Forests beneath the grass

Proceedings of the regional workshop on advancing the application of assisted natural regeneration for effective low-cost forest restoration

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Proceedings of the Regional Workshop on Advancing the Application of Assisted Natural Regeneration for Effective Low-Cost Restoration

Bohol, Philippines, 19-22 May 2009

Edited by
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Assisted natural regeneration (ANR) is a forest restoration and rehabilitation practice successfully used for converting *Imperata cylindrica* and other grass-dominated areas into productive forests. It is a simple, inexpensive, and effective technique that relies on the natural processes of plant succession. ANR application is based on fire prevention and management, control of grazing, suppression of grasses, and nurturing of seedlings and saplings of indigenous trees.

PREFACE

Although forests have been increasingly recognized for the wide range of environmental and social values essential to our planet's well being, unsustainable forest and land-use practices continue to destroy and degrade millions of hectares of forests in Asia and the Pacific each year. Vast areas of these deforested and degraded lands have been taken over by highly invasive grasses such as *Imperata cylindrica*. These largely unproductive grasslands harbor little biodiversity and provide very few livelihood options for local people.

In various locations across the region, renewed efforts are being made to restore forests to previously degraded sites. Approaches range from large-scale forest plantation development, to agroforestry, to passive natural regeneration. Assisted natural regeneration (ANR) is a forest restoration approach, based on concepts of enhancing ecological succession processes, including regeneration and growth of indigenous species. Experiences with ANR demonstrate that this approach is particularly successful in engaging local communities by addressing some of their basic priorities, reducing the risk of forest fires, and creating new income generating opportunities. ANR also significantly reduces the costs of forest restoration, making it a particularly attractive alternative to costly plantation establishment.

FAO has recognized ANR as an effective forest restoration approach and has been promoting its benefits through various capacity-building efforts for several years. Partnerships for promoting ANR have been particularly successful in the Philippines, where the ANR approach has been piloted and practiced on a limited scale for more then three decades. The regional workshop, organized in Bohol, the Philippines, in May 2009, captured not only the main achievements of the three-year Technical Cooperation Programme Project "Advancing the Application of Assisted Natural Regeneration in the Philippines," but also the key lessons learned over the years from ANR practice in the Philippines and other countries of the region. It was particularly encouraging to witness the commitment from the private sector for investing in ANR and from the Government of the Philippines for integrating ANR in its long-term rural development strategies. The valuable experiences presented by the regional participants and their interest to embrace ANR techniques and adapt them to local conditions gives us even greater hope for forest restoration and rehabilitation throughout the Asia-Pacific region.

Ongoing global efforts to curb climate change provide even greater impetus for forest restoration efforts. The compilation of experiences presented in this publication is one small, but important contribution in support of ANR as one additional tool for the challenges of forest restoration and improved forest management.

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FOREWORD

The three-year partnership project: “Advancing the Application of Assisted Natural Regeneration [ANR] for Effective Low-Cost Forest Restoration” underscores the potential of this alternative forest restoration and rehabilitation measure in the wake of forest degradation, rapid loss of biodiversity, and poverty alleviation concerns in forest land areas.

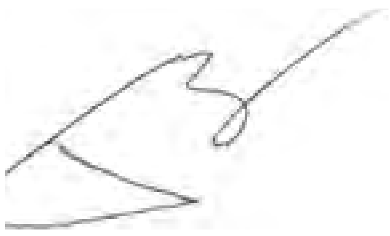
ANR is also relevant, now that the effects of climate change loom large in the horizon, for its opportunities for mitigation through carbon sequestration as well as adaptation through enhancement of ecosystems and disaster risk reduction.

Various lessons learned have come to fore from this three-year undertaking opening a wide range of recommendations to make ANR an even more viable approach to restore degraded forests through the natural ecological processes.

It is heartening to note that the move to strengthen participation of local communities, local government units, the private sector and other stakeholders in ANR application runs parallel to DENR’s participatory approach of governance. We adhere to co-management in forest development, conservation and protection as a means to sustainable forest management.

The Project’s concluding activity - a Regional Workshop, has generated a wealth of information on all aspects of ANR implementation and how these could be further improved, putting emphasis not only on institutional interventions but public-private alliances as well, among others. The Regional Workshop also paved the way for an exchange of invaluable knowledge and experiences related to forest rehabilitation efforts with presenters from Asia and the Pacific.

It is with great appreciation that we recognize the efforts of the Food and Agriculture Organization (FAO) to initiate the documentation of the proceedings of the Workshop and all its significant findings through a publication on ANR. The FAO has been a staunch partner in promoting the application of ANR techniques - our sincere thanks!



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The regional Workshop on Advancing the Application of Assisted Natural Regeneration for Effective, Low-Cost Forest Restoration" held in Bohol, the Philippines, 19-22 May 2009, was only one milestone in the long history of ANR activities in the Philippines. Over the past three decades a number of ANR "champions" have emerged from the Philippines, demonstrating immense energy and enthusiasm. The Philippines, the Asia-Pacific region and indeed the world, owe much to their tireless efforts to promote and advance the application of ANR. Several of these individuals were instrumental in the success of the three-year project supported by FAO to promote the application of ANR in the Philippines.

Mr Patrick C. Dugan, Mr Ernesto Cadaweng and other Bagong Pagasa Foundation staff have worked assiduously to pioneer ANR approaches and share them across the country. Local community leaders, in particular the mayors of the three ANR project pilot sites in Bataan, Bohol, and Davao del Norte enthusiastically embraced ANR and made it a reality on the ground. Mr. Leonardo Florece and Mr Dominigo Madulid contributed greatly to our better understanding of the "science of ANR". Through his unique creative approaches and links with the media, Mr Paulino Manalo promoted ANR and helped raise awareness of the potential of ANR among a wide range of people from all walks of life. Mr Percy Sajise – a true pioneering champion on ANR – successfully advised and guided the project and tied all the pieces together in synergy. The ANR story in the Philippines would certainly not have the same positive outcome without the strong support from the Department of Environment and Natural Resources (DENR). In fact, many of the most enthusiastic new ANR promoters are DENR officials, led by DENR Secretary Jose Atienza, Jr., Forest Management Bureau (FMB) Directors Romeo Acosta and Marlo Mendoza, Assistant Director Neria Andin and Forester Nonito Tamayo. The implementation of the FAO-supported project and the organization of the regional workshop would have been impossible without the dedicated support of Foresters Emma Castillo, Roberto Oliveros and the DENR/FMB ANR team at the Regional and Provincial levels of the three pilot sites. The workshop itself benefitted greatly from the expert facilitation skills of Ms Socorro Feliciano who helped participants to crystallize their ideas and maintain their focus.

The list of individuals contributing to the advancement of ANR in the Philippines certainly is extensive. While some of these long-time champions, such as Mr Pedro Walpole, Mr William Granert, Ms Rowena Soriaga, and Mr Patrick Charles Dugan Jr. participated in the workshop, many others have labored behind the scenes to put ANR ideas into practice.

The Bohol workshop was organized with the objective of sharing the experiences from the Philippines and learning from other countries about the needs, opportunities and challenges for ANR application on a wider, regional level. Therefore, to a large

extent, the success of the workshop was due to the presence of the experts from different countries. Their views enriched the discussions and opened up new possibilities for wider application of ANR. Their valuable inputs – captured in this publication – are gratefully appreciated.

FAO has actively promoted ANR approaches for over a decade, both in the Asia-Pacific region and in other parts of the world. The recently concluded ANR project in the Philippines benefited greatly from the attention and support of the FAO Office in the Philippines, and we can proudly say that Mr Kazuyuki Tsurumi, FAO Representative in the Philippines, Mr Genaro Castro, Ms Sarah Lacson and the rest of the country office staff are now true "ANR believers". The support received from the team in FAO headquarters, particularly from Ms Linda Rosengren and Mr Jim Carle is very much appreciated.

This publication would not have been possible without the technical revisions by Mr Percy Sajise, and the editing work of Mr Robin Leslie. Sincere gratitude is also extended to Ms Janice Naewboonnien for final proofreading and Mr Christopher Entwistle, Ms Sansiri Visarutwongse and Mr Jeremy Broadhead for the publication layout and cover design.

