection, and in the long run a species richness comparable to that of the original forests, although species composition may be different.

3. CASE STUDIES, BACKGROUND

3.1 INTRODUCTION

The following chapters present a summary of information and observations gathered mainly through a field study during autumn 1995 at three project locations in Indonesia. The project sites under consideration were 1) Kerinci in Jambi province, Sumatra, 2) Nanga Pinoh in West Kalimantan province, and 3) Riam Kanan, South Kalimantan province. Location of the project sites within Indonesia is shown in Figure 3:1. Project sites were chosen on basis of a) expanse of grasslands, b) assumed social and environmental benefits of reforestation, c) assumed need for technical and financial assistance for reforestation efforts, d) assumed support of the local government and the local people to reforestation efforts.

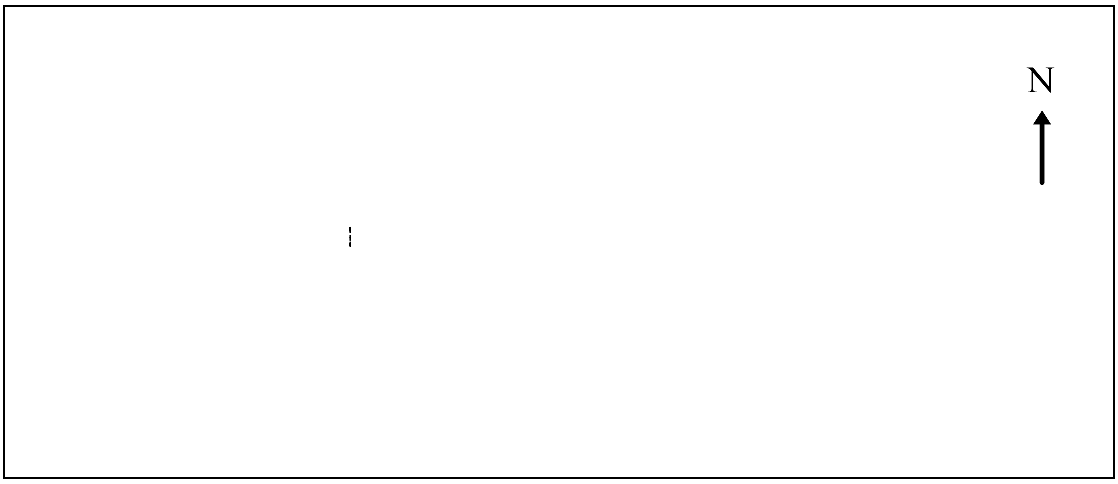

Figure 3:1. Map showing the location of project sites within Indonesia

3.2 METHODOLOGY

As the information was collected through a limited period of time the next chapters only give a broad impression of the situation on the site. The fieldwork consisted of interviews and discussions with farmers, local authorities and staff from NGOs and research institutions working with issues related to grassland rehabilitation on the site. A sample of the villages were chosen for farmer interviews. The farmers interviewed were chosen on basis of experience and knowledge about the village members; usually Village Heads or elderly persons. Background information was found at province, district and sub-district governmental offices and forest authorities. To the extent possible, key information was obtained from different sources and cross-checked. Where background data were not found in published reports, the specified source of information refer to the relevant governmental offices on the site.

Kerinci: Data were obtained through farmer interviews in 8 villages surrounding the grassland areas in sub-districts Sungai Penuh and Air Hangat: Sungai Jernih, Koto Keras, Koto Lolo, Talang Lindung (Sungai Penuh) and Koto Tuo, Sekungkung, Semumu, Belui Tinggi (Air Hangat). Local government authorities (Bupati, Bappeda, Forest office) at district and province level provided background data, and additional data were obtained at the office of WWF in Sungai Penuh.

Nanga Pinoh: 8 villages in Nanga Pinoh and Kayan Hilir sub-district were visited: Nanga Man, Manding, Engkurai, Sungai Pinang, Kebebu, Nanga Man and Priang. Background information, maps and other additional information were obtained at 1) Inhutani III[22] basecamps (Blonti and Kebebu), 2) provincial planning and government offices in Pontianak, district offices in Sintang, and sub-district office in Nanga Pinoh, 3) Inhutani office in Pontianak, and 4) District Forest Office in Nanga Pinoh. Two ongoing research projects investigating performance of different species for grassland rehabilitation at Inhutani basecamp Blonti were also visited.

Riam Kanan: Sources of information include: 1) Interviews and group discussions in 5 villages around the Riam Kanan lake, all located in Aranio sub-district: Tiwingan Lama, Tiwingan Baru, Artain, Rantau Bujur, and Rantau Balai; 2) discussions with staff at the Reforestation Technology Institute (BTR) in Banjarbaru, and forest officials (Kanwil, District Forest Office). The extensive research which has been carried out in the area and in neighbouring Riam Kiwa, including the research by BTR, the Enso/FINNIDA (ATA-267) project, and the work by Potter (1987, 1995) and Dove (1986), were used for comparison and supplementary information.

[22] In the following, 'Inhutani' is used as a short form of PT. (Persero) Inhutani III.

4. KERINCI, SUMATRA

Summary

Kerinci is situated in the western part of Jambi province, Sumatra, and has the second largest expanse of grasslands in the province. The district forms an enclave within the Kerinci Seblat National Park and has a relatively high population density. Reforestation of grasslands could yield benefits through increased land productivity, which in turn could increase the local welfare and possibly reduce the pressure on the National Park. Moreover, the district is an important part of the Batang Hari watershed, and reforestation could contribute to reducing the flooding problems in lower lying parts of Jambi.

The area covered by grasslands fluctuates due to land availability and (off-farm) income opportunities. Farmers prefer to cultivate the forest (shifting cultivation) and collect income from other sources instead of cultivating Imperata grasslands. The establishment of the national park has reduced the area of available land, which in turn has resulted in a decrease in grasslands in some areas. Reduced income opportunities have worked in the same direction. In Air Hangat, migration of people to more attractive lands has locally increased grassland areas.

Local farmers support reforestation of grasslands, provided it is economically feasible for them. Up to now governmental efforts of reforestation have failed due to a lack of incentives for protection and maintenance of the planted areas. There has been insufficient cooperation between the authorities and the villagers, accompanied by differing views on strategies for reforestation, e.g. choice of species: Farmers prefer cinnamon because of high and stable economic returns and easy maintenance. The government, on the other hand, do not support monocultures of cinnamon due to the erosion problems in the plantations. Instead, they want to focus on various multipurpose species.

It is clear that reforestation efforts in the area must be farmer-based. Grassland management has to focus on increasing the area productivity, at the same time as flexibility should be a major concern. This can be done by using local cropping and agroforestry systems. Efforts should be made to investigate systems for growing cash tree crops, such as cinnamon, without producing environmental problems. Furthermore, management of the national park should be seen in the context of agricultural development, aiming at creating incentives for long term conservation of the forest resources.

4.1 LOCATION AND PHYSICAL DESCRIPTION

The study was conducted in Sungai Penuh and Air Hangat sub-districts in Kerinci district (Figure 4:1). Kerinci is situated in the western part of Jambi province between 1°41'-2°26' south latitude and 101°08'-101°50 east longitude. It covers an area of 4200 km^2 (420 000 ha), and consists of 6 sub-districts. The district capital is Sungai Penuh, situated at 750 m.a.s.l. The Kerinci-Seblat National Park (KSNP) accounts for 51.6% of the district area. The remaining area consisting of settlements and agricultural lands is defined as an enclave within the national park. The enclave mainly belongs to the catchment area of Batang Merangin river which drains to the east and is a tributary to the river Batang Hari. The distance to Jambi is 470 km and takes around 12 hours by car, and to Padang on the western coast (the main market) 277 km and 5 hours. The roads are winding and have many sharp curves, but are generally in good condition.

Sungai Penuh and Air Hangat

Sungai Penuh and Air Hangat sub-districts make up a total of 124 200 ha or 29.6% of the district area (Table 4:1). Grasslands are found on the hillsides, where the topography is characterised by moderatly to very steep slopes (16-75%). Numerous smaller valleys and ridges form a rough and hilly landscape. The rocks on the hillsides are plutonic (intrusive igneous rocks) and intermediate tuff (agglomerate), while on the plains there are alluvial sediment deposits. The predominant soil type in the study area is Andosol (71.7%). See Table 4:2 below.

Table 4:1. Area, population and villages of Sungai Penuh and Air Hangat sub-districts, Kerinci district.

Sub-district	Area (ha)	Population	Population density (persons / km^2)	Villages
Sungai Penuh	52 000	61603[A)]	118,5	50
Air Hangat	72 200	42036[B)]	58,2	31
Average	-	-	88,35	-
Total	124 200	103639	-	81

[A)] 1994
[B)] August 1995

Source: Sub-district offices, Sungai Penuh and Air Hangat.

Table 4:2. Soil type distribution, Sungai Penuh and Air Hangat.

Sub-district	Andosol	Latosol	Podsol	Alluvial	Total
Air Hangat	61818 (86,2%)	480 (0,67%)	-	9402 (13,1%)	71700
Sungai Penuh	26940 (51,8%)	19395 (37,3%)	4279 (8,2%)	1380 (2,7%)	52000
Total	88756,62 (71,7%)	19874,62 (16,1%)	4279 (3,4%)	10781,842 (8,7%)	123700

Source: Badan Pertanahan Nasional Kabupaten Kerinci 1994. Area coverage in ha. Percentage of total in paranthesis.

Figure 4:1. Map of Kerinci district including *Imperata* grasslands. *Source: Peta Kegiatan Penghijauan Kabupaten Dati II Kerinci, Propinsi Dati I Jambi.*

Climate. Average annual rainfall in Kerinci for the years 1990-1994 was measured at 1450 mm (BMG Cabang Kabupaten Kerinci). Temperature generally ranges from 17.4 - 28.0°C, averaging at 23°C (District Forest Office, Sungai Penuh). The agroclimatic types in the area are B_1 and B_2, i.e. a dry season of up to three months, normally in the period between April to September. Generally there are less climatic variations through the year in Kerinci than in other parts of Jambi. (Syawal pers. comm.; District Forest Office, Sungai Penuh).

Land use. The main land use systems include wetland rice (*sawah*) on the plains, and a zone of permanent cultivation (monocultures and mixed gardens) on the lower parts of the slopes. Common crops include cinnamon (*Cinnamomum burmani* or cassiavera, kulit manis), clove tree, bananas, vanilla trees, peanuts, rubber, coffee, cassava and dryland rice. The hillsides are dominated by *Imperata* grasslands and bushland, with some shifting cultivation (*ladang*) plots. There are few trees in this zone, except for some remaining patches with pine trees (*Pinus merkusii*) from the regreening projects (see below). Outside the enclave there is a gradual change from open grasslands to secondary forest and finally primary forest.

Agricultural systems involve both permanent and rotational cropping. Farmers typically have wetland rice fields (*sawah*) and unirrigated dryland areas. In the village they have permanent plots of fruits and vegetables in an agroforestry arrangement (mixed gardens). The indigenous agroforestry systems (local name *Pelak*, in indonesian *Kebun Campur*), mainly provides subsistence goods. These agroforestry systems have a wealth of annual and perennial crops, including coffee, cinnamon, banana, mango, cassava, avocado, papaya, maize, peanuts, soybean, cucumber, tomato, potato, *Garcinia mangostana* (manggis), *Lansium dumesticum* (duku), *Durio zibethinus* (durian), and *Toona sureni* (surian). These systems are most widespread in the sub-districts of Sungai Penuh, Air Hangat, Danau Kerinci and Gunung Kerinci. In Gunung Raya and Sitinjau Laut sub-districts, monoculture systems with cinnamon dominate, commonly mixed with coffee (Gunung Raya) and rubber (Sitinjau Laut). In Gunung Raya, coffee is grown in mixture with cinnamon until the canopy of cinnamon closes. This system requires much labour in the establishment phase, but when the plants are older the labour requirement is low. The peak harvest of coffee is from May to July, while cinnamon branches are harvested twice a year (WWF and PHPA 1994).

Around and above the villages farmers grow annual crops such as dryland rice and peanuts on terraced fields. In the grasslands, crops are grown in a rotational system. Before the national park was established, farmers commonly had shifting cultivation plots in the forest area. This is now forbidden, but illegal shifting cultivation still represents a considerable problem for the national park management. In other cases, farmers have begun to cultivate more grasslands in response to increased land limitations. Opening of one plot of 1 ha was said to take around 1 month, involving 1) cutting and sun-drying of *Imperata* (some use herbicides), 2) collecting and burning, and 3) using an hoe to open the area. Ploughing is not common. Most of the grasslands are found in steep areas with high erosion susceptibility. In the permanent plots on the foothills farmers use terracing to minimise erosion.

The Kerinci Seblat National Park (KSNP) covers an area of 996 850 ha in four provinces. The Park hosts a wealth of species and ecosystems, with over 4000 plant species, 180 bird species (39 endemic), and 144 mammals, seven of which are only known to occur within the park (Kerinci-Seblat Integrated Conservation and Development Project, 1994). It is the largest conservation area in Sumatra, and the third largest in Indonesia. The province of Jambi has the largest share of the national park (40%), followed by West Sumatra (25%), Bengkulu (21%), and South Sumatra (14%). The area was proposed to become a national park as a result of extensive research done by FAO and PHPA[23]. Their management plan formed the background for the proposal of the Minister for Agriculture in 1982, No.736/Mentan/X/1982. At that time the Park consisted of 1 484 650 ha. In 1985, the area was reduced to 1.25 million ha through revisions on the Forest Consensus Map (TGHK), and further revisions left out most of the lowland and hill forests. The KSNP project office is situated in Sungai Penuh, and was established in 1984.

Human encroachment is one of four main threats to the Park, along with roads, mining, and logging. Encroachment involves shifting cultivation, permanent cropping and cinnamon plantations, as well as collection of non-wood forest products and illegal hunting. Roads facilitate agricultural expansion by opening the forest for settlers and providing of access to markets. The Kerinci district has the largest share of households with farm land within the park (11 500 out of 15 000). Measures to reduce agricultural encroachment include the recently introduced Multipurpose Tree Program (*Program Pohon Kehidupan*), where farmers are encouraged to grow indigenous tree species and are given 20 year usufruct rights to the land (Kerinci-Seblat Integrated Conservation and Development Project, 1994).