Introduction

Why assisted natural regeneration?

For decades, foresters, ecologists and policy makers have sought effective, low-cost approaches and techniques to help reverse the continuing loss of forests in Asia and the Pacific. Recent years have been marked by increased recognition of the multiple benefits forests provide, triggering new approaches to address multiple forest management objectives and to effectively involve increasingly diverse stakeholders. “Looking beyond” has indeed become the new paradigm for forest management.

Conventional plantation establishment remains a logical priority for forest managers, particularly where wood production is a primary objective. Currently, forest plantations account for 7 per cent[1] of the global forest area and are a significant contributor to reverse global trends of forest loss. Despite the various benefits of forest plantation development, the magnitude and complexity of the deforestation problem implies the need for diverse approaches to increase forest cover.

Massive deforestation and land-use changes taking place over the last century in the Asia-Pacific region have turned wide areas of formerly forested areas into low-productivity grasslands. *Imperata cylindrica* alone covers over 35 million hectares[2] throughout the region. These grasslands are important to some of the people that live around them and use them for grazing animals or for shifting cultivation, but they generally provide few benefits relative to the potential productivity of the land. Restoration of these degraded areas is therefore a challenge that requires careful consideration of a full range of socio-economic and ecological characteristics of each site.

Assisted natural regeneration (ANR) is a forest restoration technique based on the ecological principles of secondary succession. ANR has been successfully used to enhance local biodiversity and restore ecological processes in many areas, particularly in the Philippines. ANR approaches place strong emphasis on community involvement and offer a variety of opportunities for diversifying livelihoods.

What do we know about ANR?

ANR emphasizes the importance of fire management, protection against destructive grazing, control of invasive grass species and assisting the growth of naturally occurring tree seedlings. Similar principles have been applied in various forms or in combination with other methods in many areas around the world.

In 1989, the Department of Environment and Natural Resources (DENR) formally

1. Key findings, Forest Resource Assessment 2010, FAO
2. Garrity *et al*. (1997)

adopted ANR as a recommended method for restoration of forest cover, but field implementation did not progress significantly for many years. This was primarily due to inadequate capacity and lack of awareness among forestry officials and a dearth of successful field-based ANR examples. In 2006, a three-year project was launched with FAO support to compile and document experiences in implementing ANR, and to mainstream its principles among a variety of stakeholders.

The ANR experiences in the Philippines demonstrate that this approach is best suited for ecologically vulnerable areas such as critical watersheds, where maintenance of the original flora and fauna is important and in areas where communities are supportive of forest restoration[3].

Practical application of ANR revealed some important technical aspects to be considered for establishing a solid ANR foundation: These include: 1) site selection; 2) site-species matching; 3) site modification for catalyzing the growth of preferred species; 4) enrichment or supplemental planting; 5) site protection; and 6) site monitoring. However, the most important ANR lesson emerging from the Philippines is the importance of strong collaboration with local communities and private businesses for successful long-term results.

What are the future prospects for ANR?

At the time of the ANR workshop in Bohol in May 2009, two issues were dominating the headlines – the global financial crisis and climate change. One year later, the headlines remain the same, and the world is still struggling to respond to these challenges. Forestry has emerged at the forefront of discussions on climate change, and new understanding of the roles of forests has created new opportunities for supporting sustainable forest management through various carbon sequestration initiatives and programs. At the same time, in response to the economic crisis, many governments have embraced forestry-related activities as part of their economic stimulus programs.

This newly gained recognition of the importance of the forestry sector has unlocked prospects for various innovative approaches for promoting and funding forest restoration. As one example, in early 2010 a new project that includes ANR techiques was registered under the Clean Development Mechanism (CDM)[4]. Given the difficulties forestry projects have experienced in participating in the CDM, this is a strong encouragement for further up-scaling of ANR activities. In the Philippines, private sector commitment has emerged for supporting future ANR activities through corporate social responsibility initiatives and the DENR plans to use ANR for restoring around 9,000 hectares under its new Upland Development Program. These developments may help generate significant momentum to be further fostered.

3. Sajise, (2003)
4. List of registered A/R project, available at: http://cdm.unfccc.int/Projects/DB/TUEV-SUED1245851243.49/view

In addition to climate change concerns, loss of biodiversity is another global issue closely linked to deforestation. Supporting natural regeneration, and fostering the growth of indigenous species that are well adapted to local conditions, is helping to enhance local biodiversity and therefore becoming increasingly important.

As population pressures continue to mount, issues such as ownership and resource tenure rights, income generation, and traditional land-use patterns will increasingly collide with the development visions of policy makers. Lessons from ANR implementation are particularly important in designing approaches that work for the local people and take in consideration the unique ecological and social characteristics of each site targeted for restoration.

Harvesting lessons: overview of the regional workshop

The regional "Workshop on Advancing the Application of Assisted Natural Regeneration for Effective, Low-Cost Forest Restoration" was organized from 19-22 May 2009, in Bohol, the Philippines, as a concluding activity of the three-year FAO-supported project aimed at promoting ANR in the Philippines. Both the project and the workshop were implemented in collaboration with the Philippines Department of Environment and Natural Resources (DENR) and the Bagong Pagasa Foundation.

Key objectives of the workshop were to:

- enhance awareness and understanding of the basic principles, opportunities and challenges of implementing ANR in Asia and the Pacific;
- exchange information and lessons learnt from the three-year FAO-supported project in the Philippines;
- identify key policy, technical, social, financial, and capacity requirements for successful ANR implementation and up-scaling;
- identify and discuss the potential for involving the private sector and establishing public-private partnerships for successful natural forest restoration and rehabilitation; and
- exchange knowledge and experience related to forest restoration efforts in Asia and the Pacific, with a view toward fostering regional cooperation and up-scaling of efforts.

Over 70 participants, representing government, civil society, private sector, academe and development partners involved in ANR and similar practices in the Philippines and the Asia-Pacific region, attended the workshop (Annex 1: List of participants). The workshop received significant interest from senor-level officials. Mr. Antoineto Pernia, Chief of Staff of the Provincial Government of Bohol welcomed the participants; Mr. Kazuyuki Tsurumi, FAO Representative in the Philippines, provided opening remarks; and the Honorable Jeremias Dolino, DENR Assistant Secretary for Visayas and

Mindanao, delivered the key introductory message. A one-day field visit to the project site in Danao, Bohol, was organized as part of the program.

The Bohol workshop dedicated significant attention to the future potential of ANR and focused on identifying new partners and innovative mechanisms for financing and up-scaling. Forest practitioners and researchers from several countries from across the Asia-Pacific region shared a wealth of knowledge and information on different forest restoration approaches applied in their countries – demonstrating a diversity of methods in line with available funding, degrees of forest and land degradation, local socio-economic conditions and specific management objectives.

"Forest beneath the grass" is a compilation of experiences, examples and lessons learned intended to foster sharing of existing knowledge on ANR and to provoke new ideas on how ANR can be further adapted, nurtured, and harnessed in the future. The selected papers present ANR experiences in the Philippines and related forest restoration initiatives throughout the Asia-Pacific region. These, coupled with a synthesis of the workshop observations, discussions and recommendations, are provided to guide and motivate further work in rehabilitating and restoring the region's degraded forest lands.

Workshop observations, recommendations and conclusions

Given the rapid ongoing loss of biodiversity and the negative global impacts of climate change, there is an urgent need for cost-effective and efficient forest restoration and rehabilitation on a massive scale. The high cost of traditional forest restoration and rehabilitation strategies is a serious constraint to addressing this need, especially for developing countries with limited financial resources. It is in these contexts that assisted natural regeneration (ANR) deserves urgent attention. Although called by various names, ANR provides a low cost approach to forest restoration and rehabilitation. ANR implementation is particularly relevant in restoring biodiversity, enhancing ecosystem services and increasing carbon sequestration for mitigating climate change.