Land use rights. There are different perceptions of how land ownership is obtained and maintained between the villagers and the government. Among the villagers, land use rights are regulated through customary land tenure (*hukum adat*) and ownership certificates are not common. To demarcate the boundaries between properties, farmers use certain tree species such as *Dracaena sp.* (jervang) and *Toona sureni* (surian). Due to the matrilineal social structure, land is inherited through the women. People not originally from Kerinci can buy land only if married to a local man or woman. For example, a man from the region marrying a woman from another district has no inherited land, but is allowed to buy land. Forest land is also regulated through customary laws (*hukum adat*). The establishment of the national park in this way resulted in a loss of use rights to areas which the farmers regard as their lands.

According to the Agrarian Law (UUPA), customary land rights are only accepted for lands claimed before the law was declared (24.9.1960). This means that customary owned land within the forest will not be accepted by the government. Therefore, no compensation is given for loss of lands due to the national park establishment. Grasslands which have not been cultivated for a long time (fallow lands) may according to the law be considered as neglected by the people, and in this case the government may take over the responsibilities

[23] FAO = The Food and Agriculture Organisation of the UN; PHPA = Directorate General of Forest Protection and Nature Conservation, Ministry of Forestry, Indonesia.

and rights (Agrarian law chapter 15). If the grasslands are to be used for reforestation projects, farmers which have made the land claims after 1960 may still receive some compensation for loss of trees and houses (UU no. 24/92 chapter 16, verse 1b).

These differences in perceptions of land ownership between the government and the local people are important to consider prior to reforestation projects. Up to now, reforestation has been managed by the forest officials with farmers only being labourers involved in activities such as nursery, land preparation, planting and maintenance. Current plans indicate that there may be a change towards giving more responsibility to the local farmers, using a concept where "who grow the trees are the ones who should harvest (fruit, wood, etc.)". However, this concept is yet to be applied.

Population. The population of Kerinci district is around 281 250 (Statistical Office of Jambi province, 1993). Population data for Air Hangat and Sungai Penuh are presented in Table 4:1, and Table 4:3 shows population of the villages we visited. Most farmers in the study area are ethnic Kerinci or originate from neighbouring districts. Some migration to other districts through transmigration schemes was reported. Around 84% of the labour force is employed in the agricultural sector. The rest is working in government agencies, armed forces, merchandise and other sectors.

Table 4:3. Visited villages in Air Hangat and Sungai Penuh sub-districts.

Sub-district	Village name	Population (1995)
Air Hangat	1. Koto Tuo	732
	2. Sekungkung	1183
	3. Semumu	645
	4. Belui Tinggi	429
Sungai Penuh	1. Sungai Jernih	834
	2. Koto Keras	1246
	3. Koto Lolo	1075
	4. Talang Lindung	754

Source: Sub-district offices, Air Hangat and Sungai Penuh.

Major crops for cash income in the area include cinnamon, rice, peanuts, rubber, and coffee. Some of the agricultural production is sold in Sungai Penuh, while the most important market is Padang in West Sumatra. Even though Jambi is the province capital, it is of little importance as market for agricultural products. Average income in Air Hangat and Sungai Penuh is around 1 million rp. per year per household, while general income in the agricultural sector (not including cinnamon) amounts to 1.5 million rp./year/household.

4.2 *IMPERATA* GRASSLANDS

Imperata grasslands are mainly found on the hillsides of Kerinci valley. On official maps, grasslands are commonly included in the categories 'critical lands', 'unproductive drylands', or associated with bushlands (*semak belukar*), regrowth and secondary forest. Based on the map in Figure 4:1, the total area of *Imperata* grasslands and bushlands in

Kerinci is around 19 800 ha. Other estimates vary considerably. For non-productive drylands (mainly grass- and bushlands) two estimates are 16 075 ha[24] and 23 349 ha[25]. Another recent study calculates an area of 7790 ha for *Imperata* grasslands alone[26]. The distribution among sub-districts is shown in Table 4:4. It can be seen that while estimates for Air Hangat are fairly similar (3570, 3080, and 3200 ha, respectively), those for Sungai Penuh range from 2200 ha (26) to 6025 ha (24). Some of the variation can be explained from different categorisation; the latter probably include both *Imperata* grasslands and bushlands. If 'critical lands' are included in the estimate (26), the area figure rises to 13 255 ha for the whole district. *Imperata* grasslands occur in a mosaic with bush- and shrublands, cultivated areas, and some scattered tree plots. In the grasslands, species commonly associated with *Imperata* include (local names) randu and pakis (grasses) and rapun (shrub). Each household had reportedly between 0.5-4.0 ha of *Imperata* grasslands and drylands in Sungai Penuh and Air Hangat sub-districts.

Table 4:4. Estimates of non-productive lands and *Imperata* grasslands in Kerinci district, distributed by sub-district.

Source (cf. footnotes)	Land category	Gunung Kerinci	Air Hangat	Sungai Penuh	Sitinjau Laut	Danau Kerinci	Gunung Raya	Kerinci district
24	Non-productive dryland	7156	3570	6025	601	0	5997	23 354
25	Non-productive dryland	4185	3080	3415	265	885	4245	16 081
26	*Imperata* grasslands	650	3200	2200	160	620	960	7790
Total area of sub-districts	All	100 000	72 200	52 000	35 500	76 800	83 500	420 000

The grasslands in the area have according to the farmers been present since the colonial period. Two important factors determining the extent of grasslands include (off-farm) income opportunities and availability of lands. Farmers generally avoid cultivating the *Imperata* grasslands if alternatives exist. The national park establishment has reduced land availability. First, the national park has restricted the shifting cultivation in the forest. In Sungai Penuh, most farmers had lands within the national park boundary, and thus got restrictions on use after the national park was established. No financial compensation was given, but the farmers who lost land due to the national park got seeds for tree planting within the national park from which they are allowed to harvest fruits (tree cutting not allowed). Secondly, farmers living within the national park boundaries were forced to move. Some of them joined the transmigration programmes and moved to other districts, while others went back to their home villages, were they have land rights according to traditional laws (*hukum adat*).

[24] Badan Pertanahan Nasional Kabupaten Kerinci 1994
[25] Laporan Survai TNKS Propinsi Dati I Jambi, Kerjasama Bakosurtanal dan Bappeda Tingkat I Jambi 1990, and Laporan Survai Pemetaan Penggunaan Tanah BPN Kab. Dati II Kerinci.
[26] National Land Use Institute, 1995

In Air Hangat, migration to other districts has locally increased the grassland area[27]. Compared to Sungai Penuh, less farmers in Air Hangat had customary lands within the national park. One reason for migrating was said to be to avoid cultivation of grasslands. In other places, the grassland area was reduced as a result of farmers' efforts to increase income, and recent governmental reforestation efforts.

Fire is used to clear lands for cultivation, to provide young *Imperata* shoots for the cows, and to keep wild pigs away from the farmlands. Wild pigs create much damage to the farmers by eating seeds and plants. In the interviews, some farmers considered fire control as difficult, but most held the view that fire could be controlled. Furthermore, some said they earlier had burned grasslands, while now they had begun to cut the grass and collect it before burning, in order to ease fire control. One farmer said he never burnt the lands due to the negative environmental impacts.

In addition to cow fodder, *Imperata* is used for roof covering of temporary houses. Despite its practical use, farmers say they see grasslands as a major problem, due to 1) low soil fertility, 2) *Imperata* is difficult to eradicate, and 3) *Imperata* has a negative effect on crops (shade and allelopathy). Some of the farmers use herbicides (roundup), but not all can afford this due to the high expenses. Others only use burning and hoeing for eradicating *Imperata*. Erosion is also a major problem, particularly when opening the lands by hoe. Grassland is generally known to have low rates of soil erosion due to the very dense root system of *Imperata*, although in the steepest hills erosion may still be a problem.

Many farmers had experience with cultivation of grasslands. In Sungai Penuh, a number of farmers said that when they settled (10-20 years ago) the area now under cultivation was *Imperata* grassland. Although *Imperata* represents a considerable problem, farmers seem to have few problems in cultivating the land if no other options for income generation exist.

Farmers generally support rehabilitation efforts to increase the productivity of the lands. The farmers in both sub-districts we visited had experience with reforestation programmes which they considered as unsuccessful due to (1) lack of communication between farmers and the authorities; (2) farmers were not asked which species they wanted to plant. The most preferred species for planting is cinnamon (cassiavera); (3) lack of financial support, particularly for maintenance of the planted fields, and (4) planting in the wrong time of the year (summer / dry season).

Cinnamon was introduced by the Dutch. The tree has many features which makes it attractive for small-scale farmers: Easy treatments, needs little or no maintenance, prices are high and marketing is secure. The price of dry bark is around Rp. 6000,- or equal to US$ 3,- per kg. Concequently, people regard it as the best choice for increasing on-farm income. Usually, when the government introduces other species, people show interest for them in

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[27] In Koto Tuo village in Air Hangat, it was reported that *alang-alang* land had increased from 30 to 50 ha due to recent migration of 100 families to Tanjung Jabung. In this village there had been (1993) a governmental reforestation project which, according to the farmers, had been unsuccessful, because farmers got the wrong species for planting. They wanted cinnamon, but got other species (such as jengkol).

the beginning. But many of the species are new to the farmers and market prospects are less favourable than those of cinnamon. In turn, farmers lose interest in the species and do not maintain the planted fields.

History of reforestation and current policies

Reforestation started in 1978/79 with the regreening project. A total of 7000 ha have been planted. The main species for the regreening project has been *Pinus merkusii*, with some *Paraserianthes falcataria* and *Toona sureni* (Susilo 1995). Reforestation is seen as especially important in Kerinci because the area is a part of the Batang Hari river watershed. People believe that land use change is one of the major causes of the frequent flooding in Jambi city. The planted areas have suffered from frequent fires, and only about 10% of the plantation has been successful (Susilo *op.cit.*). As mentioned above (points 1-4) the failure may be partly explained by inappropriate species and lacking motivation of the people to maintain the planted areas and protect them from fire. One main constraint is that many of the species are unknown to the farmers. Furthermore, farmers cannot afford to wait until the trees can be used for timber, fruit harvest or other products. Farmers get support for planting, but little or no money is provided to maintain the fields and protect the plants.

Current reforestation projects focus on multipurpose tree species in mixed plantations. The forest department and agricultural department have programs for better use of grasslands. Criteria for choosing species are profitability, conservation benefits, marketing possibilities and maintenance requirements. Priority species are coffee, vanilla, orange, avocado, mangosteen (*Garcinia mangostana*), breadfruit (*Artocarpus sp.*), snack fruit (*Salacca edulis*), candlenut (*Aleurites moluccana*), *Arenga sp.* (aren), *Artocarpus integra* (nangka), and *Gnethum sp.* (melinjo). Extension services include information and handing out seedlings to the farmers. The program implementation is constrained by budget limitations. Cinnamon is the most desirable species from the farmers' viewpoint, of reasons mentioned above. However, cinnamon is seen as unfavourable for reforestation due to the environmental problems it causes. As it is typically planted in monocultures where all trees are cut at the same time, erosion is likely to follow. Therefore, the instructions from the local government are that only a few seeds or seedlings of the species should be given to each farmer.

Ongoing projects on Imperata grasslands.

The following paragraphs describe ongoing and relevant projects in the area:

1. Public Forest (Hutan Rayat). The trees are planted on national land, but farmers keep a communally accepted ownership. In the period 1991-95, a total of 2319.25 hectares have been planted in Kerinci district. Table 4:5 show the figures for Sungai Penuh and Air Hangat sub-districts. 50% of the area has been planted with trees mainly used for wood products, e.g. *Toona sureni*, *Calliandra*, and *Albizia sp.* Fruit trees account for 40% (e.g. coffee, candlenut, *Artocarpus integra*, *Pitchecelobium jiringa* (jengkol), *Durio zibethinus* (durian), and cinnamon, and the remaining 10% grasses such as *Pennisetum purpurea* (elephant grass), and local species like sereh. The purpose of introducing the grasses is to replace *Imperata* as animal fodder. Extract of sereh leaves is also used as medicine. The seeds and planting costs are provided by the government, but there is no support for maintenance. The costs of planting are 100 000 rupiah per ha. The main constraint of this project has been that farmers only care for cinnamon due to the high financial returns for this species, and therefore neglect other species. Uncontrolled fire has been a major problem, killing the young seedlings and opening land for *Imperata* invasion. Due to the experiences gained from this project, the future plan is to focus more on extension, such as discussion with farmers and handing out information leaflets before reforestation is undertaken.

Table 4:5. Planted area in the project 'Public Forest' (Hutan Rayat); Sungai Penuh and Air Hangat sub-districts.

Sub-district	1991/92	1992/93	1993/94	1994/95	Total
Sungai Penuh	-	275 ha	75 ha	160 ha	510 ha
Air Hangat	315 ha	-	200 ha	318 ha	848 ha

Source: District Forest Office, Sungai Penuh.

2. Sample Unit Conservation (UPSA: Usaha Pelestarian Sumberdaya Alam). This project focuses more on soil conservation than the one above, and involves annual crops (peanuts, chili, tomato, melon), perennial crops (coffee), fruit trees (*Nephelium lappaceum*, mango, cinnamon), and grasses (elephant grass). Around 2000 ha have been planted since the project started in 1991. The farmers are given seeds, fertilisers, financial support and equipment (hoes) for terracing and cultivation of grasslands. One unit (10 ha) is financed with a maximum of 8 million rupiah, depending of the slope of the lands (steeper lands means more support). One unit may consist of several farmers. Because of the high amount of financial support, the program has been relatively successful (60%).

3. Seeds to farmers (Kebun bibit desa). In this program farmers are provided with seeds. Total area planted since 1991 is around 4000 ha. Except seeds (normally 1650 per ha), no other support is given. The seeds are of different kinds of multi-purpose tree species (MPTS). Timber trees accounts for 40%, and fruit trees 50%. The rest is elephant grass. The program has not been successful. The main reason is said to be similar as for program 1: The farmers only want to plant cinnamon. In some cases cinnamon has been planted within the national park. As a consequence, the government has reduced the number of cinnamon seeds given to each farmer. For the future, the authorities are planning to increase the support for maintenance. One tree might need 500 rupiah for maintenance, while today it is supported only with 20 rupiah.