In this regard, the regional workshop generated the following observations:

- The need to identify key elements and enabling conditions for successful implementation of ANR under various biological, ecological and socio-cultural contexts because of the highly diverse conditions in which it can be applied.
- Effective use of information, education and communication materials, including case studies illustrating best practices, which will enhance appreciation and increase understanding of ANR among all segments of society, particularly among the younger generation, educational institutions, local officials, community groups and upland residents.
- Clearly define ANR for audiences at various levels (i.e. communities, local governments, politicians, private sector and government agencies) to improve

the understanding of ANR as a concept and with respect to its application under different socio-cultural and ecological conditions.

- ANR must be seen as one approach among various options available to address forest rehabilitation needs aligned within each country's national forestry programme according to objectives and resources available for implementation.
- ANR offers considerable opportunities to sequester carbon to assist in mitigating climate change, but this potential remains largely unrecognized and underappreciated.
- ANR provides an effective method for communities to enhance local water resources, including contributing to improved downstream water quality and reliability.
- The success of ANR depends on clear recognition and effective involvement of local people in its implementation, underscoring the need to further improve the ways by which communities are provided with incentives and capture the benefits of ANR-based forest rehabilitation.
- The indigenous knowledge of local communities can enhance the sustainability and effectiveness of ANR in many areas.
- Sound research on botanical and wildlife dynamics, water regimes, carbon sequestration rates, soil conditions and socio-economic factors related to ANR implementation is needed to establish a solid foundation upon which to base decisions related to choice of technologies and practices, incentives, ecological requirements of alternative enrichment species, management modalities and others.
- There are clear opportunities to build on and adopt the Philippine experience in ANR to address the forest rehabilitation and restoration needs of many other countries in the Asia-Pacific region.
- Mechanisms are needed to better facilitate the exchange of lessons learned on the successes and failures of ANR implementation and to effectively and widely disseminate such lessons such as through FAO's e-learning platform.

Considering these observations, the regional workshop participants recommended that:

1. Policies and regulations should be revised, as appropriate, to improve the enabling conditions for implementing ANR on a sustainable basis, including incentives and resources from local governments to encourage and strengthen community participation and involvement.
2. Information dissemination, advocacy and extension should be strengthened to more effectively promote ANR application by local communities and the private sector.
3. A systematic effort should be initiated to identify and engage effective community-based ANR efforts that seek to enhance livelihoods and community well-being while restoring ecological processes.
4. Various creative and innovative public-private partnerships should be encouraged to provide more support and resources for ANR implementation and upscaling such

as through corporate social responsibility.

5. Increased support should be provided for research to improve the science-based rationale for effective and efficient implementation of ANR as a means of forest restoration and rehabilitation.
6. Mechanisms should be established to promote linkages and partnerships at national and regional levels while concurrently enhancing the exchange of lessons learned for improving the application of ANR within countries of the Asia-Pacific region.
7. Materials should be developed and various mechanisms used for integrating ANR into the curricula of schools at all levels including the training of teachers on the basic elements of ANR.

There was overall agreement among workshop participants on the importance of ANR as an option for more cost-effective and appropriate forest restoration and rehabilitation primarily for enhancing ecological services and addressing poverty, livelihood needs and climate change mitigation. However, it was recognized that the sustainability of ANR depends on how well it can respond both to the immediate and long-term needs and objectives of various stakeholders across time and space.

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Learning from experience: advancing ANR in the Philippines

Cost comparison analysis of ANR compared to conventional reforestation

Bagong Pagasa Foundation

Introduction

This paper presents information on the average costs per hectare to implement assisted natural regeneration (ANR). It then compares these costs with expenses normally incurred when conventional reforestation methods are applied. The objective is to help facilitate decisions on whether or not to include ANR in forest restoration planning.

ANR costs are derived from records of expenses incurred during implementation of the FAO-assisted Project TCP/PHI/3010 (A) at three sites in the Philippines over three years. The data show average costs in order to take into account the different conditions at the sites. Data on costs to implement conventional reforestation methods are derived from information on the average prevailing costs of projects implemented by the Government of the Philippines and private sector companies. In both cases (ANR and conventional reforestation) the data only present direct costs. The data do not include administrative and other indirect expenses which will vary considerably depending on who and/or what entity manages implementation. Neither do the data include boundary delineation nor fencing. The latter is an option that may be needed in areas threatened by pasturing of stray animals.

An analysis of costs shows that forest restoration via ANR is approximately 50 percent less expensive than conventional reforestation. Results of project experience show an average ANR cost of US$579 per hectare. When conventional reforestation methods are applied, the average cost is about US$1 048 per hectare.

Basic assumptions for cost comparison analysis of ANR vs. conventional reforestation

- ANR sites are dominated by *Imperata cylindrica* but contain an average of approximately 800 suppressed pioneer regenerants per hectare.
- Average area of firelines required per hectare – 1 000 m^2.
- Firelines maintained (reweeded) eight times within three years.
- Three-year implementation timeframe.
- Twelve ringweeding cycles in conventional reforestation:
  - six in year 1; three each in years 2 and 3.
- Nine pressing (lodging) cycles in ANR: 3/year x 3 years.

Table 1. Average forest restoration cost per hectare (US$)

Item	Unit	Unit cost (US$)	No of units		Amount (US$)	
			REF	ANR	REF	ANR
1. Fireline establishment and maintenance	p.d.	3	32	32	96	96
2. Locating and marking regenerants	p.d.	3	-	3.2	-	10
3. Pressing (lodging) Imperata	p.d.	3	-	90	-	270
4. Staking 2 500 planting spots	p.d.	3	6.25	-	19	-
5. Digging 2 500 planting holes	p.d.	3	25	-	75	-
6. Cost of seedlings	slg	0.1	3 000	-	300	-
7. Hauling 3 000 seedlings to the field	p.d.	3	12	-	36	-
8. Planting/re-planting 3 000 seedlings	p.d.	3	30	-	90	-
9. Ringweeding 800 regenerants	p.d.	3	-	36	-	108
10. Ringweeding 2 500 planted seedlings	p.d.	3	113	-	338	-
11. Herbicide to spray firelines	Litre	10	8	8	80	80
12. Labour to spray herbicide	p.d.	3	5	5	15	15
			Total		**1 048**	**579**

Note: p.d. = person day; slg = seedling; REF = conventional reforestation methods.

Explanatory notes for Table 1

1. Average 1 000 m^2 firelines ÷ 250 m^2 accomplishment/p.d. x 8 cycles	32 p.d.
2. Average 800 regenerants/ha ÷ 250 average accomplishment/p.d.	3.2 p.d.
3. 10 000 m^2 ÷ 1 000 m^2 accomplishment/p.d. x 9 (times) within 3 years	90 p.d.
4. 2 500 p.d. ÷ 400 average accomplishment/p.d. (includes gathering of stakes)	6.25 p.d.
5. 2 500 planting spots ÷ average 100 holes accomplishment/p.d.	25 p.d.
6. 3 000 seedlings (includes 20% allowance for culling and replanting)	3 000
7. 3 000 seedlings (incl. 20% allowance) ÷ 250 average accomplishment/p.d.	12 p.d.
8. 3 000 (including 20% allowance) ÷ 100 average accomplishment/p.d.	30 p.d.
9. 800 regenerants ÷ 200 aver. accomplishment/p.d. x 9 (times) in 3 years	36 p.d.
10. 2 500 planting spots ÷ 200 aver. accomplishment/p.d. x 9 (times) in 3 years	113 p.d.
11. Systemic herbicide (e.g. glyphosate) 4 litres per application x 2 applications	8 litres
12. 10 000 m^2 ÷ 2 000 m^2 average accomplishment/p.d	5 p.d.

Average accomplishments

grubbing out grass (e.g *Imperata*) in firelines	m^2	250/p.d.
locating and marking regenerants	regenerant	250/p.d.
pressing (lodging) of *Imperata* and other grasses	m^2	1 000/p.d.
ringweeding of pioneer regenerants or planted seedlings	plant	
staking of planting spots, including gathering of stakes	spot	
digging planting holes	hole	
hauling seedlings to planting spots	slg	
planting and replanting	slg	100/p.d.
spraying herbicide on firelines (including hauling water)	m^2	2 000/p.d.