Other government plans. From next year (1996), government plans include introduction of 1) silk worms and white mulberry tree (*Morus alba*)[28], and 2) bee farming. The objective of introducing these new systems is to increase the income of the farmers in order to reduce encroachment within the national park.

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[28] The silk worm / *Morus alba* system is expected to give rapid and high economic outputs. It takes 20 days to 1 month to get cocons. Production costs are low: 1 box of silkworms (20 000 silkworms) costs 25 000 rp. + maintenance of *Morus alba*. The cocons have a high value. 1 kg cocon is worth 4000-5000 rp., depending on quality and size. 1 box can generate 10-20 kg cocons per harvest (20 days - 1 month). Average profitability is thus: (4000 x 15 - 25.000) rp. = 35 000 rp. 4 kg cocon gives 3 kg silk cotton. 1 kg silk cotton is worth 45 000 rp. (Prihatono pers.comm.).

4.3 DISCUSSION OF FEASIBILITY

Costs and benefits of reforestation

In a climatic change perspective, three aspects are important. First, reforestation of the grasslands will sequester carbon and increase the above- and belowground carbon storage. Secondly, if the grasslands are used more intensively, the pressure on the national park could be reduced. Both factors are important for carbon sequestration strategies. Besides these aspects, it is clear that if reforestation contributes to increasing the welfare of the communities, it will also increase their reciliency towards potential climate changes.

The potential environmental benefits of reforestation include (a) soil conservation, (b) watershed conservation, and (c) biodiversity benefits.

(a). Establishment of a tree cover would be beneficial both for soil fertility and structure. Still, strategies must be carefully planned: a tree cover *alone* does not necessarily give these benefits.

(b). The rivers in the enclave drain to the east, and the area is a part of the watershed of the Batang Hari river. One major reason for choosing Kerinci was that land use changes here in the upper parts of the watershed are considered to have greater impact on the water flow than changes in lower lying areas. A forest cover acts as a buffer against fluctuations in water supply and contributes to reducing the flooding problems in the lower lying parts of the district, as well as stabilises the local climate. However, efforts in Kerinci must probably be joined by efforts in other districts to give a significant effect.

(c). Reforestation would provide timber and other products which today are collected in the forest. This could reduce pressures on the forest areas, but the overall effect will also depend on other factors such as population growth and enforcement of forest boundaries. Furthermore, a tree cover of secondary forest could act as a buffer zone for the national park and reduce the negative ecological effects created by the sharp edge at the forest margin.

Even though the farmers are able to overcome the problems of developing grasslands into more productive lands, it is clear that support is needed in order to enable the farmers to intensify the cultivation systems and in turn increase their welfare.

Strategies for reforestation

Strategies for reforestation should be small-scale in nature and based on close cooperation with the local farmers. The reasons for this include: 1. The individual farming plots are small and the lands are owned by community members through a system of traditional rights; 2. Grasslands are found in relatively small patches and complexed with bushlands, patches of trees, and cultivated (*ladang*) plots. 3. Population pressure on land is relatively high and has been increasing in recent years. 4. Industrial timber management is constrained by steep slopes with difficult accessibility, long distance to main markets and lack of an established timber industry in the region. The risk of facilitating illegal logging is also a reason why the government does not want to encourage a local timber industry (Prihatono, pers.comm.).

The two crucial factors for reforestation success are establishment and maintenance. Lack of capital limits the farmers' ability to invest in management tools and equipment. Therefore, it is obvious that financial support is needed in the establishment phase (for fertilisers, technical equipment, herbicides, etc.). The impression is that farmers in the region have good knowledge about planting and maintenance of tree crops. Still, technical support may be important, e.g. if new tree species are introduced.

Motivation for maintenance is maximised by rapid, secure and continuous returns of economic or non-economic goods from the planted species. The alternative value of land is relatively high, and farmers will probably be reluctant to invest time and money in reforestation programs unless there is a security against losses if the program fails. Control of fire is the main factor for the establishment of a permanent tree cover. To a large extent this will be achieved once farmers see the benefit of controlling fire in the planted areas. Still, support may be needed to improve the existing methods of fire control.

The high economic returns from cinnamon plantations give strong incentives for the farmers to grow monocultures of this species. One should be aware of the environmental problems of monocultures and the economic risk of relying only on one commodity. Thus efforts should be made to encourage diversification of the sources of income and subsistence goods in order to increase flexibility. One challenge here is to preserve and develop indigenous agroforestry systems. At the same time, it should be investigated how cinnamon plantations could become more environmentally sound, e.g. by 1) growing cinnamon in mixture with other species (which is done today in the agroforestry systems), or 2) diversifying the age distribution of the cinnamon stands e.g. through strip planting, because uniform age distribution and simultaneous harvesting create large environmental problems.

The importance of considering agricultural development and forest protection jointly has often been mentioned (see e.g. Murray 1993). A study from Muara Hemat village in Gunung Raya sub-district, revealed that excess labour from October to April resulted in increased pressure on the forest (WWF and PHPA 1994). The challenge is to create a more even distribution of labour throughout the year, and to transfer abundant labour force to existing cultivation lands rather than the forest (WWF and PHPA *op.cit.*). Reforestation strategies will likely include both trees and crops, e.g. by using local agroforestry systems. Crops are important as they give immediate and continuous returns to the farmers. The selection of trees and crops to be planted should be developed in close cooperation with the farmers. Furthermore, the farmers should be fully responsible for the implementation. Reforestation implemented by forest agencies alone, which has been the case in many of the earlier reforestation projects, may create a feeling that the foresters are the only ones responsible for plantation management and maintenance.

The next project phase should be coordinated with the management of the national park, including NGOs (such as WWF in Sungai Penuh[29]). Cooperation with these institutions may lead to more focus on biodiversity conservation in the next phase. It may be assumed that the pressures on the national park will not decrease under present conditions because the forest appears to be more attractive for cultivation than grasslands. Two management options are (1) Provision of strong incentives for reforestation of grasslands in order to make national park encroachment less attractive; (2) Give the farmers rights to sustainable use of the forest resources. When traditional rights that do not threaten the 'integrity' of the ecosystem are recognised, farmers will have better incentives to protect the forest from unsustainable resource utilisation practices.

[29] The WWF office in Sungai Penuh was established in 1990.

5. NANGA PINOH, WEST KALIMANTAN

Summary

The study area represents 1000 km^2 (100 000 ha) in Sintang district dominated by Imperata (alang-alang) grasslands and bushlands (semak belukar). Reforestation efforts started in 1976 through the Inpres[30] project. The forestry company PT. (Persero) Inhutani III took over the area in 1986, and the lands are currently managed as an industrial timber estate (HTI plantation). The Inpres plantations suffered from uncontrolled burning and have largely been unsuccessful. Although fire is the direct causal factor, farmers say the plantations were unsuccessful due to lack of information to villagers, lack of cooperation between the authorities and the people, and lack of other kinds of support to the villagers. Up to now, plantation species have mainly been Acacia mangium and Pinus merkusii. After 1994 Inhutani has introduced other species such as Gmelina arborea and rubber (Hevea brasiliensis).

The area has a low population density, with an (estimated) average of 10-15 persons per km^2. Most people live along the Melawi river, which divides the area into a northern and a southern part. Farmers in the area say they have lost lands due to the plantation activity, but the general impression is that villagers would accept and support reforestation efforts if they get appropriate compensation for the loss of land, e.g. in the form of employment, support for rubber plantations in the village lands, support for other subsistence and cash crops (fruits, wetland rice), and for building of houses. Young Imperata shoots are currently used for animal fodder, while the grass represents a problem weed in the cultivation fields.

Discussed strategies for reforestation fall into two main categories: (1) plantations with villagers as labourers, and (2) village woodlots or agroforestry systems. Natural regeneration should also be considered. Fire is the main factor determining the success of plantations. It is clear that effective fire control requires that farmers see the benefit of protecting the plantations.

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[30] INPRES = Presidential Instruction (*Instruksi Presiden*)

5.1 LOCATION AND PHYSICAL DESCRIPTION

The study area is located between 111°40'-112°15' east longitude and around 00°10' south latitude in Sintang district, West Kalimantan (Figure 5:1). The city of Nanga Pinoh is situated along the river Melawi at the western edge of the study area, 30.9 metres above sea level. The road distance from Nanga Pinoh to the province capital Pontianak is 459 km, and to the district capital Sintang 69 km. The road is asphalted and has an overall good condition. From Nanga Pinoh the study area can be reached either by road (via Blonti / Nanga Mau or Kebebu) or by boat along the Melawi river.

The legal status of the area is for the most part Limited Production Forest (*Hutan Produksi Terbatas*); the rest is Regular Production Forest (*Hutan Produksi*). It is currently managed by a state-owned forestry company (PT. Inhutani III) under a HTI (*Hutan Tanaman Industri*) plantation scheme (Appendix 2). The area is divided by the river Melawi into a northern (Nanga Pinoh North) and southern part (Nanga Pinoh South). The area is located in 4 sub-districts, of which Nanga Pinoh accounts for the largest share. The other sub-districts are Kayan Hilir, Ella Hilir and Kayan Hulu.

The total area of Nanga Pinoh North and Nanga Pinoh South is 100 000 ha (target area). The area is generally flat along the river (sloping 0-2%). To the north and south the landscape becomes more hilly with the topography varying from flat to rolling (sloping 2-15%) (Pemda Sintang 1994). The soils in the area are generally infertile red-yellow podsols, with a pH around 4,5 (Table 5:1). The climate types in the region are B_1 (a zone along the Melawi river) and A, which means that the dry season is normally less than 2 months (Oldeman *et al.* 1980)[31]. Average annual rainfall for the years 1988 to 1993 was recorded at 3.671 mm for the Sintang district as a whole. The highest rainfall was measured in December (376 mm and 20 days with rain) and lowest in June (181 mm and 10 days with rain) (Pemda Sintang 1994). At the meteorological station in Nanga Pinoh the mean monthly temperatures for the years 1985 to 1995 varied between 25.1°C and 27.7°C, with an average of 26.5°C (Sub-district office, Nanga Pinoh).

[31] Cited by Pusat Penelitian Tanah (1984)

Figure 5:1. Location of study area (Inhutani III concession area) within the sub-districts Nanga Pinoh, Kayan Hilir, Kayan Hula and Ella Hilir. Ng.=Nanga. *Source: Peta Pembangunan Hutan Tanaman Industri PT. Inhutani III, Kabupaten Dati II Sintang, Propinsi Kalimantan Barat.*

Land use. Cultivated areas in and around the villages include shifting cultivation (*ladang*), wetland rice fields (*sawah*), and rubber plantations. However, the main part of the study area consists of *Imperata* grasslands, bushlands (*semak belukar*) and secondary forest. (See also sketch map below). The southern area has a larger share of bushlands and secondary forest than the northern area. Estimated areas of land use and vegetation types in the sub-districts Nanga Pinoh, Kayan Hilir, Kayan Hulu and Ella Hilir are shown in Table 5:2.

Table 5:1. Soil chemical parameters for soils at three locations in Nanga Pinoh, West Kalimantan.

Location no.	Depth (cm)	C-org (%)	N-org (%)	P- avl (ppm)	K (meq /100g)	Ca (meq /100)	pH (H_2O)	pH (KCl)
I_1	0-25	6.60	0.29	29.44	0.41	2.48	5.40	4.10
	25-60	1.60	0.16	17.99	0.14	1.65	5.50	4.10
	> 60	0.90	0.10	2.17	0.16	2.07	5.60	4.10
I_2	0-25	6.56	0.32	18.11	0.37	1.87	5.40	4.20
	25-60	1.53	0.15	7.19	0.16	2.06	5.10	4.40
	> 60	0.78	0.10	21.89	0.15	1.67	6.00	4.40
I_3	0-25	6.93	0.29	7.30	0.37	2.09	5.20	4.40
	25-60	1.10	0.14	51.12	0.15	1.83	5.50	4.50
	> 60	0.64	0.08	21.80	0.15	1.61	5.50	4.50

Location: I_1 = Near BC Kebebu, I_2 = Between BC Kebebu and BC Blonti, I_3 = Near BC Blonti. avl = available, org = organic. *Source: Draft Report, Forest and Nature Conservation and Development Center, Bogor.*

Table 5:2. Land use, Sintang district, 1993. All figures in hectares (ha).

Sub-district	Village	Wetland rice (*Sawah*)	*Tegalan*	Shifting culti-vation	*Perke-bunan*	Mixed garden	*Imperata* grass-lands	Bush-lands	Re-growth	Secon-dary and Primary forest	Plan-tation forest	Total area (ha)
Kayan Hilir	775	1569	606	1069	1207	34	500	970	39775	47165	20000	113670
Kayan Hulu	197	322	222	1056	7635	32	5050	2403	43600	33233	-	93750
Ella Hilir	140	1307	1500	1488	2044	325	38200	682	2614	65290	80	113670
Nanga Pinoh	3230	1561	1569	960	2156	224	32410	7746	113184	71200	9580	243820
Total	4342	4759	3897	4573	13042	615	76160	11801	199173	216888	9660	564910

Source: Pemda Sintang (1994).

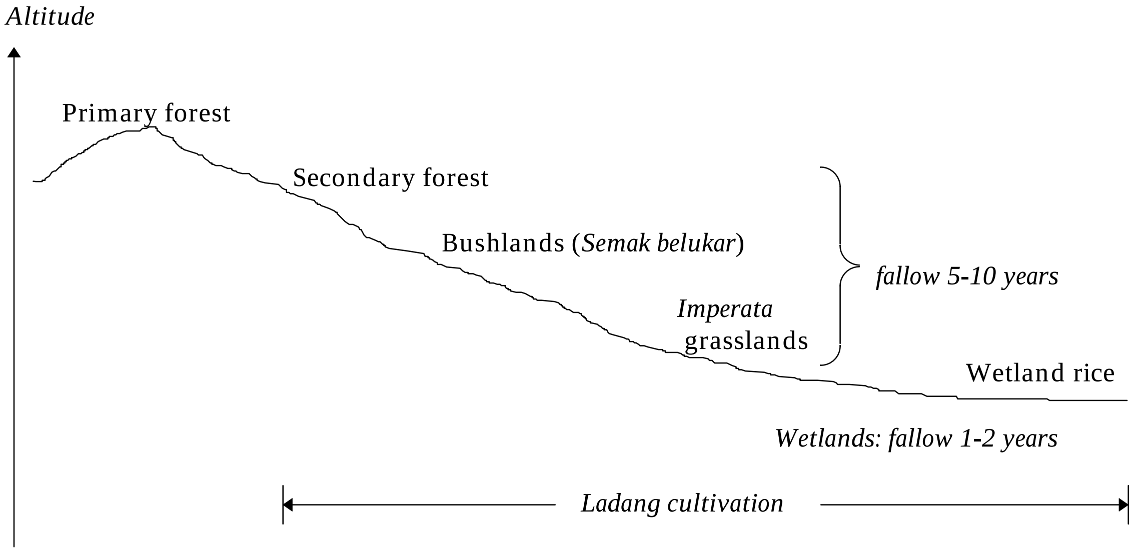

Figure 5:2. Sketch map showing variations in land use and vegetation pattern in the region with altitude and topography. *Source: Setiadi (pers.comm.)*

Agricultural systems. Traditionally, the people in the region practice shifting cultivation(*ladang*). In addition, there are significant areas with more recently introduced wetland rice (Table 5:2). The available area for shifting cultivation was reported to be around 5 ha per household. After cutting of the vegetation, fire is used to prepare the land for cultivation. Farmers use a hoe or a stick to plant rice, commonly in association with maize. The lands are cultivated for 1-2 crop rotations. The lands are then abandoned and new areas are cleared. The fallow period for dryland (hill) areas was said to be 5-10 years and 1-2 years in wetter areas. Close to the villages farmers have mixed gardens where they plant fruit trees (such as banana, coconut, mango, *Durio zibethinus*, *Artocarpus integra*, *Nephelium lappaceum*, and *Eugenia sp.*), vegetables and rubber. Rubber is the main cash crop. Villages close to Nanga Pinoh also sell rice, bananas and other fruits on the market. Fertilisers are not traditionally used, but some farmers said that they got fertilisers from the agricultural department in Nanga Pinoh and Inhutani which they used in crop fields and rubber plantations. The main livestock animals include cows (sapi), ducks, hens, goats, and pigs (non-muslim communities).

Land use rights. The indigenous inhabitants in the area regard all lands to be their lands, regulated through informal arrangements and inherited rights (*hukum adat*) which are approved by the village headman. However, as mentioned above the formal land owner is PT. Inhutani III, and only land near the villages is regulated for *hukum adat*. Only a few of the villagers have an owner certificate. Near the city of Nanga Pinoh, property certificates are more common and informal customary land tenure less important.

Population. The total population of the four sub-districts Nanga Pinoh, Kayan Hilir, Kayan Hulu and Ella Hilir is 88.542 (Table 5:3). The population density varies between 11.2 to 18.9 persons per km^2. In Nanga Pinoh sub-district the population has increased from 33.470 in

1990 to 38.752 in October 1995 (Sub-district office, Nanga Pinoh). Transmigrants (including people from Java, Sumatra and Kalimantan) to Nanga Pinoh mainly settle in the village of Tanjung Sari, which is located outside the study area. In the study area, indigenous people (often referred to as *Dayak* people) form the majority of the inhabitants. Some immigration was reported, mainly from the same sub-district, but the overall population increase is rather small.

Table 5:3. Population and area data for 1993[1)].

Sub-district	Area (km^2)	Total pop.	Pop. density (persons / km^2)	Male pop.	Female pop.	No. of house-holds	Villages (desa)	Village subdiv. (dusun)
Kayan Hilir	1136,70	19 287	16,97	9837	9450	3444	13	44
Kayan Hulu	937,50	17 744	18,93	9196	8548	3808	14	48
Nanga Pinoh	2438,20	38 752	15,89	19 852	18 900	9432	21	74
Ella Hilir	1136,70	12 759	11,22	6594	6165	2610	8	74
All sub-districts	5649,10	2628	15,67	6594	6165	19294	56	240

[1)] Population data for Nanga Pinoh is from October 1995. *Source: Data Hasil Sosek Data Pokok Tahun 1993 and Sub-district office, Nanga Pinoh.*

Table 5:4 shows population and population density in the villages in Nanga Pinoh sub-district that lie within the Inhutani area. The main share of the population inhabits the area along the Melawi river. In Nanga Pinoh city, a large part of the population is employed in other sectors than agriculture and forestry (petty business, governmental employees, etc.). When excluding the city from the calculations, the population density of the villages close to the concession area is 11.9 persons / km^2. In Nanga Pinoh sub-district the average income amounts to 125 000 rp. / month. While working in the Inhutani plantations (2-3 weeks a year), farmers earn between 7000 and 10 000 rp. per day.

Table 5:4. Population and population density in villages where village area is affected by the Inhutani area, Nanga Pinoh sub-district.

Village name	Area (km^2)	No. of sub-divisions (dusuns)	Population oct. 1995	Population density (persons / km^2)
Engkurai	174,560	3	1072	6,1
Sungai Pinang	176,560	3	1873	10,6
Nanga Man	152,560	4	2005	13,1
Manding	106,560	3	1248	11,7
Nanga Kebebu	90,560	3	1293	14,3
Tanjung Paoh	92,560	4	2027	21,9
Takela[A)]	39,560	3	1359	34,4
Tengkajau	122,560	3	1249	10,2
Nanga Belimbing	114,560	4	1503	13,1
Paal[A)]	30,560	3	5131	167,9
All villages	1100,6	33	18760	17,04 (without Paal and Takelak: 11,91)

[A)] Part of Nanga Pinoh city. *Source: Fakta dan Analisis, Kecamatan Nanga Pinoh (1995); Data Kependudukan, Nanga Pinoh, 1995/1996.*

5.2 *IMPERATA* GRASSLANDS

The total estimated grassland area in the four sub-districts is 76 160 ha or 13,5 % of the total area (Table 5:2). Existing maps for land use and *Imperata* grasslands are not very detailed, focusing on district level and including both bushlands (*semak belukar*) and *Imperata* grasslands. As seen from Figure 5:3, most of the study area is classified as '*Imperata* grasslands and bushlands'. This coincides with our observations, although it should be noted that there also exists areas of secondary forest and small remains of the Inpres plantation[32]. The area planted by Inhutani in the years 1991/92-1995/96 amounts to 24 885 ha (Table 5:5). There are no available statistics on the level of success of recent plantings.

Figure 5:3. Land use and vegetation, Sintang district. *Source: Pemda Sintang (1994).*

According to the farmers there have been *Imperata* grasslands in the region for at least 50-60 years, or maybe longer. They generally relate the origin of grasslands to increased uncontrolled burning in the shifting cultivation fields. *Imperata* is commonly associated with other fire-resistant grasses and shrubs. In Nanga Pinoh, plant species in addition to

[32] Estimated at 7000 ha, see above.

Imperata cylindrica are *Nauclea sp.* (karamunting), keleban, and resam. Distribution and occurrence of plants and animals in the grasslands are generally determined by fire frequency, in addition to how long time the grasslands have been sustained. Farmers say there are some bird species in the grasslands, but nearly no other animals such as deer or wild pigs.

As mentioned above, fire is used intentionally in the shifting cultivation system. Farmers said that fire could be controlled. Some claimed that uncontrolled fires were a bigger problem earlier than they are today. To control fire the villagers work together in groups of 15-20 persons, and cooperate with Inhutani and the local police. If fire is prevented, bush and shrub vegetation establishes after 4-5 years. It is known among the farmers that when the vegetation reaches a height of 1-2 m, *Imperata* will disappear. Due to the poor soil conditions in the area, natural establishment of a tree cover is expected to take at least 10-20 years.

The young shoots of *Imperata* are to some extent used by the farmers as cattle fodder. One village reported that because of the plantations cows are now kept within the village area and are no longer allowed to graze in the grasslands. No other uses of *Imperata* were reported in this area.

Imperata is a problem for the farmers, both as it is difficult to eradicate in new lands and because it had a negative effect on the rice growth. Around rice plants, *Imperata* is removed manually, but the extensive root system and the rapid regrowth makes the control difficult. Farmers did not report any other measures (e.g. herbicides) for the control of the *Imperata*. After invasion of *Imperata* and decline in soil fertility the lands were left for fallow and new lands cleared. Erosion is a problem, but farmers in the area do not have any special measures to control loss of soil and nutrients but leaving the land to fallow.

Attitudes to reforestation. Farmers generally said they had lost lands due to the plantation activity. One farmer said that “Inhutani took the hills”, and as a result only the wetlands are now available for *ladang* cultivation. No compensation for the loss of lands has been given, but villagers are employed in the plantations for 2-3 weeks a year for 7000-10000 rp. per day, which gives a significant contribution to their income. Some of the villages have got support in the form of building materials, loans, facilities for sport activities etc. Inhutani has also given promises to provide the farmers with rubber plants for the coming years, for which the farmers now were preparing the lands.

The general impression is that the local communities support the Inhutani plantations in the *Imperata* grasslands provided they get something in return for the loss of lands. Farmers put weight to the following factors for whether reforestation would be successful or not: (a) provision of information about the activity to the farmers, (b) compensation in the form of employment, (c) provision of rubber and fruit seeds / plants, (d) building materials, (e) assistance for establishing wetland rice fields, and f) support for establishment of wood processing facilities.

History of reforestation. A governmental survey held by the Ministry of Forestry started in 1976. As a result of the survey the large grassland areas were classified as 'critical lands'. Shortly after the regreening project *Inpres Penghijauan* (presidental instruction) started, receiving financial support from logging concession taxes and royalties. From 1978 the plantation borders were planted with *Acacia mangium* (called 'the green line') in order to serve as a fire break for plantations of pine trees (*Pinus merkusii*). Establishment of the *Pinus* plantations began in 1981/82. The 'green line' proved unable to protect the plantations from fire. In 1995, only around 7000 ha[33] of the *Pinus* area (33 419 ha) from the *Inpres* project still remained. Inhutani III took over the lands in 1986 and started the planting program in the early 1990s. From 1994/95 *Gmelina arborea*, rubber, and several other species have been introduced in addition to *Pinus* and *Acacia* (Table 5:5). Current plans are that 60% of the plantings will be of *Pinus merkuusi*, 30% of various species (*Acacia sp., Gmelina arborea, Ochroma lagopus, Swietenia spp., Antocephalus chinersis*), and the remaining 10% of rubber. Instead of the 'green line', Inhutani has constructed roads to act as fire breaks (called 'yellow lines' due to the soil colour).

Table 5:5. Reforestation in Nanga Pinoh (north and south), 1978-1995[1)], Inpres and Inhutani III plantations.

Project	Year	Species (ha)				
		Acacia mangium	*Pinus merkusii*	*Gmelina arborea*	Rubber	Other [2)]
Inpres	1978/79	5700,00				
	1979/80	2700,00				
	1980/81	3390,00				
	1981/82	1606,87	1367,00			
	1982/83		8533,00			
	1983/84		8928,70			
	1984/85		171,50			
	1985/86		50,50			
	1986/87		6353,60			
			3146,40			
	1987/88		3659,01			
			1000,00			
Inhutani III	1991/92	1482,24	4824,46			
	1992/93	0	6045,12			
	1993/94	1930,61	4088,34			
	1994/95	1201,74	4651,43	28,01	227,18	342,50
	1995/96	0	64,23	0	0	0
TOTAL	1977-1996[1)]	18011,46	52883,29	28,01	227,18	342,50

[1)] Data is lacking for the years 1989-1991.

[2)] *Albizia sp., Peronema cannescens, Ochroma lagopus, Swietenia spp.*

Source: 1) Inpres: Laporan Proyek Reboisasi DAS Kapuas Propinsi Dati I, Kalimantan Barat, 1988. 2) Inhutani III: Realisasi Tanaman HTI, PT. Inhutani III Unit Pontianak. 1995.

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[33] Preliminary estimates

The following paragraphs present some preliminary results from ongoing and relevant research projects at Blonti Basecamp, Nanga Pinoh North:

1. Study of growth of 10 species (Desti, pers.comm.); *Gmelina arborea, Peronema cannescens, Acacia mangium, Durio zibethinus, Pinus merkusii, Albizia falcataria, Antocephalus chinersis, Swietenia spp., Ochroma lagopus,* and *Hevea brasiliensis* (rubber). All species are indigenous to the area. Initial treatments are 1) burning *Imperata*, 2) after 1 month roundup is used to kill new *Imperata*, 3) a hole is made and fertiliser added. 4) After 1 week, seedlings are planted. After that, the fields have been maintained by clearcutting *Imperata* around the plants once every 3 months. After 10 months, the species that grew best was *Gmelina arborea*, followed by *Antocephalus chinersis*, *Albizia falcataria*, and *Ochroma lagopus*. *Pinus merkusii* had the slowest growth of the species studied.
2. Another project studied performance due to variations in fertiliser input (Desti, pers.comm.): The growth of 6 different species was studied. Variations in fertiliser included 1) time of adding fertiliser, 2) dosis, 3) type of fertiliser. After 9 months, *Gmelina arborea* had the best growth, followed by *Ochroma lagopus, Acacia mangium, Antocephalus chinersis, Albizia falcataria,* and *Pinus merkusii*. The growth of the plants will be monitored for three more years.
3. A study of the growth of 19 types of *Acacia mangium* in grasslands (Desti, pers.comm.): 17 of the types originated from Australia, 1 from Papua New Guinea, and 1 was a local species. After 9 months, the species from Papua New Guinea showed the best growth. All species from Australia performed better than the local *Acacia* species.
4. Measurements of erosion in planted fields (Hendromono pers.comm.): Erosion was measured in fields planted with five different species: *Gmelina arborea, Pinus merkusii, Aleurites moluccana, Ochroma lagopus,* and *Peronema cannescens*. The *Gmelina* species originates from India, the others are indigenous. The fields were maintained two times a year, involving *Imperata* removal and adding of fertilisers. As in the other projects, *Gmelina* achieved the best results. This species has a deep root system which is beneficial for soil conservation. The seedlings were planted in December 1994 and the project will continue for five years.