Factors that impact on costs

To work effectively in forest restoration, it is essential to adapt methods to suit prevailing conditions. These include (among others) climate, soil fertility, existing vegetative cover and topography. These conditions will vary from site to site and will affect the amount of input required to attain forest restoration objectives. For example, there is a high risk of fire in areas with long dry seasons. Thus, it may be necessary to establish more firelines than would be the case in areas with well-distributed rainfall throughout the year.

Similarly, activities on steep terrain will normally require more person days per hectare than on moderately sloping or level terrain. Because labour is a major input in all forest management activities, labour productivity is a major factor to consider. Obviously, the average daily accomplishment rate of workers assigned to the various tasks will impact on total costs. Another important factor is the efficiency of supervisors who oversee implementation and the level of community participation and cooperation that can be enlisted.

In addition, the objectives of forest restoration must also be taken into account. For instance, if the forest restoration objective is to rehabilitate a watershed or improve wildlife habitat, the desired vegetative cover would be a diverse mix of species. ANR is ideal for these purposes. On the other hand, if the ultimate objective is development of a timber plantation, alternative strategies can be formulated to combine ANR and conventional reforestation methods. For instance, ANR can comprise the first phase of plantation development and focus on enhancing the growth of existing pioneer regenerants to serve as nurse trees for the final timber crop. Furthermore, the fire prevention measures taken to protect naturally-growing pioneer species will also benefit the timber crop.

Discussion of cost items

Firelines: Table 1 assumes that (i) approximately 1 000 m^2 of firelines will be established per hectare; i.e. approximately 10 percent of the total area and (ii) the firelines will be maintained through ringweeding eight times during a three-year implementation period. These figures (1 000 m^2 and eight maintenance cycles) may vary considerably depending on conditions. For instance, as noted above, more firelines will usually be required in areas with long dry seasons where there is a relatively high risk of fire. In any case, fireline establishment and maintenance are essential ingredients for success in both ANR and conventional reforestation.

Locating and marking regenerants: In general, if 800 regenerants per hectare are located, marked and conscientiously tended, the resulting canopy cover after three years will be adequate to shade out *Imperata cylindrica* and other fire-prone grasses.

Thus, ANR costs indicated in Table 1 assume location and marking of 800 regenerants. However, it is often possible to find more than 800 per hectare. In such cases, the project implementers may decide to locate and mark more than 800 in order to expedite canopy closure. Conversely, in some sites natural regeneration will be poor and it will not be possible to locate 800. In such cases, enrichment planting may be required. Enrichment planting may be accomplished with seedlings as in conventional reforestation, or via direct seeding.

Pressing (lodging) of Imperata: This activity is explained in the Field Guide Manual developed in the FAO-assisted project in the Philippines from which the data herein were derived. Copies of the Manual may be requested from FAO, Bangkok. ANR promotes pressing (lodging) rather than cutting as a more cost-effective method for inhibiting the growth of *Imperata* and other fire-prone grasses. In general, cutting stimulates the growth of grass, whereas pressing slows down growth.

Staking of 2 500 planting spots and digging 2 500 planting holes (in conventional reforestation): These cost items in Table 1 assume that 2 x 2 metre spacing will be followed in conventional reforestation. If wider spacing is adopted, the number of person days required, and consequently the costs, will be less than the amounts indicated in Table 1.

Cost of seedlings (conventional reforestation): This cost item is highly variable, depending on the species and the type of seedling (i.e. potted or bare root) and the number of seedlings. The amount per seedling indicated in Table 1 (US$0.10) is an average, subject to adjustment based on seedling type and species.

Hauling, planting and replanting 3 000 seedlings (conventional reforestation): This seedling quantity makes allowance for approximately 20 percent mortality and/or culling.

Ringweeding 2 500 planted seedlings (conventional reforestation): Most conventional reforestation projects include nine ringweeding cycles over three years. However, this is a highly variable figure, dependent on how fast the weeds grow and how thoroughly each ringweeding cycle is carried out. If roots of the weeds are grubbed out, nine cycles will normally be sufficient. However, if the weeds are simply cut, but not grubbed out, regrowth of the weeds will be fast and more ringweeding cycles may be required.

Ringweeding 800 regenerants: This figure is based on the average number of regenerants located and marked per hectare. If more regenerants are found and the implementers decide to mark and tend them, costs indicated in Table 1 will increase. Project experience indicates that ringweeding of regenerants should be implemented at least three times each year, or a total of nine times during three years. This is in addition to pressing (lodging) which is also a maintenance activity.

Herbicide and labour to spray herbicide on firelines: The costs indicated in Table 1 are based on project experience. However, costs will be higher if the work is not properly timed. Herbicides are not effective if applied on rainy days and if the *Imperata* and other fire-prone grasses are not in an active stage of growth. Good training and close supervision are essential inputs for effective use of herbicides. Conversely, costs may decrease if the *Imperata* (etc.) have been effectively controlled by ringweeding (maintenance) within the firelines.

Conclusion

Project experience clearly validates that forest restoration can be accomplished at lower costs with ANR than via conventional reforestation. Thus, if the principal objectives of forest restoration are rehabilitation of vegetative cover on watersheds and wildlife habitats, ANR is a logical choice. The principal reasons for lower costs are the elimination of expenses for seedlings, digging of planting holes, planting and replanting. ANR takes full advantage of existing regeneration on site including seedlings of pioneer tree species and woody brush.

The results of project experience also validate that three years of ANR implementation can expedite the growth of a sufficient number of pioneer trees per hectare to establish the first phases of what can eventually develop into a mature forest. This first phase also comprises a nurse crop that can be interplanted with commercially valuable timber species, if the objective is development of a production forest. Additionally, if appropriately thinned, the nurse crop developed via ANR can be interplanted with shade-tolerant agroforestry species such as cacao, coffee, black pepper, pandan, ginger and others.

Hopefully, results of the FAO-assisted project will encourage others to apply ANR wherever feasible and appropriate to expedite the restoration of forest cover on millions of hectares throughout Asia that are currently dominated by *Imperata cylindrica* and similar fire-prone grasses. Rehabilitation of these grasslands will contribute to carbon sequestration and can help address the problems of global warming and climate change.

Assisted natural regeneration and biodiversity in the Philippines

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Introduction

A botanical inventory and vegetation survey of assisted natural regeneration (ANR) sites was conducted from August to November 2007 and January to March 2009 to document and describe the status of the vegetation before and during the implementation of the actual assisted regeneration methods.

The inventory included species inventory, vegetation analysis and photo documentation to gather baseline data and monitor the changes in the vegetation at the project sites.

The study sites (Appendix I) were in the major island regions in the Philippines: ANR Site I – Limay, Bataan (Luzon); ANR Site II – San Miguel, Danao, Bohol (Visayas); and ANR Site III – Balagunan, Davao del Norte (Mindanao).

These sites were characterized by different climate types. Based on the Coronas Modified Classification of the Philippine Climate, Site I fell under Type I. This site had two pronounced seasons: the dry season which prevails from November to April and the wet season for the rest of the year. Site II fell under Type IV where rainfall is more or less evenly distributed throughout the year. Site III fell under Type III where the seasons are not very pronounced and it is relatively dry from November to April (Appendix I).

The three sites also differed in climate types based on ratios of dry to wet months. Site I was classified as Type D where it is generally dry with rain insufficiently distributed (at most six dry months). Site II was classified as Type C where it is moist, with rain sufficiently distributed with five dry months. Site III was characterized as Type A which is wet and rainy (Appendix I).

Based on information from the Bureau of Mines and Geo-Sciences (1982) the soils of Site I and its vicinities had Quarternary volcanic cones with ultramafic, coralline, siltstone and shale complexes. Site II soils were interspersed with volcanic and sedimentary rocks. Site III had volcanic, serpentinite, diorite, limestone and alluvium complexes (Appendix I).