5.3 DISCUSSION OF FEASIBILITY

Costs and benefits of reforestation

The Inhutani concession area covers 100 000 ha of which a major share consists of grass- and bushlands. The technical potential for CO_2 fixation can thus be assumed to be large. The people living in the area have limited income opportunities. Increasing land productivity by reforestation gives opportunities for increasing the income basis of the farmers, provided that the new practices are acceptable to the people. Establishment of a tree cover may provide an opportunity for improving soil conditions and checking erosion, conservation of water resources, and increasing the diversity of flora and fauna.

Establishment of a permanent forest cover for production of wood and other commodities means a loss of land basis for the traditional shifting cultivation practices. Implementation of large-scale plantations in the whole target area would be in conflict with the traditional rights and interests of the local people. Throughout history, land scarcity has been one of the driving forces for intensification of the agricultural systems. However, this is a transition that needs a long time period, while the implementation of current reforestation programs causes rapid changes in land use. Farmers' needs should thus receive considerable attention. To compensate for the loss of land and make the farmers able to develop on their own premises, technical and financial support should be provided, e.g. for establishing village rubber plantations and wetland rice fields.

The environmental benefits will strongly depend on the design of reforestation. Fire protection roads ("yellow lines") may increase erosion locally. To improve soil conservation and create favourable conditions for a diverse flora and fauna, a higher diversity of trees in the plantations should be considered. Monoculture plantations with single canopy structure will be unfavourable for soil conservation, as erosion susceptibility may increase compared to dense grasslands (cf. Young 1989). Monoculture plantations with exotic fast-growing species could in some cases be justified for a rapid outshading of *Imperata*. At the same time it has been argued that they may create favourable conditions for a more diverse tree species selection in later plantation rotations, or as a first step for natural regeneration of local tree species (Tampubolon *et al.* 1995, Kuusipalo *et al.* 1995).

Reforestation strategies

Two approaches are considered: (1) plantations where villagers work as labourers, and (2) village woodlots and agroforestry systems managed by the local people.

1. One strategy includes plantations where Inhutani is the owner and manager, and farmers are employed on contract-basis. This is the strategy which is currently undertaken by Inhutani. Farmers in the area say they have lost what they consider as their lands as a result of the plantation activities. It is clear that this strategy involves a large conflict potential, and the motivation of the people to protect the plantations will be low unless they get financial or other kinds of support for fire control. On the other hand, the employment in Inhutani plantations give significant contributions to the farmers' cash income. In addition, farmers were promised to get rubber plantations to be managed by themselves in the near future, which may at least in the short term reduce the potential for conflicts.

2. Another strategy is smallholder agroforestry systems. The main cash crop in the area is rubber, which the farmers want for developing their own village plantations. Much attention has been given to rubber agroforestry systems (RAS) in recent research for grassland rehabilitation (Bagnall-Oakeley 1995, Van Noordwijk *et al.* 1995b). See also section 2.5.2. Rubber represents a reliable source of income and fits in a strategy of developing existing systems because farmers often grow rubber trees in their shifting cultivation fields. Similarly, the complex systems increase productivity at relatively low costs and provides a wide range of benefits, including fruits, timber, soil conservation and biodiversity. Village plantations of RAS seem to be an interesting option for reforestation of grasslands in the area, but more information is needed on how the systems are managed at present and what kind of support is needed.

Farmers need a clear and secure recognition of rights to their cultivation lands. Rubber agroforestry systems would increase land productivity and may reduce the use of fire in shifting cultivation practices. The systems also increase flexibility and income diversification, which in turn could reduce economic risk. The large area and the low population density imply that plantations may be feasible, at least in some parts of the area. Several requirements for the success of plantations were mentioned by the farmers (see above), including compensation for the loss of land and various kinds of support. Furthermore, the feasibility of plantations will be decided by the environmental soundness and economic viability. Opportunities for natural regeneration, possibly facilitated by enrichment planting, should also be considered. Earlier sections have discussed large-scale plantations versus smallholder, community-based plantations. The area is a HTI plantation, with Inhutani as the concession holder. Regulations should be put place to safeguard local needs and profitability demands. For the plantation work, job security and clear employment contracts are necessary.

Fire control. The most efficient means of controlling fire would be to reduce the use of fire as a management tool, especially for shifting cultivation. However, villagers will continue to practice shifting cultivation until they have more attractive alternatives. These practices will always imply a risk of uncontrolled burning. Although farmers have techniques to control fires in their own cultivation plots, they will be less concerned about the surrounding grass- and bushlands. Recognising land use rights of the communities and supporting cultivation systems that do not necessitate regular burning should be main priorities. Current means of controlling the spread of fire include roads used as fire breaks (‘yeIlow lines’), watchtowers, herbicides to kill *Imperata* in the planted rows, and penalties for those who causes the fire. The farmers said that fear of getting penalties made them more careful about when and how they burn the lands. These control measures may contribute to reducing the fire problem, but it appears that the problem of man-made fires will not be solved until the people who cause fire feel that the benefits of fire control exceed the costs. It is known from other places in Indonesia that putting fire to plantations is a way of protesting against reforestation. One positive motivation factor would be to grow tree species that are familiar to the villagers, and from which they will get benefits. This could be trees that Inhutani manages and the villagers use products from, or tree plantings owned entirely by the farmers. Another arrangement, which was observed in Riam Kanan, South Kalimantan (cf. chapter 6), is that farmers (on their own initiative) grow annual and perennial crops between the trees in the plantation. Where such systems are properly arranged and give increased crop yields, they give strong incentives for protecting the lands from fire damages.

6. RIAM KANAN, SOUTH KALIMANTAN

Summary

Riam Kanan is located in Aranio sub-district of Banjar district. The Riam Kanan water catchment, covering an area of around 1278 km^2, is of crucial importance for the water supply to the cities of Banjarmasin, Banjarbaru and Martapura, and reforestation of the region's Imperata grasslands is today a major priority.

In addition to the water conservation benefits, reforestation could potentially reduce forest encroachment problems and contribute to reducing erosion problems in the farmers' cultivation fields and sedimentation problems in the hydropower basin. Other benefits are improved habitats for wildlife and plants. However, large-scale implementation of plantations in the area is likely to have a negative impact on the local communities' welfare, as some villages already have limited agricultural areas. Moreover, current plans for implementation of the protection forest regulations would involve large social costs as the communities would have to move their households out of the area. A new government decree may however change these regulations.

Fire has been the major threat to the success of plantations. Since reforestation started in 1983, more than 40% of the plantations have failed due to fire damage. However, the underlying reason may not be that fire cannot be controlled, but that the people do not care for the plantations. Farmers say that lack of information, lack of maintenance, wrong species and inadequate financial support are the main reasons for failure. At the same time, some plantation areas had experienced success. This was due to farmer-initiated cultivation of annual and perennial crops between the trees, which in turn creates a strong incentive for fire protection.

Species for planting should be chosen on the basis of ability to withstand and outcompete Imperata, conservation criteria (soil, water, biodiversity), use for local communities, and fire tolerance. Recommended reforestation strategies include 1) Investigate potential improvements in the agricultural systems that could fulfill the functions of a tree cover concerning water and soil conservation, 2) investigate potentials for natural regeneration with participation of local people, 3) support and encourage farmers to plant annuals and perennial food crops within the plantations to increase motivation for fire protection, and 4) general improvements of the plantation management.

6.1 LOCATION AND PHYSICAL DESCRIPTION

Location and area coverage. The study was conducted in Aranio sub-district in Banjar district of South Kalimantan, located between 3°22’ and 3°41’ south latitude and 114°24’ and 114°55’ east longitude, and covering an area of 1166.35 km^2 (116 635 ha). See Figure 6:1. The whole sub-district is protected area, with the primary aim of securing the water supply for the region. Aranio sub-district lies within the Riam Kanan Catchment area (1278.33 km^2) (Said 1995). The artificial Riam Kanan lake was formed by the hydro power dam PLTA Ir. PM. Noor, finished in 1973. At the highest water level (HWL) the lake covers an area of 68 km^2 or 5.8% of the sub-district[34]. The altitude of the lake is 52.00 metres above sea level at the lowest water level (LWL) and 59.86 m at HWL. The Riam Kanan catchment area provides water for domestic use, irrigation and hydroelectricity, and is of major importance for the region. The population of the cities Banjarmasin, Banjarbaru and Martapura is 952 053 (Bappeda Dati I Kal-Sel, 1994). 39 872 ha[35] of Riam Kanan catchment area are classified as ‘critical lands’, having particularly high priority for conservation. The classification is set according to three criteria: 1) slope, 2) soil characteristics, based on vulnerability to erosion, and 3) average rainfall (Said 1987).

Population. The total population of Aranio sub-district is 7702 (October 1995), spread over 12 villages[36] (see Table 6:1 below). The villages were relocated when the upper parts of the valley were submerged after the dam was built. The overall population density is 6.6 persons per km^2. The population size is rather stable. In the period 1987[37]-1995, population decreased by 1.2%, from 7797 to 7702. There is occasional immigration from neighbouring districts, and some also come from Java and Madura. Javanese and Madurese people are known to be better farmers than the Banjarese. According to the sub-district office in Aranio, around 90% of the people are indigenous *Banjar*. The remaining 10% consists of people from Java, Madura as well as some *Dayak* people. 99% of the inhabitants are muslims.

Sources of income. Farming is the main occupation in the area, employing around 80% of the labour force. The most important cash crop is peanut. Other sources of income include water melon, various fruits, rattan, salary from reforestation projects, livestock sale, fisheries, boat operating, and some diamond mining. Due to the conservation status there is no logging consessions in the catchment area, but illegal logging represents a problem. The average income per household is recorded at around 1 million rupiah per household per year, with large differences between sectors.

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[34] This number has recently been revised down from 92 km^2 (Regional Planning Office, Banjarmasin).
[35] The estimate is based on a water basin area of 92 km^2.
[36] According to sub-district office in Aranio. Other sources uses a number of 14 villages: Anawit and Manunggal is added to the villages in Table 6:1.
[37] Source of 1987 data: Pemerintah Daerah Tingkat II Banjar.

Figure 6:1. Map of Aranio sub-district including *Imperata* grasslands. *Source: Peta Rupabumi Indonesia, Edisi I-1991, and Peta Vegetasi Hutan dan Penutupan Lahan Propinsi Dati I Kalimantan Selatan.*

Table 6:1. Villages in Aranio sub-district, Banjar district.

Village	Total Population (October 1995)	Male	Female	Estimated time to sub-district office (hours)
Tiwingan Lama	930	478	452	0.5
Tiwingan Baru	659	339	320	1.0
Kalaan	590	294	296	4.5
Belangian	330	174	156	4.0
Benua Riam	593	281	312	4.0
Bunglai	978	500	478	2.5
Apuai	351	194	157	3.0
Rantau Balai	485	232	253	5.0
Pa'au	392	201	191	3.0
Artain	382	202	180	2.0
Rantau Bujur	818	371	447	4.0
Aranio	1194	614	580	0.03
Total	7702	3880	3822	-

Source: Data Monography of sub-district Aranio, Banjar district 1995, and Monography of villages in Aranio sub-district.

Infrastructure. From Banjarmasin and Banjarbaru, the area can be reached by road to Tiwingan Lama, and from there to the other villages by boat. The distance from Banjarbaru to Tiwingan Lama is 25 km. The road is asphalted and in good condition. It is also possible to reach the area by car through Riam Kiwa valley to the villages of Rantau Balai and Rantau Bujur, but from Riam Kiwa to the villages the road is in a very bad condition.

Topography, geology and soils. We have divided the area into three main zones (Figure 6:2):

(1) North-northwest: Very steep hills (sloping 26-60%). The rocks are sedimentary, with tropodults and dystropepts soil types (USDA classification[38]) of fine to medium fine texture.

(2) In the 'middle' zone, around the Riam Kanan lake, topography varies from montaneous topograpy with sedimentary rocks and very steep hills (41-60%) to an area south of the lake with flat to undulating terrain (2-8%) and rocks of serpentinit, periodittt, dolerit and basal. The peninsula near the lake centre has a hilly landscape (sloping 16-25%) with metamorfic rocks. Soil types are tropodults, dystropepts and some tropoaquepts, with rough to fine texture.

(3) The south-southwestern part is montaneous, with generally more than 60% sloping. Rocks are mainly sedimentary, except for a section of ultrabasic rock (perioditt, serpentinitt, basal). The terrain lies more than 300 metres above sea level. Soil types are dystropepts, tropodults and paleodults, with fine to rough texture. (Pusat Penelitian Tanah, Bogor)

[38] Soil Survey Staff (1975)

Figure 6:2. Topography, geology and soils, central parts of Aranio sub-district. The classification refers to the text. *Source: Pusat Penelitian Tanah, Bogor.*

Climate. For the period 1965-1990, average annual rainfall in Aranio sub-district was recorded at 2548 mm / year, and temperatures ranged from about 26.1 to 30.3°C (Universitas Lambung Mangkurat and Kelompok Program Studi Lingkungan 1992). The region belongs to the agroclimatic zones C_1 and C_2, i.e. the dry season is normally less than 3 months (Oldeman *et al.* 1980).

Land use. Only the mountain areas and upper hillsides are covered by natural forest, although some scattered patches of secondary forest can be found in the lower lying areas. The areas around the lake are dominated by *Imperata* grasslands, bushlands, cultivated areas, and plantation forest areas. In the numerous smaller river valleys there are typically secondary tree species in association with cultivated plots, as farmers know that these areas provide favourable nutrient and moisture conditions.

Legal status. In 1985, 106 400 hectares of the Riam Kanan catchment area were included in the Tahura Sultan Adam Conservation Forest. According to the Presidental decree No.52 (1992), all of the Aranio sub-district (112 000 ha) and 87.6% of the Riam Kanan catchment area are now included in the Great Forest Park (*Taman Hutan Raya*), consisting of:

- Protection Forests (*Hutan Lindung*): 1) 55 000 ha established on the 8th of January 1975 (101/KPTS/VIII/1975), 2) 13 000 ha established 8th of May 1976 (SK-GUBJEND No.33 TH1976)
- Wildlife Sanctuary (*Suaka Margasatawa*): 36 400 ha, established on the 23rd of October 1980 (No.65/KPTS/Um/10/1980).
- Educational Forests (University of Lambung Mangkurat), 2000 ha established on the 31st of December 1980 (Governor decree No.44/PHT/1980)
- Other protected areas: 5600 ha.

In the protected areas, no human exploitation is permitted (Appendix 1). Current plans imply that people have to move out of the area. According to the Provincial Forest Office in Banjarbaru, implementation is planned to start in 1996. The destination is still under consideration. However, a new government decree, issued in september 1995, may indicate a change in this policy. The decree says that people would be allowed to plant multipurpose tree species on protected forest land, and to harvest non-timber products from those trees (Tomich pers.comm.).

Land use rights. Land tenure in the villages is arranged according to customary land rights. The status of Protection Forest implies however that the government is the formal owner of the lands, and does not accept the customary land ownership. Hence, no certificates are issued.

Agricultural systems. At present, the agricultural systems in Riam Kanan includes both permanent plots of fruit trees and other perennials (home garden and mixed garden), and traditional shifting cultivation (*ladang*) areas.

In and around the villages, farmers have permanent plots of home gardens or mixed gardens where they grow a mixture of crops for fruit, wood, and other purposes. Common crops include banana, rubber, mango, candlenut (*Aleurites moluccana*), durian (*Durio zibethinus*), and jackfruit (*Artocarpus integra*). There are large differences between the villages concerning development of these systems. Development of mixed garden systems have been hindered by the existence of more attractive alternatives for income generation (such as small scale mining activities), as well as the fact that the protection forest status means that cultivation is illegal. But in some villages, such as Rantau Bujur, the farmers have developed agroforestry systems.

In the shifting cultivation (*ladang*) fields, peanuts (main crop), rice and vegetables are planted together with fruit trees such as banana, papaya, candlenut (*Aleurites moluccana*), durian (*Durio zibethinus*), and rambutan (*Nephelium lappaceum*). The planting of perennial crops in the *ladang* fields, thus intensifying the land use, is reported to be a fairly new practice which mainly results from reduced land availability. The fruit trees are maintained for several years after the annual cropping is finished. The fields are generally opened through the following stages: (1) The first step is to cut the *Imperata* and trees/bushes. (2) Secondly, farmers make a firebreak around the area and burn the lands. Some use herbicides to kill *Imperata* 2-3 months after burning[39]. (3) Thirdly, the crops are planted by using hoe or a woody stick. Some farmers use cattle ploughing (see below), although it is expensive and difficult due to the steep and hilly terrain. 4) The cultivation plots are maintained for some years. After the cultivation period the lands are abandoned and new lands opened. The abandoned lands will quickly be invaded by *Imperata* and other pioneer grasses. Fruit trees are kept and maintained also in the fallow period. The length of the cultivation period compared to the fallow period depends on a number of factors including availability of lands, fertilisers, cattle ploughing and herbicides.

In Tiwingan Baru village, the *ladang* lands were organised into 50 metre wide strips on the hillsides. After the lands become depleted of nutrients, farmers move to a new strip next to the old one. This was a recently introduced method.

Some farmers cultivate lands along the lake where the fields dry up when water level is lowered during the dry season. This is fertile land because of the sedimentation of organic material. The time period before the water table raises allows farmers to grow seasonal crops such as beans, peanuts, maize, rice and various kinds of vegetables (Universitas Lambung Mangkurat and Kelompok Program Studi Lingkungan 1992).

Dove (1986) describes two main rotational agricultural systems in the Riam Kanan valley: 1) based on *Chromolaena odorata*[40] and secondary forest, and 2) based on *Imperata cylindrica*. The first is a traditional swidden cultivation system with a short cultivation period (10-20% of the time). Lands are left to fallow when nutrients are depleted and the lands invaded by *Imperata*. The fallowed lands are opened again when *Chromolaena* and/or ligneous growth (shrubs and trees) have replaced *Imperata. Chromolaena* is known to outcompete *Imperata* in the absence of fire. *Chromolaena*-dominated lands are easier to cultivate than *Imperata* lands.

The second system is more intensive (4-7 years cultivation and 3 years of fallow), implying cultivation of up to 70% of the time[41]. Lands are cultivated until *Imperata* is replaced by prostrate grasses which are more difficult to till or weed than *Imperata*, and cultivated again after *Imperata* returns. However, the system depends on ploughing and is only used by the farmers who own cattle themselves, or can afford to rent cattle or hire Javanese ploughing teams. The first system is found in the valley and close to villages, while the second dominates in more remote areas with less capital and more available lands per household. The view on *Imperata* is thus opposite in the two systems: In the first system, *Imperata* is the indicator of when the lands should be left to fallow, while in the other system *Imperata* indicates when lands could be cultivated again after the fallow period.

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[39] Van Noordwijk *et al.* (1995a) notes that this practice may reduce the amount of herbicides necessary to kill *Imperata* to the half.

[40] *Chromolaena* is a perennial shrub which was earlier known as *Eupatorium odoratum* L. (Holm *et al.* 1977, cited by Dove 1986).

[41] This system is hence not a shifting cultivation system, which is defined as having a longer period of fallow than cultivation (Suharti 1993).

In Artain village it was reported that land scarcity (due to reforestation programs) has resulted in more permanent cultivation, where fire no longer is used for opening the lands. Farmers instead use herbicides such as Round-up etc. in order to kill *Imperata* and other grasses. However, accidental fires still occur as a result of fish smoking, sigarettes, or spreading from neighbouring villages.

Each farmer was reported to have around 3-5 ha available lands for *ladang*. Although the population density is low, many villages have experienced a reduced availability of lands due to reforestation activities. Those who can afford it use herbicides (roundup) and cattle ploughing in order to increase the capacity of cultivation per year: If herbicides are used, farmers said they could open up to 2 ha/year, while without herbicides the capacity per year was reduced to less than 1 ha. Herbicides also provide opportunities for opening new lands that were too difficult to use earlier. Both herbicides and cattle ploughing are recently introduced methods. Fertilisers in use are Urea, TSP, and some KCl. Farmers rarely use animal manure, except for cultivation of areas after they have been grazed by cows. *Albizia procera* (Birik tree) is nitrogen fixing and is known among the villagers to increase the growth of rice (Akbar pers.comm.).

Changing to livestock production is a way of overcoming the difficulties of agricultural expansion caused by reforestation and watershed protection activities. It also reduces some of the problems of pest attacks on crops. Cattle is used for ploughing, which improves the cultivation system. Common livestock are cows, buffaloes, goats, hens and ducks.

6.2 *IMPERATA* GRASSLANDS

Distribution and patch size. It is claimed that there have been grasslands in the region since before Indonesian independence. Potter (1995) reports that frequent burning to ensure fresh feed for cattle was common in the Riam Kiwa valley already before 1860. This may in turn have resulted in expansion of *Imperata* grasslands. The lower parts of the valley were largely deforested by 1890. Since then, the grassland area has increased considerably (Potter 1987). In Riam Kanan, most of the areas on which the villagers settled after the dam was constructed were dominated by *Imperata*. Present distribution of grasslands can be seen in Figure 6:1. The total area (not included bushlands) is around 28 400 ha. Other available estimates for area coverage show large variations. For the water catchments of Riam Kanan and neighbouring Riam Kiwa, grasslands were in 1984 estimated to cover 23 233 ha or 7.6% of the area (Said 1987). If bushlands (*semak belukar*) are included, the area rises to 33 829 ha (11.13%). An estimate for the first established part of the Protection Forest (55 000 ha) in Riam Kanan watershed, indicates that 35 000 ha (63.6%) are *Imperata* grasslands (Dinas Kehutanan Propinsi Dati I Kal-Sel 1995).

Grasslands are found as large areas and smaller patches in the village *ladang* areas. The reforestation projects have resulted in local decreases in grassland areas. In Rantau Balai village, it was reported that the area of *Imperata* grasslands had decreased from 5000 ha in 1988 to 3000 ha in 1995 due to reforestation. Farmers also said that there were less illegal wood cutting now than before, which in turn contributed to reduction in the grassland areas. In Artain village, people said that the grassland area had decreased because it was outcompeted by another grass introduced by the Japanese[42].

Flora and fauna. Generally, the occurrence of plant and animal species is lower the more frequently the land is burned. Common grasses and shrubs associated with *Imperata* in the grasslands include: *Saccharum sp.* (gelagah), *Chromolaena sp.*, *Vernonia sp.*, and *Melastoma sp.* In areas where fire is excluded for one year or more, tree species such as *Vitex pubescens* invade (Akbar pers.comm.). Other trees found in grasslands and lands in early stages of regrowth are: *Schima walicci, Albizia procera, Macaranga sp.*, komoloko, and bangkirai. The fauna of the grasslands is poor compared to the nearby forest areas, and comprises only a few birds and mammals. Common animals are wild pig, mice, deer, porcupine, snakes, *Varanus salvator,* and *Mabuoya sp.* (kadal). Wild pigs, mice and porcupines represents a considerable problem in the cultivation fields. Deer can sometimes be a problem in the plantations by eating tree leaves.

Use of fire. The controlled burning period differs among villages, from the middle of the dry season (July/August) to one month after the start of the rainy season. Farmers work together in groups to control the fires. They make use of firebreaks, i.e. strips of lands around the fields where vegetation is removed before burning (called *Ilaran api*). In Tiwingan Lama, *Imperata* is cut and sun-dried before burning, because it is known that lands become easier to cultivate than if *Imperata* is burnt standing. In addition to water, tree branches and banana leaves are used to kill the fires at the sides of the plots. Wind speed and direction are also considered before burning. By using this system, farmers say that fire is easy to control. The current regulation on burning is that farmers have to report to the district forest office before burning. As mentioned above, in one village (Artain) farmers said they no longer used fire for land clearing. The problem of fire in reforestation projects is further elaborated below.

Use of Imperata. Imperata is used for roof covering for temporary houses in the *ladang* fields (one roof made of the grass lasts around 3 years). Young *Imperata* shoots are grazed by cows. In one village (Tiwingan Lama) it was mentioned that extract of *Imperata* rhizomes had been used as medicine in earlier times.

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[42] *Chromolaena* (shrub) is also claimed to be introduced by the Japanese, sown during World War II ("Japanese weed"). Dove (1986) found no evidence for this to be true. The author concludes that *Chromolaena* probably came as a consequence of changes in the agricultural systems (as a result of the Japanese administration) which reduced the fire frequency in grasslands. Reduced burning favours *Chromolaena* over *Imperata.*

Erosion. Terracing has been introduced in some villages to reduce the erosion problems in the area. Another measure is planting of perennial crop and tree species along the contours. It is known that for steep slopes, herbicide treatment is more favourable than ploughing or hoeing. For reforestation projects on lands with more than 25% sloping, only herbicides are used for land preparation (Akbar pers.comm.).

Farmers' view on reforestation. *Imperata* dominated grasslands are seen as wasted and useless lands, and in principle farmers welcome rehabilitation efforts, provided that they can keep their cultivation areas. The view on previous and ongoing reforestation programs was observed to differ among villages. Two views will be discussed in the following.

(1) In Rantau Balai and Rantau Bujur villages, people said reforestation had been successful. The main reason was said to be that farmers are allowed to plant annual and perennial crops under the plantations. The first 6-7 months they grow rice (main crop) and peanuts. After this period, farmers change to perennials such as coffee. These arrangements are at the villagers' own initiative, and they get no support from plantation companies or the government. The villagers are employed in the plantations around 4 months during site preparation and planting, and for some maintenance the first two years. After that no maintenance is undertaken. Some negative effects on villagers' cultivation lands were reported, such as loss of land and negative shade effects, but no compensation has been given. For the future, farmers hope they will keep their lands for shifting cultivation and that the plantations will have trees which are more useful for them. The farmers have been promised rubber and candlenut, but have up to now only got plantations with species that give little benefits to them. Other preferred species are coffee and durian (*Durio zibethinus*).

(2) In Tiwingan Lama, Tiwingan Baru and Artain people said they regard reforestation as positive because trees increase land productivity. The problem is lack of communication and lack of support for maintenance. People said they often had been surprised when reforestation started because they had not been informed about the project in advance. Therefore, they feared that their cultivation areas would be reduced. In addition, they did not know the tree species in the plantations. Furthermore, when employed in plantations they have experienced that although the salary budget is 5000 rupiah per day, they may only get 2000 rp./day by the field responsible. Consequently, farmers say they have lost their belief in reforestation projects. One proposal for improving plantation management was that the money for reforestation should be administrated through a local youth organisation (called *Karang Taruna*). Fire risk could also be reduced through removing a larger share of the grass under the plantation. In the villagers' own rubber plantations, farmers said fire was prevented because they continuously removed *Imperata* between the trees.

History of reforestation. The Inpres reforestation program started in the area in 1983/84 (Dinas Kehutanan Propinsi Dati I Kalimantan Selatan 1995). Since 1991, there have been reforestation projects supported by OECF (Overseas Economic Cooperation Fund[43]). Main tree species used for reforestation are *Pinus merkusii*, *Acacia mangium*, and *Eucalyptus sp.*;

[43] OECF is a project cooperation between Indonesia and Japan.

other species used are *Acacia auriculiformis*, *Albizia falcataria*, *Peronema cannescen*s, *Gmelina arborea*, *Durio sp.* (durian), *Aleurites moluccana* (candlenut), *Hevea brasiliensis* (rubber), and *Artocarpus sp.* (breadfruit).

Table 6:2 gives an overview of the reforestation project in Riam Kanan for the years from 1983 to 1993. The planted area is 20 724 ha, of which according to official statistics as much as 8580 hectares (41.4%) have burnt. The table shows that the OECF plantations up to now have been less subject to fire than the Inpres plantations (the share that has not burnt is 75.61%, compared to 45.2% of Inpres). The table does not, however, say how much of the planted area that has been *technically* successful. The overall success of the plantations, i.e. the remaining plantation area, may be as low as 10% of the original (Akbar pers.comm.).