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Materials and methods

Field research was undertaken with the assistance of two botanical researchers, local NGO members and local Department of Environment and Natural Resources (DENR) staff in Limay, Bataan from 25-28 July 2007 and 6-9 January 2009 or 18 months after the initial survey; in San Miguel, Bohol from 5-11 August 2007 and 1-6 February 2009 or 18 months after the initial inventory; and in Balagunan, Davao del Norte from 26 October to 1 November 2007 and 22-27 February 2009, 16 months after the initial survey. Visits to the offices of the local government and the DENR (regional, provincial, municipal branches) were made prior to the actual fieldwork.

Species inventory

A detailed species inventory was conducted in the three ANR sites. Voucher specimens were collected in duplicate. These were pressed in newspaper and soaked in denatured alcohol prior to processing in the Philippine National Herbarium (PNH) in Manila. The specimens were then dried and later identified by comparison with herbarium specimens at the PNH and consulting botanical references.

Local names of the plants were recorded in the field. The equivalent scientific names were cross-referenced with entries in the *Dictionary of Philippine plant names* (Madulid 2001). These were then matched with the identification of the species based on the voucher specimens collected and the specimens deposited at the PNH.

Vegetation analysis

Due to the limited time in the field, purposive sampling of the vegetation in the area was conducted. This was done to obtain samples that appeared to be representative of the population or of the entire vegetation cover to ensure that a range from one extreme to the other was included. The selection of the representative samples is based on the initial ocular assessment of the different vegetation types based on the dominant species found in the area. The positions of the sampling plots, transects or quadrats were recorded using a GPS (Garmin 76™).

An analysis was conducted to describe the physiognomy of the vegetation and forest structure in the area. The plot method for Site I was used because of the patchy nature of the remnant forest there. The point centre quarter method (PCQM), a plotless sampling technique, was used for Sites II and III so a wider area could be covered. This technique was applied because the forest area for sampling at these two sites was larger than at Site I.

The plot method was accomplished by enclosing a 100 m^2 plot, with dimensions of 10 m x 10 m, using a fibreglass meter tape. All the trees with diameter at breast height (dbh) equal to or greater than 10 cm dbh were identified and represented by a voucher specimen. The dbh was measured using a meter tape. The height of the trees was measured using a laser range finder.

The PCQM method was carried out with a 100 metre fibreglass meter tape. Sampling points were designated every 10 metres. In each sampling point, the four trees nearest to the centre tree with a 10 cm dbh were identified and represented by a voucher specimen. The distance to the centre tree and tree height were measured using a handheld laser distance meter (Trimble Spectra Precision Laser HD150). The dbh was also measured with a measuring tape.

The undergrowth and ecotone areas were sampled using quadrats. The quadrats had dimensions of 1 m x 1 m. The species in the quadrat were identified and the number of individuals per species were determined and recorded. Voucher specimens of the species were also collected.

Later, 10 m x 10 m plots were established in grassland areas. One metre high PVC pipes were used to mark the corners of the plot. The different wildlings within the plot were identified and the density of each species was recorded.

Computation of the importance value index was made to determine the dominant species in the area. The Shannon-Weiner Diversity Index and Equitability Index were used to estimate and compare the species diversities of the different sampling areas or vegetation types. 'Species Diversity and Richness' in a Windows© programme (Henderson & Seaby 1997) was used to calculate alpha diversity indices. This was done to compare the species diversities of the different sampling areas or vegetation types within and between sites.

Results and Discussion

Ecosystem and species diversity in the ANR sites

Site I had five vegetation types: grassland, remnant Dipterocarp forest, secondary forest, *Lithocarpus* forest and plantation forest (*Pouteria campechiana*). This was determined in a ground survey and by noting the dominant species and the physiognomy of the vegetation. The grassland was dominated by an introduced forage grass, *Hyparrhenia rufa*, with emergent *Eucalyptus* and other secondary growth plants. The presence of *Eucalyptus* trees in the area indicated that it was formerly a reforestation project site. Mature trees of two Dipterocarp species, namely *Shorea contorta* and *Shorea polysperma* could be found in the remnant primary forest. A third Dipterocarp species, *Anisoptera thurifera* subsp. *thurifera*, stood out in one corner of the site. The three Dipterocarps were mother trees and sources of the wildlings abounded in the forest floor. The secondary forest was dominated by *Ficus* spp. while the Lithocarpus forest was dominated by *Lithocarpus sulitii*.

Site II had three vegetation types, namely grassland, secondary forest and plantation forest (*Gmelina arborea*). The dominant species in the grassland were *Imperata cylindrica, Rottboellia exaltata* and other grass species such as *Chrysopogon, Setaria, Themeda* and *Miscanthus*. The grassland was also characterized by numerous emergent plants such as *Gmelina, Ficus, Syzygium, Melastoma, Antidesma, Evodia* and *Dillenia*, among others. In open grassland at the site, *Dicranopteris linearis* was a co-dominant of *Imperata cylindrica*. In the secondary forest, indicator species such as *Colona serratifolia, Cratoxylon sumatranum* and *Commersonia bartramia*, among others, predominated. *Dipterocarpus grandiflorus,* a prime timber species, was also recorded in the site.

Site III had grasslands, secondary forests and plantation forests (*Gmelina arborea, Leucaena leucocephala* and *Vitex parviflora*). *Imperata cylindrica* and *Saccharum spontaneum* were the dominant species in the grassland and associated with non-grass species such as other weeds and ferns. There were emergent individuals of *Gmelina, Macaranga, Abrus* and *Polyscias* in the grasslands. The secondary forest was dominated by *Piper aduncum, Trema orientalis, Leucaena leucocephala, Macaranga tanarius, Ficus odorata, Ficus septica, Pipturus arborescens* and *Polyscias nodosa* among others. *Piper aduncum* was an invasive alien species.

Site I was the most diverse in terms of types of ecosystem represented. It had grassland, plantation forest and forest patches dominated by different species (Dipterocarp forest, *Lithocarpus* forest, secondary forest). The forest type in Sites II and III was fairly similar even if it occurred in disjunct patches.

Site III had the most species of vascular plants, followed by Site II and Site I.

Site II had the greatest number of trees and most diversity per 100 m^2. It had an average of 26 trees per plot and was represented by 45 different species. This was followed by Site III with an average of 22 trees and 9-22 species and Site I with 12 trees and 2-5 species per 100 m^2.

Site II had the highest tree density and this could account for the smaller trunk diameter of trees which ranged from 10-35.2 cm. Site I had the largest trees with diameters of 10-124.2 cm (10-80 cm in diameter at Site III).

Table 1. Comparison of plant diversity features of the three ANR sites

	Site I	Site II	Site III
Number of species	108	122	152
Number of genera	93	110	138
Number of families	44	50	61
Vegetation types	Grassland, remnant Dipterocarp forest, secondary forest, Lithocarpus forest, plantation forest (*Pouteria campechiana* and *Eucalyptus* spp.)	Grassland, secondary forest, plantation forest (*Gmelina arborea*)	Grassland, plantation forest (mixed), secondary forest
Dominant species in grassland	*Hyparrhenia rufa*	*Imperata cylindrica, Chrysopogon, Setaria, Themeda, Miscanthus, Phragmites, Cyperus, Centrosoma, Lantana, Calopogonium, Fimbristylis, Mimosa, Chromolaena, Sorghum, Scleria, Premna, Urena, Habenaria*	*Imperata cylindrica, Saccharum spontaneum, Mimosa pudica, Pteris, Chromolaena, Fimbristylis, Oplismenus, Desmodium, Sida, Coelorachis, Sorghum, Mikania scandens Lantana, Lygodium, Hyptis, Piper, Macaranga, Cynodon, Flagellaria, Desmodium*
Emergent plants in grassland	*Eucalyptus* sp., *Blumea balsamifera*	*Gmelina, Ficus, Syzygium, Melastoma malabathricum, Antidesma ghaesembilia, Evodia, Pandanus, Dillenia, Uvaria, Maesa, Breynia, Artocarpus*	*Gmelina arborea, Macaranga, Abrus, Polyscias, Piper aduncum, Blumea balsamifera*