Table 6:2. Reforestation in Riam Kanan.

Year	Reforestation program	Species	Planted area (ha)	Burned area (ha)	Remaining area (ha)
1983/84	INPRES	*Eucalyptus*	850	850	0
1984/85	“	“	500	500	0
1985/86	“	*Acacia sp., Pinus sp.*	500	500	0
1986/87	“	*Acacia mangium*	1700	133	1567
1987/88	“	“	750	750	0
1988/89	“	“	1575	52,5	1522,5
1989/90	“	“	2525	2223	302
1990/91	“	“	1700	537	1163
“ “	OECF	*Acacia mangium, Albizia falcataria*	3447	1899	1548
1991/92	Inpres	*Acacia mangium*	500	7	493
“ “	OECF	*Acacia mangium, Albizia falcataria*	2000	333	1667
1992/93	INPRES	*Acacia mangium*	1000	800	200
“ “	OECF	*Acacia mangium, Albizia falcataria, Gmelina arborea*, and other[A)]	3677	-	3677
Total			20724	8584,5 (41,4%)	12139,5 (58,6%)

[A)] Including *Durio zibethinus*, *Aleurites moluccana*, *Hevea brasiliensis*, and *Artocarpus sp.* (sukun).
Source: Dinas Kehutanan Propinsi Dati I Kalimantan Selatan, and Balai RLKT Wilayah VIII.

The Reforestation Technology Institute (BTR, *Balai Teknologi Reboisasi*) in Banjarbaru carries out research in Riam Kiwa on the use of natural succession for reforestation of grasslands, and involvement of local communities (Sagala 1995):

(1) Natural succession by using fire breaks (the Zoefri Hamzah model): To protect the fields from fire, the grasslands are divided into 5-20 ha large plots, using *Gmelina arborea* as fire break species. The concept is shown in Figure 6:3 below. The area for fire breaks is prepared through using herbicides, and is managed intensively for 18-20 months. In this way, natural succession will occur. The adjacent natural forests are important as dispersal centres for indigenous flora and fauna to the regrowing areas.

(2) Cooperation with local communities: *Gmelina arborea* and *Parkia javanica* are planted in rows in an agroforestry arrangement. Villagers are involved in managing the plots and trained in fire protection. Farmers protect and manage *Parkia* because the fruits have a reasonable price. Instead of *Parkia*, other species could also be used, e.g. *Artocarpus integra, Durio zibethinus, Aleurites moluccana, Mangifera odorata, Hevea brasiliensis,* and *Artocarpus sp.* (cempedak). The project also involves training the people to protect the field from fire, and planting of rattan to give additional income. One aim is to replace shifting cultivation by other cultivation systems.

In Riam Kanan, BTR is conducting research on mixed species plantations. Ongoing research projects are (Akbar pers.comm.): (i) Spacing trial of fire break border: The aim is to find a suitable distance between trees in the row. *Gmelina arborea* is planted in a randomized complete block design, with 3x2, 3x3, 3x4, 4x4 and 4x2 m spacing. (ii) Strip width trial of fire break borders: The aim is to find the most suitable strip width for fire protection. *Gmelina arborea* is planted in strips of 9, 12, 15, 18, and 21 metres. (iii) Mixed-species plantation trial, which aims at finding suitable species for mixed species plantations, including local species. The lay-out of the mixed-species plantations is shown in Figure 6:4.

Figure 6:3. Using fire breaks of *Gmelina arborea* for natural succession of grasslands, Zoefri Hamzah Model. *Source: Sagala (1995).*

Figure 6:4. Arrangement of tree planting, mixed-species plantation trial, Riam Kanan. Species: Gm=*Gmelina arborea*, Pt=*Parkia sp.*, Kp=*Ceiba petandra*, Kr=*Hevea brasiliensis*, Mg=*Acacia mangium*, Sg=*Peronema cannescens*, Mh=*Macaranga sp.*, Tr=*Artocarpus sp.*, Ps=pasang (local name), Br=*Albizia procera*. *Source: Akbar, pers.comm.*

6.3 DISCUSSION OF FEASIBILITY

Costs and benefits of reforestation

The potential benefits of grassland reforestation in Riam Kanan deviate little from the two preceding case studies. In addition to increased carbon sequestration and storage, reforestation would yield climate change benefits if it leads to reduced forest encroachment. It would also contribute to conservation of water resources, which is the main reason for the protection forest status and the governmental reforestation efforts in Riam Kanan. Furthermore, soil erosion represents a problem as it both reduces soil productivity and increases sedimentation in the hydropower basin. These problems could be reduced by establishing a permanent tree cover, and/or improving erosion control measures in the crop fields. Other potential benefits are improved habitats for wildlife and plants. However, the feasibility of reforestation will strongly depend on which strategy is chosen. Large-scale implementation of plantations is likely to have a negative impact on the welfare of the local communities. As mentioned above, some villages had lost a significant part of their cultivation lands to plantations. Moreover, present plans for implementation of the protection forest regulations would involve large social costs as the communities would be forced to move their households out of the area. Many of the villages were also moved when the dam was built in 1973. A new government decree may however change these plans, as mentioned in chapter 6.1 above.

Strategies for reforestation.

Recommendations for improving the management include:

1. Investigate potential improvements in the agricultural systems that could fulfill the functions of a tree cover concerning water and soil conservation. These are systems that would allow people to continue living in the area. Experiences from other places in Indonesia (e.g. Java and Sumatra) show that agroforestry systems have large structural similarities with natural forests, and could hence fulfill the same functions regarding soil and water conservation.

2. Investigate potentials for natural regeneration with participation of local people, particularly in areas where grasslands are still abundant. The overall population density is low, and natural succession may be feasible in some areas. Some villages also use natural forests as a supplier of fruits and other goods. Studies on methods for natural succession are undertaken by BTR in Banjarbaru. The results show that there may be opportunities to involve local people and minimise losses from uncontrolled burning.

3. Support and encourage farmers to plant annual and perennial food crops within the plantations to increase motivation for fire protection, as practiced in Rantau Balai and Rantau Bujur. These systems would also give soil conservation benefits, as erosion would be reduced and the input of organic material increased.

4. Improvements to the plantation management. These may be (a) planting of species that are more useful to the farmers, through providing fruits or other goods, than those currently planted. (b) Increase the species mix in plantations to reduce erosion, and increase the diversity of habitats for plants and animals. (c) Fire control measures, including fire-break borders with fire-resistant species (e.g. *Gmelina arborea*). The use of *Acacia mangium* plantations as fire break borders in Nanga Pinoh (chapter 5) was however not successful. (d) More information to farmers before planting and more discussions through the planning process, (e) more maintenance is needed in the plantations. (f) Further, an ‘executive body’ or business enterprise may be needed to coordinate the activity in the field.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 THE SITUATION

Large scale contiguous *Imperata* grasslands in Indonesia occupy around 8.6 million hectares of land of variable production potential. This area is considered by both the Government and the local authorities to produce less benefits to the local people, to the nation, and to the global community, than its potential as a reforested area. However, there are many stakeholders involved in these grasslands and their aims may be conflicting.

There are several ways that reforestation could yield climate change mitigation benefits, although with a varying level of confidence: (1) Increasing above- and below ground biomass in order to remove carbon from the atmosphere on a long term basis; (2) Increasing the productivity of the lands (e.g. through establishment of agroforestry systems) as a means of reducing pressures on natural forests and in turn lowering carbon releases from land conversion. (3) Producing durable products, replacing fossil fuels with fuelwood, and using wood instead of fossil fuel consuming products to maximise the carbon storage.

Rehabilitation of degraded grasslands through reforestation carries a significant potential for yielding benefits without regard to climate change. Properly managed, it may provide long term sustainable economic benefits to the country, and income generating opportunities and increased welfare for local communities. Furthermore, a forest cover could produce a number of goods and services such as timber and non-timber products, soil and water conservation, and biodiversity benefits.

Thus, grassland rehabilitation appears in most cases to be socially beneficial and economically a ‘no-regret’ option, which in terms of climate change implies that it could reduce net emissions of greenhouse gases at zero or negative costs. Still, there are institutional, economical and social barriers for its implementation. Costs and benefits of reforestation are distributed unequally in time and space, and the short term financial feasibility for the actors is not obvious. These obstacles make it necessary to give support in the establishment phase, as well as to provide incentives for long-term maintenance of the forested areas. Previous experiences have demonstrated that proper care of the social aspects and issues relevant to the local communities are key to a sustainable reforestation success.

This feasibility study has reviewed the most recent research works and studies on various aspects of grassland management. Consultations have been undertaken with people in the Government and in three remote grassland locations, one in Sumatra and two in Kalimantan. These locations differ in terms of population size, density and ethnicity, topography, grassland area and patch size, legal situation, applied management systems, and agricultural practices.

The common attitude among people in the three locations is that grasslands do represent a management problem, sometimes small, sometimes large. In all locations the grasslands were claimed by the local people for traditional use, mostly as a part of shifting cultivation systems. The grass is to some extent used as animal fodder and roof cover. Despite this, farmers would always welcome rehabilitation of the grasslands to forest cover if this would increase their income and welfare.

So far, reforestation efforts have been unsuccessful in a high proportion of the cases. The main reason for the failures is uncontrolled fire. Grasslands left to fallow and protected from fire will over time reestablish a forest cover through natural succession. Fires are partly accidental and partly a result of intentional actions to provide cattle fodder, clear lands for cultivation or hunt animals. The problem of man-made fires appears to be due to social constraints rather than technical ones, arising from a lack of support for large-scale reforestation efforts from the local communities. Farmers generally have measures to control burning in their own fields, but have few incentives to protect the plantations. This arises due to several factors, including (a) inadequate communication and cooperation between the government or the investor and the local farmers; (b) lack of established land tenure rights. Farmers have generally not been compensated for loss of lands, because traditional rights are not respected or legally accepted; and (c) farmers do not know the planted species and often do not believe that they will receive benefits from the plantations. Additional problems are lack of forest plantation maintenance, and inappropriate reforestation techniques and species selection.

7.2 RECOMMENDATIONS

1. *Reforestation of grasslands should be promoted, but only when it is socially, economically and environmentally justified.*

Reforestation cannot be justified on the basis of carbon sequestration alone. Reforestation strategies should contribute to economic and social development, and the local communities should receive adequate benefits from the activities. Reforestation should also be undertaken in a way that facilitates an increase in biodiversity and contributes to reducing pressures on natural forests. Strategies for reforestation may involve: (1) development of local agroforestry systems, (2) forest plantations, or (3) natural forest regeneration. Where appropriate, strategies may be used in combination. The choice of strategy will depend on economic efficiency criteria, on the preferences of the local communities, and on environmental impacts in the area. It seems clear that reforestation have the greatest chances of being successful when strategies are based on existing agricultural practices on the sites.

2. Priority should be given to the provision of incentives for local participation and to secure proper maintenance.

Reforestation should only be attempted when the local communities are in agreement with the reforestation proposal and support the investment. An absolute necessity is that the local people understands and have confidence in the efforts. Existing or potential conflicts that may hinder reforestation, either within communities or between communities and the investor, must be resolved prior to reforestation.

The economic risk carried by local participation in reforestation schemes should be minimised by giving appropriate financial and technical support throughout the establishment phase and later for reforestation maintenance. Priority should be given to strategies with low input and maintenance costs. Reforestation should aim at contributing to diversifying the farmers' income sources and should not limit the options for future development.

Clearly defined, legally accepted and adequately enforced land use rights are fundamental for any long-term planning and maintenance; for local farmers as well as for private investors. Specific arrangements for these rights will however differ with the conditions on the site.

3. Recommendations for the next project phase

A third phase of this project should be implemented. The main objectives will be to enhance local development, to monitor carbon sequestration of reforestation programs, and to assess the social, economic and environmental impacts linked to reforestation projects on degraded grasslands. Local capacity building will be a major thrust of the next project phase. The project work would assist Indonesian authorities in fulfilling the requirements under the Framework Convention on Climate Change (UNFCCC), and to facilitate development efforts in grassland areas.

Preferably one or two sites should be selected from the present three for inclusion in the next phase. This is in order to simplify management, have more frequent research monitoring and supervision, and improve communication. The site(s) should be monitored over a long time period in order to assess carbon sequestration and to evaluate the social, economic and environmental impacts linked to reforestation. All three sites studied in the present phase have projects for reforestation of the *Imperata* grasslands, but they have been largely unsuccessful so far. There are indications of changes toward more farmer-oriented reforestation strategies, including a selection of species that yield more benefits to the local communities. These projects could be good starting points for further work. The next project phase should therefore continue to monitor these programs at a low level in order to enable the use of data from those areas when developing the third phase case study project.

4. Strengthening of cooperation with other institutions

The existing research collaboration between the Indonesian Ministry of State for Environment in Jakarta and the Center for International Climate and Environmental Research in Oslo (CICERO) should be strenghtened. The project network should be increased to include the Center for International Forestry Research (CIFOR) and the Regional Office of the International Centre for Research in Agroforestry (ICRAF) in Bogor, as well as bilateral donors in Indonesia.

5. Specific recommendations for the three case study areas

Kerinci

- The main focus should be on refining the local agricultural systems.
- Attention should be given to improving the environmental soundness of cinnamon production.
- Research should be initiated for the use of new multi purpose tree species.
- Any reforestation program has to be coordinated with the national park management strategy. In the buffer zone grasslands adjacent to the National Park, natural regeneration should be the reforestation strategy, possibly supported by enrichment planting of indigenous tree species.

Nanga Pinoh

- The forestry company Inhutani III should increase the active participation of the local people. More benefits and responsibility to the local communities is expected to improve fire protection.
- More efforts should be placed on finding the optimal choice of species, using the results from ongoing research projects.
- Mixed-species plantations should be considered.

Riam Kanan

- Focus should be on reforestation systems that would work with the local people presently living in the forest plantation area. Agroforestry and improved fallow systems should be a priority research topic. Options exist where there seem to be few conflicts between reforestation for watershed conservation and the development objectives of the local people.
- More research should be undertaken on natural regeneration and secondary forest establishment.