Dominant species in plantation forest	*Pouteria campechiana*	*Gmelina arborea*	*Gmelina arborea, Polyscias nodosa, Leucaena leucocephala, Vitex parviflora*
Dominant species in remnant primary forest	*Shorea, Ficus, Voacanga*	*Dipterocarpus grandiflorus*	*Shorea contorta Vatica* sp.
Dominant species in secondary forest	*Ficus, Gyrocarpus, Mallotus, Lithocarpus sulitii*	*Colona serratifolia, Cratoxylon sumatranum, Commersonia bartramia, Ailanthus, Lithocarpus sulitii, Gomphia serrata*	*Piper aduncum, Trema orientalis, Leucaena leucocephala, Macaranga tanarius, Ficus odorata, Ficus septica, Pipturus arborescens, Polyscias nodosa, Mallotus paniculatus, Melanolepis multiglandulosa, Ficus minahassae*
Number of tree species in a 100 m^2 plot	2-5	45	9-22
Number of trees in a 100 m^2 plot	7-16	25-27	15-28
DBH of trees in a 100 m^2 plot (cm)	10-124.2	10-35.2	10-80
Dominant species of ground cover and above	*Pouteria campechiana, Centrosema, Lantana camara, Alpinia, Lycopodium, Abrus precatorius, Melia, Tabernaemontana pandacaqui, Litchi chinensis*	*Nephrolepis, Gmelina, Guioa, Caryota, Wrightia laniti, Miscanthus floridulus, Grewia, Lygodium, Selaginella, Alpinia*	*Glochidion, Alpinia, Lygodium, Pteris, Piper aduncum, Streblus, Scleria, Abrus precatorius, Coffea, Ficus* sp., *Gmelina arborea, Pteridium, Leucaena leucocephala, Gliricidia, Buchanania,*
Dominant species of the ecotone vegetation	*Lantana camara, Chromolaena odorata, Tithonia diversifolia, Urena lobata, Centrosema pubescens, Ipomoea* sp., *Voacanga globosa*	*Dinochloa, Pteris, Miscanthus, Alpinia, Caryota, Stachytarpheta, Pandanus, Gliricidia*	*Bambusa* sp., *Imperata cylindrica, Alpinia, Cynometra, Piper aduncum, Pipturus, Macaranga, Andrographis, Colona serratifolia, Musa, Desmodium, Chromolaena, Leucaena, Glochidion, Psidium, Flagellaria, Stachytarpheta*

Shannon-Weiner Diversity Index (tree vegetation)	0.234 (plantation), 1.82 (remnant forest), 1.332-1.55 (secondary forest), 0.637 (Lithocarpus forest)	0.00 (plantation), 3.328 (secondary forest)	1.604 (plantation), 1.788 (secondary forest)
Shannon-Weiner Diversity Index (grassland)	(0.00) 0.886-1.718	1.55-2.005	0.782-1.959
Equitability Index (tree vegetation)	(0.083) 0.355-0.774	(0.00) 0.874	0.578-0.730
Equitability Index (grassland, ecotone, wildling and ground vegetation)	(0.00) 0.237-0.460	0.408-0.538	0.202-0.609

Forest and grassland species diversity was highest in Site II, followed by Site III and lowest in Site I. This is supported by the Equitability Index of the trees which was highest in Site II and lowest in Site I.

The non-tree species diversity was relatively the same among the three sites.

- *Tree density:* Site II > Site III > Site I
- *Tree species wealth:* Site II > Site III > Site I
- *Tree diameter:* Site I > Site III > Site II
- *Forest species diversity:* Site II > Site III > Site I
- *Grassland species diversity:* Site II > Site III > Site I

Grassland vegetation in Site II was in a more advanced stage of regeneration, with more and diverse emergents. It was apparent that the site was established earlier, allowing for the proliferation and growth of pioneer second-growth species. More uniform grassland vegetation with mainly *Blumea balsamifera* as emergents was observed in Site I. Apparently this was an earlier stage of regeneration and the area had only been converted to an ANR site recently. This underlined the importance of the tree vegetation around the grasslands as it was the source of propagules for the pioneering non-grass species in the grassland areas.

Changes in diversity before and during ANR

In a span of 17-18 months, notable changes have been observed in the biodiversity of the sites which could be attributed to the application of ANR techniques.

In Site I, the extent of the grassland vegetation appeared to be unaltered before and during the ANR project, but the pressing of the grasses allowed the *Eucalyptus* seedlings to grow rapidly from less than 1 metre or lower than the grasses to over 3 metres in height. This could be noted particularly in the grasslands near the road and the firebreak at the lower part of the ANR site. While *Blumea balsamifera* and *Derris* sp. occurred sporadically in the grassland area during the early months, these plants did not survive due to the more aggressive and sturdy grass (*Hyparrhenia rufa*) which dominates the area. *H. rufa*, locally called 'damong-ranchero', which was not recorded by Merrill (1923) to be found in the Philippines in the early 1920s. It is actually a native of Africa which was deliberately introduced as fodder for cattle in Bataan only during the 1950s. It is highly adapted to fire and produces abundant seeds; thus it spreads quickly on hillsides, including the ANR site. Other plants that persist in the grassland but have very slow growth due to competition with *Hyparrhenia rufa* are kasuy (*Anarcardium occidentale*), coconut (*Cocos nucifera*), kakawate (*Gliricidium sepium*), mangga (*Mangifera indica*), avocado (*Persea americana*) and guava (*Psidium guajava*). These are fruit trees that are remnants in the abandoned settlement or farms at the site. Other natural secondary vegetation elements in the grassland which indicate that the area is developing to tree vegetation are *Pittosporum* sp., *Tabernaemontana subglobosa, Trema orientalis, Breynia* sp. and *Melanolepis multiglandulosa.*

The firebreaks, which are maintained by constant brushing, yielded open ground for the growth of Dipterocarp wildlings beside the remnant Dipterocarp forest and *Lithocarpus* and *Parkia* wildlings beside the *Lithocarpus* forest. No wildlings could be found in the ecotone along one side of the remnant Dipterocarp forest which was less brushed over in the period of observation.

The persistence of *Hyparrhenia rufa*, an exotic forage grass in the area, can be attributed to its deep root system and sturdy stems. The grass is also known to be fire-resistant (Randall 2002). Even after the plants have been pressed, the stems of this grass stand and persist over time. The prolific growth of the grass could also be attributed to its reproductive biology whereby it already starts to flower even when the plant is just 20 cm high. This grass can reach 2 metres in height and the plants were in flower during the second visit. In Costa Rica, this species was observed to be intolerant of shade and persists after annual burning unlike other competing woody plants and other grasses such *Cynodon dactylon*, *Digitaria decumbens*, and *Paspalum notatum* (Daubenmire 1972).

In Site II, the natural regeneration of the vegetation from grassland to forest was more apparent with the emergence of several reforestation species, natural secondary forest species and other indicator species. *Dicranopteris linearis*, a sturdy fern was beginning to co-dominate the landscape in an almost pure grass/sedge-dominated grassland. The growth of herbs and shrubs, in association with grasses and sedges, *Melastoma affine, Desmodium triflorum, Mussaenda philippica, Crotalaria* sp., *Gomphia serrata,* *Ilex brunnea, Neonauclea bartlingii,* and *Trema orientalis,* among others, strongly indicated that the site was in the early stage of development to secondary forest.

While some grassland areas in the site were already characterized by the presence of reforestation species (*Gmelina arborea, Tectona grandis, Leucaena leucocephala*) and secondary tree species (*Antidesma ghaesembilia, Macaranga tanarius, Trema orientalis, Commersonia bartramia, Lagerstroemia speciosa, Colona serratifolia, Cratoxylon sumatranum, Leucosyke capitellata*), the emergence of wildlings of these species indicated successful application of the ANR techniques. This supports the earlier observation that the species dominating the secondary forest have been a constant source of seeds for the regenerating areas that surround it. Species that are indicators of a more advanced state of forest ecosystem like *Lithocarpus sulitii*, *Palaquium* sp., *Canarium* sp. and *Dipterocarpus grandiflorus* were still conspicuously absent in the regenerating grassland in the area.

In Site III, the wildlings of the nearby secondary forest, such as *Macaranga tanarius*, *Glochidion rubrum*, *Polyscias nodosa*, *Cratoxylum sumatranum* and the highly invasive *Piper aduncum,* were starting to emerge in the grassland area where ANR techniques had been applied. The presence of newly-formed stands of *Piper aduncum* indicated that this species has gained a foothold and may soon spread to larger areas in the site. This species, a native of Southern Mexico, is known to be highly aggressive and can form dense stands to the exclusion of native plants (Siges *et al*. 2005). Other aggressive secondary forest species that were starting to grow in the grassland areas were *Psidium guajava*, *Leucaena leucocephala* and *Gliricidia sepium.* This indicated that the grassland ecosystem was shifting to pioneer secondary forest. While *Shorea contorta, Vatica* sp., *Lithocarpus sulitii* and *Canarium hirsutum* were among the indicators of an advanced forest in the area, wildlings of these species were not found in the regenerating grassland vegetation signifying that it may take time for the area to reach maturity.

Conservation significance of the biodiversity at the ANR sites

The three ANR sites had elements of high conservation significance with the presence of several threatened species and also alien invasive species.

Dipterocarp species, which are components of lowland evergreen rain forests in the country, were found at the sites although there are a few individuals only. In Site I, large *Shorea contorta, Shorea polysperma* and *Anisoptera thurifera* trees still existed and served as mother trees for wildlings which had successfully emerged in the firebreaks or ecotone maintained at the site. In Site II, a *Dipterocarpus grandiflorus* shed seeds during the first visit in October 2007. In Site III, *Shorea contorta* and *Vatica* sp. were also recorded in the secondary forest. Except for *Vatica* sp., all these species are classified in the *IUCN red list of threatened species* as ‘critically endangered’.

Other species in the IUCN Red List are *Ardisia squamulosa* (Vulnerable), *Diplodiscus paniculatus* (Vulnerable), *Trema orientalis* (Vulnerable) in Site I; *Dillenia philippinensis* (Vulnerable), *Pterocarpus indicus* (Vulnerable), *Artocarpus blancoi* (Vulnerable), *Trema orientalis* (Vulnerable) and *Vitex parviflora* (Vulnerable) in Site II; *Cycas silvestris* (Vulnerable), *Macaranga grandifolia* (Vulnerable), *Pterocarpus indicus* (Vulnerable), *Artocarpus blancoi* (Vulnerable), *Trema orientalis* (Vulnerable) and *Vitex parviflora* (Vulnerable) in Site III.

Invasive alien species are of conservation concern because they aggressively replace indigenous species in their natural habitats. Common examples in all the ANR sites are *Imperata cylindrica, Lantana camara, Chromolaena odorata, Psidium guajava* and *Leucaena leucocephala* among others. They are characterized by persistent root systems or rhizomes and fruits with numerous seeds which easily disperse and germinate even in poor soils. These species are also drought-resistant and can withstand fire.

Hyparrhenia rufa, which is the dominant grass in Limay, Bataan, is a species that despite application of ANR techniques is persistent because of its deep root system and sturdy stem which is resistant to fire and resilient to pressing. The aggressive and persistent characteristic of this grass species is significant in the ecology of the entire area. D'Antonio & Vitousek (1992) noted that exotic grasses, in general, compete effectively with indigenous species over a wide range of ecosystems and at the same time are capable of altering ecosystem processes from nutrient cycling to regional microclimate and can tolerate or even enhance fire.

Piper aduncum, commonly known as bamboo piper, is a small tree native to Central and South America. It is a widespread invasive species and comprises an almost pure stand of forest in Site III. The same species has spread in the forests and open lands of Davao, Bukidnon, and other provinces in Mindanao.

In other countries, the species was observed to invade and establish itself in open unshaded areas, its seeds dispersed by birds, bats and rodents, and can be propagated by suckers or cuttings. The plant has numerous uses for soil-retention structures, fuelwood, house construction material and medicine, among others. Experiments have shown that it accumulates biomass and nutrients (Rogers & Hartemink 2000) and has significant effects on soil productivity providing good planting ground for cash crops like sweet potatoes. However it has soil-drying properties (Siges *et al.* 2005).

Being a notorious invasive species, its spread in Site III must be controlled by uprooting the young plants in the open areas and applying herbicides to the more mature plants.

Conclusion

The three ANR sites exhibit unique geophysical and botanical components. These sites are under different climatic zones and have varying geological complexes. All of the three sites have a mosaic of vegetation types which include grasslands, secondary forests, remnant primary forest and (abandoned) plantation forests. Furthermore, the species composition, species dominance, diversity and structure of these sites are markedly different.

For all the ANR Sites, it is recommended to maintain the firebreaks/ecotones by brushing techniques beside the existing forest stands; ring-weeding of areas around natural regenerants and reforestation species in the grasslands; vigilance in fire detection and fire control; ensuring that the plants inside the plots are monitored and properly cared for; production of a large-scale map of the site where the vegetation can be depicted and the plots marked for monitoring purposes.

Firebreaks should also not be limited to ecotones or vegetation boundaries but should run across the slope or along the contour as well as running up and down the slope (vertically) within vast grasslands.

Firebreaks can also be in the form of green fuelbreaks where tree wildlings can be transplanted at very close intervals.

Research should be continued within the permanent plots. This can be done through the establishment of concrete posts at the corners to guarantee plot perpetuity. Monitoring of changes in species composition in the grassland permanent plots, including wildling/emergent growth within the plots, monitoring of vegetation structure, species diversity, species composition and microclimatic and edaphic conditions must be continued.

Monitoring the introduction and spread of invasive alien species should also be done in order to launch appropriate preventive and mitigation measures when this happens.

Establishment of nurseries for threatened species such as *Shorea polysperma*, *Shorea contorta*, *Anisoptera thurifera* and *Dipterocarpus grandiflorus*. These nurseries will serve as sources of propagules for reforestation.

To further enhance the success of the ANR techniques in the sites, the following activities are also recommended:

Site I

1. Subsequent transfer of some *Shorea, Lithocarpus* and *Parkia* wildlings to other sites to limit competition over space in these areas. However, it should be studied whether this will be conducive to the plants' growth.
2. Finding the right method for controlling the spread of *Hyparrhenia rufa* especially in the hillsides and rolling grasslands where the species has already spread. Mechanical pulling of the grasses or applying herbicides can be tried.

3. Establish green fuelbreaks along the contour of the vast grasslands in the site by planting species which are already found in the site like *Gliricidia sepium, Syzygium cuminii,* and *Gmelina arborea*.
4. Physical removal of dry litter and flammable plants like *Chromolaena odorata* and dried ferns.
5. Widen the firebreak around the *Lithocarpus* forest as the litter of these trees are highly flammable.

Site II

1. Planting of economic species such as banana, pineapple, etc., within the multi-purpose firebreaks.
2. Establish green fuelbreaks in hills dominated by *Dicranopteris.* The thick mat of dead leaves of *Dicranopteris* is highly flammable and thus are a fire hazard during the dry season. Pressing of the *Dicranopteris* plants can also help.
3. Establish green fuelbreaks along the contour of the grasslands in the hills by planting species which are already found in the site like *Gliricidia sepium, Acacia mangium, Syzygium cuminii,* and *Gmelina arborea*
4. Physical removal of dry litter and flammable plants like *Chromolaena odorata* and dried ferns.
5. In ecotones where *Dinochloa* and *Pteris* dominate, wider firebreaks should be established as these species are flammable.

Site III

1. Physical removal of young *Piper aduncum* plants.
2. Application of herbicides on more mature trees of *Piper aduncum.*
3. Harvest *Piper aduncum* stems for their commercial value.
4. Survey of the extent of dispersal/distribution of *Piper aduncum* within the site and its vicinities.
5. Determination of the ecological effects of *Piper aduncum* particularly on soil productivity, water retention and soil-binding properties.

For ANR field personnel or NGOs and local people hired in the field:

1. Training in field identification of plants, especially rare, threatened and endemic plants. Knowledge of local plant names should be encouraged.
2. Their local knowledge on the uses of plants in the ANR sites should be harnessed and recorded.