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APPENDICES

APPENDIX 1: MANAGEMENT OF CONSERVATION AREAS IN INDONESIA

Planning and management of protected areas

The Directorate General for Forest Protection and Nature Conservation (*Direktorat Jenderal Perlindungan Hutan dan Pelestarian Alam = PHPA*) is responsible for the creation of protected areas and the Directorate General of Forest Inventory and Landuse Planning (*Direktorat Jenderal Inventariasi Hutan dan Tata Guna Hutan = INTAG*) for survey and demarcation of protected area boundaries in the field. Identification and gazettal must be done by PHPA in close cooperation with the regional planning board (*BAPPEDA DT I and II*). BAPPEDA contributes to the environmental, socio-economic and management surveys. The governor of the province has to formally suggest an area to be protected to the Ministry of Forest for gazettal. Once a conservation area has been gazetted the area is removed from the jurisdiction of the provincial authorities and management responsibility comes to rest with PHPA. Protection forest (*Hutan Lindung*) is administred and managed by the provincial forestry service (*Dinas Kehutantan*) under the technical guidance of Sub-directorate of Protected Forest (*Subdit Hutan Lindung* at Regional Office (*Kanwil*) and Ministry of Forestry). *Dinas Kehutanan* is accountable to the governor of the province.

The role of Ministry of State for Environment in management of conservation areas

In 1978 a special Ministry of State for Environment (*LH: Lingkungan Hidup*) was created by Presidental Decree (No.28, 1978) to provide an institutional basis for coordinating environmental issues. LH was endowed with the responsibility for developing environmental policies and the coordination of activities that concern the protection and management of the environment. The implementation of environmental policies and regulations is the responsibility of the various sectoral agencies. Now, the main implementation agency is the environmental implacts control agency (BAPEDAL).

At regional level LH sets up offices within the Ministry of Home Affairs (called *Biro Bina Lingkungan Hidup = BLH*) that advises the regional government. In addition, the "Environmental Study Centres" called *PPLH* (*Pusat Study Lingkungan Hidup*) or *PSL* (*Pusat Study Lingkungan*) was set up. This is a part of the state university network and involve in research, education/training and advise on environmental issues. Because at the regional level it is the Governor who is given responsibility for environmental policies, BLH is situated within his Office. The environmental study centers are wholly part of the Lembaga Penelitian (research centre) of each University and receive basic running costs from the Ministry of Education and Culture.

Role of provincial authorities in conservation areas

The Minister of Forestry (MoF) introduced a land zoning system called Agreed Forest Land Use Categories (Tata Guna Hutan Kesepakatan = TGHK) based on the diverse forest functions. The four main categories of forest zones are: Protection Forest (*Hutan Lindung*), Reserve Forest (*Hutan Suaka Alam dan Hutan Wisata*), Production Forest (*Hutan Produksi*) and Conversion Forest (*Hutan Konversi*). The zoning in each province, as proposed by MoF under TGHK, has to be approved by the governor and other provincial authorities following the procedures set out in the *Pedoman Penyusunan Tata Ruang Daerah* (*Keppres No. 57 Tahun 1989*). Because the planning boards (*BAPPEDA Tingkat I and Tingkat II*) play a leading role in coordinating planning, advising, and monitoring, all development programs become indirectly responsible for conservation. Once the TGHK is approved, BAPPEDA has the task to assure that no development proposals are prepared for these areas that are designated as protection forests or reserve forest within the provincial spatial plan (*Rencana Umum Tata Ruang Daerah*). In 1992 the Jambi province published the RUTRD under the Spatial Area Management Act.

No official regulation which relate to management coordination in and around protected areas between the MoF, the Provincial administration, and the Regional Autonomy Division (PUOD) of the Ministry of Home Affairs, has yet been formulated. It seems that there is no reliable administrative mechanism to ensure communication or to resolve conflicts of interest between PHPA and other groups wishing to utilise the resources in the protected areas for non-conservation purposes. In order to resolve some of the interest conflicts, the MoF is conducting high level policy reviews of land allocation and forest resource use practices. One of the approaches is to review the TGHK system and to investigate the potential to replace it with local areas for sustainable forest blocks based more on natural ecosystems and land form boundaries.

Types of protected areas

The term of protected area (*Kawasan Lindung/Konservasi*) as applied in Indonesian legislation, comprises reserves and protection forests as well as marine and coastal protected areas (Greenbelt and Beach Fronts). Protected areas include the following categories:

1. Reserves
   Sanctuary reserve
      - Nature reserve (*Cagar Alam*): marine and terrestrial
      - Wildlife sanctuary (*Suaka Margasatwa*): terrestrial

   b) Nature Conservation Areas
      - National Parks (*Taman Nasional*): marine and terrestrial
      - Grand Forest Parks (*Taman Hutan Raya*): terrestrial
      - Nature Recreation Forest Park Area (*Taman Wiasata Alam*): marine and terrestrial

2. Protection Forest (*Hutan Lindung*)
3. Marine and Coastal Protected Areas:
   a) Greenbelt (*Jalur Hijau*)
   b) Beach Fronts (*Sepadan Sungai/Pantai*)
   c) Water Springs

Legislation

The relevant regulations/legislation concerning the basic legal framework for the conservation of protected areas all specified in two laws, on the bases of which various of decrees have been issued to regulate the more specific do's and dont's. The relevant statutes are:

1. *The Basic Forestry Law No.5 of 1967.* The basic forestry law specifies the responsibilities of the government covering all aspects of conservation as well as the relationship between the people and state regarding forest ownership and use.
2. *The Law on the Conservation of Living Natural Resources and Their Ecosystems (Law No.5 of 1990).* This law stresses Indonesia's commitment for the conservation of its biological resources and provides a legal basis for the enactment of national parks.
3. *Minister of Forestry Decree No.687/Kpts-II/1989* sets the framework for exploitation of national parks, and terrestrial and marine reserves.
4. *Minister of Forestry Decree No.688/Kpts-II/1989* sets provisions for obtaining permission for commercial exploitation of national parks as well as forest and marine reserves.
5. *Minister of Forestry Decree No.441/Kpts-II/1990* sets provisions for setting fees and collecting dues in forests, national parks, and marine reserves.
6. *Presidental Decree No.32 of 1990* addresses the management of protected areas in far broader terms than simply conservation areas mentioned in Basic Law No.5 of 1990.

Human settlement, growing of food crops and commercial logging are prohibited in all protected areas. A selection of activities permitted or prohibited in protected areas:

Activities	Nature Reserve	Wildlife Sanctuary	Natural Recreation Park	Protection Forest
Food crops	no	no	no	no
Tree crops	no	no	yes	yes
Human settlement	no	no	no	no
Commercial logging	no	no	no	no

Source: Ministry of Forestry and FAO (1990)

APPENDIX 2: INDUSTRIAL TIMBER ESTATES (HTI)

Industrial Timber Estate (HTI) is one of eight development programs run by the Ministry of Forestry dealing with reforestation of degraded lands. HTI was established in the early 1980s with the aims of reforestation of degraded production forest lands and ensuring an adequate long-term supply of raw materials for the domestic wood processing industry (Ministry of Forestry and FAO 1990). Logging concessionaires have largely failed to reforest after logging, and HTIs are intended to compensate for this. Furthermore, HTIs are meant to reduce deforestation rates, first by providing substitutes for wood from natural forests, and secondly by offering transmigrants employment in plantations as an alternative to slash-and-burn cultivation practices (HTI-Trans). Current regulations specify that 30% of the concession area should be preserved for conservation and for the benefit of the villagers. Villagers can become labourers, and they can sell their agricultural production to the concession company.

The HTI program was not successful in the first years. Between 1984 and 1989 only 69 000 ha out of the target of 1.5 million ha plantations were realised. In 1990 the program was changed (Government Regulation No.7/1990) to give better incentives to private investors. A system of property rights similar to that of concessions for natural forest logging (HPH) replaced contractual relationship. Still, HTI concessions do not confer ownership or control of land rights. Concessionaires are given land tenure for 35 years.

A set of financial incentives is offered. Government equity and interest free loans are given to joint venture companies. The loan period ranges from ca. 16 to 40 years, with grace periods between 8 and 15 years (Lattunen *et al.* 1995). The aim is to have 6.2 million ha of HTI plantations in Indonesia. For the period 1989/90 to 1993/94, around half of the aim (1.5 million ha) was achieved. A HTI concession holder must prepare plans for the first 5 and 25 years within 18 months after the concession right was issued. The concession requires that the total area is planted within 25 years (Lattunen *et al.* 1995).

APPENDIX 3: LIST OF PLANT SPECIES

Indonesian name	English name	Latin name
Akasia		*Acacia auriculiformis*
Alang-alang	Cogon or Blady grass	*Imperata cylindrica*
Aren	Sugar palm	*Arenga pinate*
Balsa		*Ochroma lagopus*
Birik		*Albizia procera*
Cabe	Chili	
Calliandra		*Calliandra sp.*
Cempedak		*Artocarpus sp.*
Cengkeh	Clove	*Syzygium aromaticum* L.
Duku		*Lansium dumesticum*
Durian	Durian	*Durio zibethinus*
Emplam		*Mangifera indica*
Gelagah		*Saccharum sp.*
Gmelina		*Gmelina arborea*

Indonesian name	English name	Latin name
Jabon		*Antocephalus chinersis*
Jagung	Maize	*Zea mayz*
Jambu		*Eugenia sp.*
Jengkol	Jengkol	*Pitchecelobium jiringa*
Jeruk	Orange	*Citrus sp.*
Jervang		*Dracaena sp.*
Kapuk/Randu		*Ceiba petandra*
Karamunting		*Neonauclea sp.*
Karet	Rubber	*Hevea brasiliensis*
Kayu Alaban		*Vitex pubescens*
Kayu karamunting		*Nauclea sp.*
Kecang tanah	peanut	
Kelapa	Coconut	*Cocos nucifera*
Kelukup		*Mangifera sp.*
Kemiri	Candlenut	*Aleurites moluccana*
Kopi	Coffee	*Coffea sp.*
Kulit manis	Cinnamon	*Cinnamomum sp.*
Kumpang jepang	Japanese grass	*Chromolaena odorata*
Langsat	Langsat	*Lansium domesticum*
Mahang		*Macaranga sp.*
Mahoni	Mahogany	*Swietenia spp.*
Mangga	Mangoes	*Mangifera odorata*
Manggis	mangosteen	*Garcinia mangostana*
Mangium		*Acacia mangium*
Melinjo		*Gnethum gnemon*
Mentimun	Cucumber	*Cucumis sp.*
Merana, cemara	Pine	*Pinus merkusii*
Murbei	White mulberry tree	*Morus alba*
Indonesian name	English name	Latin name
Nangka	Jackfruit	*Artocarpus integra*
Padi	rice	*Oryza sativa*
Pepaya	Papaya	*Carica papaya*
Petai	Parkia	*Parkia javanica*
Pisang	Banana	*Musa sp.*
Puspa		*Schima walici*
Rambutan	Rambutan	*Nephelium lappaceum*
Rumpat gajah	Elephant grass	*Pennisetum purpureum*
Salak	Snack fruit	*Salacca edulis*
Semangka	Water melon	*Cucumis sp.*
Sengon		*Albizia falcataria*
Sereh	Lemon grass	
Sorghum		*Sorghum serratum*
Sukun	Bread fruit	*Artocarpus sp.*
Sungkai		*Peronema cannescens*
Surian hambar		*Toona sureni*
Tebu	Sugarcane	
Terap		*Artocarpus sp.*
Terung	Eggplant	*Solanum incanum*
Tomat	tomato	*Lycopersicum sp.*
Ubi	Cassava	*Manihot sp.*
Vanilli	Vanilla	*Vanilla sp.*

APPENDIX 4: SOIL CLASSIFICATION

No.	Type		USDA (1975)	FAO/UNESCO (1974)
1.	Organosol	Organosol Saprik	Hemic Troposaprists	Dystric Histosols
2.	Gleisol	Gleisol Histik	Histic Tropoaquepts	Histic Gleysols
3.	Kambisol	Kambisol Distrik	Fluventic Dystropepts	Dystric Cambisols
		Kambisol Kromik	Typic Dystropepts	Chromic Cambisols
4.	Planosol	Planosol Distrik	Typic Tropoaquults/Typic Albaquults	Dystric Planosols
5.	Podsolik	Podsolik Kromik	Typic Tropodults	Orthic Acrisols
		Podsolik Haplik	Dystropeptic Tropodults/Typic Tropodults	Orthic Acrisols
		Podsolik Ortoksik	Orthoxic Tropodults	Ferric Acrisols
6.	Nitosol	Nitosol Kromik	Typic Paleudults	Dystric Nitosols
		Nitosol Distrik	Typic Paleudults	Dystric Nitosols

Source: Pusat Penelitian Tanah (1984)

APPENDIX 5: TRADITIONAL SHIFTING CULTIVATION VS. SLASH-AND-BURN SYSTEMS

The term *shifting cultivation* (*ladang* in Indonesian) describes a cropping system where lands are opened, cultivated for a few years and then left to fallow while new lands are cleared. In most cases, lands are opened by the use of fire. Shifting cultivation includes a variety of systems and practices with different crop mixtures, land clearing techniques and settlement patterns (see e.g. Suharti 1993). Normally, the average length of the fallow period exceeds the cultivation period. Shifting cultivation is an extensive cropping system which has evolved in times of low population densities and abundant land resources. Under these conditions it is considered to be a rational and ecologically sound practice (Bruenig 1989, Whitten *et al.* 1987, Raintree and Warner 1986).

It is important to distinguish between traditional shifting or swidden cultivation systems and the modern ‘slash-and-burn’ cultivation. Increased population pressures on land have in many places resulted in a change towards shorter fallow periods and a loss of traditional regulatory mechanisms on land use, where the fallow period become too short to restore the soil fertility. Consequently, this practice leads to land degradation and increased pressure on remaining forest resources, with a subsequent loss of species and air pollution in the form of greenhouse gases and particles. Slash-and-burn cultivation is often undertaken by temporary squatters. Because of the negative consequences of this modern ‘slash-and burn’ system, the current policy of the Indonesian government is to replace shifting cultivation with other systems. The use of fire for land clearing is now forbidden in Indonesia (Van Noordwijk *et al.* 1995b).