Problems encountered during the botanical inventory:

1. Lack of large-scale reference maps for the ANR sites.

2. Lack of scientific equipment such as laser finders and survey instruments. This equipment was borrowed by the consultant from elsewhere.
3. Instances when fieldwork was done on rainy days.

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Appendix I

Geophysical characteristics of the three ANR sites in the Philippines surveyed in 2007 and 2009

	Limay, Bataan (Site I)	San Miguel, Bohol (Site II)	Balagunan, Davao (Site III)
Geographical coordinates			
Grassland	***Near the road with Eucalyptus seedlings (Permanent Plot 1)*** North 14.52499, East 120.54558, 375 masl North 14.52395, East 120.54385 North 14.52414, East 120.54377 North 14.52415, East 120.54392 370-376 masl ***Near the hut (Permanent Plot 2)*** North 14.52392, East 120.54152 North 14.52376, East 120.54152 North 14.52389, East 120.54170 North 14.52373, East 120.54160 400-410 masl ***Open area near Lithocarpus forest (Permanent Plot 3)*** North 14.52462 East 120.54140 430 masl	***Plot 1 (before)*** North 14.52499, East 120.54559	***Plot 1, Site A (before)*** North 07.47779, East 125.55959 ***Plot 1, Site B (before)*** North 07.47766, East 125.56665 ***Plot 2, Site A (before)*** North 07.47800, East 125.56401 ***Lower elevation (Permanent Plot 1)*** North 07.28364, East 125.33572 87.6 masl, North 07.28368, East 125.33568, 95.9 masl North 07.28374, East 125.33572 91.3 masl, North 07.28369,East 125.33576 85.8 masl ***Mid-elevation (Permanent Plot 2)*** North 07.28401, East 125.33527,118 masl North 07.28395, East 125.33524 113 masl, North 07.28396, East 125.33518 114 masl, North 07.28402, East 125.33521, 117 masl ***High elevation (Permanent Plot 3)*** North 07.28432, East 125.33480 128 masl North 07.28426, East 125.33479, 130 masl North 07.28426, East 125.33472 133 masl North 07.28432, East 125.33473 133 masl

Ecotone	***Near remnant Dipterocarp forest (Plot 2b, during)*** North 14.31500, East 120.32624 North 14.31482, East 120.32628 North 14.31488, East 120.32635 North 14.31493, East 120.32639 400-450 masl ***Near Lithocarpus forest (Plot 4a and 4b)*** North 14.52372, East 120.54130 413 masl		***Plot 1, Site A (before)*** North 07.47668, East 125.56279 ***Plot 2, Site A (before)*** North 07.47652, East 125.56111 ***Plot 3, Site A (before)*** North 07.47876, East 125.56041 ***Plot 1, Site B (before)*** North 07.47601, East 125.56284 ***Plot 2, Site B (before)*** North 07.47693, East 125.56540 ***Plot 3, Site B (before)*** North 07.47787, East 125.56466 ***Plot 4, Site B (before)*** North 07.47965, East 125.56185 ***Plot 1 (during)*** North 07.28410, East 125.33510 123 masl North 07.28408, East 125.33504 120 masl North 07.28413, East 125.33501 119 masl North 07.28416, East 125.33508 119 masl
Remnant Dipterocarp Forest	***Plot 2 (before)*** North 14.0798, East 120.86870	-	-
Secondary Forest	***Plot 3 (before)*** North 14.52656, East 120.53925, 493 masl	***Plot 1 – Transects 1-4 (before)*** North 09.95653, East 124.26844 264 masl	***Plot 1, Site A – Transect 3 (before)*** North 07.47729, East 125.55997 ***Plot 1, Site A – Transects 4-5 (before)*** North 07.47777, East 125.55959
Other Types of Forest	***Plot 1 – Tiesa stand (before)*** North 14.52371, East 120.54352 ***Plot 4 – Lithocarpus forest (during)*** North 14.52652 East 120.54100	***Plot 2 – Transect 5 (before)*** North 09.95967; East 124.26837 at about 237 masl	***Plot 1, Site B (before)*** North 07.47778, East 125.56340 ***Plot 2, Site B (before)*** North 07.47896, East 125.56242

Climate type			
Coronas Modified Classification of Philippine Climate (Kintanar 1984)	Type 1: two pronounced seasons: dry from Nov. to Apr., wet for the rest of the year	Type IV: rainfall more or less evenly distributed throughout the year	Type III: seasons not very pronounced; relatively dry from Nov. to Apr., wet for the rest of the year
Hernandez Climate type based on ratios of dry to wet months (Kintanar 1984)	Type D: dry; rain not sufficiently distributed with at most 6 dry months	Type C: moist; rain sufficiently distributed with 5 dry months	Type A: wet and rainy
Geology/soil type			
Bureau of Mines and Geo-Sciences 1982	Zambales ultramafic complex; massive coralline limestone with siltstone and shale interbeds; Quarternary volcanic cones	Pre-Tertiary volcanic and sedimentary rocks	Basement rocks of alicia schists on volcanics, serpentinite and diorite; limestone and alluvium soils

Note: masl = metres above sea level.

Plant diversity, soil chemical changes and carbon stock assessment of a marginal ANR site in the Philippines

Leonardo M. Florece and Jesusita Coladilla[1]

Introduction

The growing concern for the development of marginal lands demands a cost-effective rehabilitation strategy in the face of poverty and environmental degradation. Most marginal lands or grasslands are characterized to be low in biodiversity and soil infertility generated by continuous burning for pasture improvement and hillside farming. Therefore, restoring the lost forest cover will not only improve biodiversity and physical conditions but also enhance the land's capacity to support local people's sources of livelihood in the uplands. Land rehabilitation will likewise contribute to mitigating climate change and environmental security.

Marginal lands, as defined by the Department of Environment and Natural Resources (DENR), are "areas once covered with tropical forest, converted to plantation forests, fire-climax *Imperata* grassland, and reproduction brush". These areas have the general characteristics of low productivity, inability to support extensive lowland-type agriculture and high in-migration rates. Falling under the category of marginal lands are open lands, grasslands, rangelands, grazing lands and pasturelands. These lands are very important ecosystem types both in terms of extent and value, and the fact that they have varied ecological and economic importance also requires immediate attention. Considerable tracts of watersheds in the country today are vegetated with grasslands and brush that support water for irrigation, hydropower and other domestic uses. Economically, about one-third of our people rely on these ecosystems for livelihoods or additional sources of fibre, timber and fuel supply. Because of low productivity, upland dwellers remain poor and the practices they are using also lead to further deterioration.

Very recently, these lands are being eyed as potential areas for biofuel production due to increasing prices of fossil fuel in the world market. Improving the productivity of marginal lands, however, remains a daunting challenge. This is because, from experience, their rehabilitation has always been futile because of poor soil condition, tenure problems and regular fire events. For instance, the DENR has already spent an estimated US$22.4 million for the reforestation of marginal lands only for them to be destroyed by fire subsequently (Table 1). Hence, if the government is keen on

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developing these areas as possible sites for biofuel, a thorough assessment of the area and a workable strategy must be developed for plantations to succeed. Proponents of biofuel assert that only lands not suited for agriculture are the subject for development in order to avoid competing with national food security. If this is true, then marginal lands are the most likely sites for biofuel production. Grasslands, barren areas and wooded grasslands are estimated to cover about 2.2 million hectares (DENR 2005).

Assisted natural regeneration (ANR) is a technique that may be utilized for the rehabilitation or development of marginal areas. The DENR has had this technology for some time. In fact, Memorandum Circular No. 17 was issued in late 1989 for DENR staff to implement the strategy in their reforestation activities. But, until today, it appears as if this approach has been underutilized despite the following advantages: (a) it is cheaper or cost effective, (b) it is ecologically desirable, (c) it promotes biological diversity, (d) it maintains hydrological integrity and (e) it can source local communities' familiarity with indigenous plant species of value to them (Sajise 1989).

Table 1. Fire occurrences and area burned from 1992 to 2004

Year	Fire events	Area burned (ha)				Total Cost $US	Size (ha/ event)
		Natural forest	Grassland	Plantation	Total		
1992******	1 106	5 064	14 404	31 842	51 310	4 091 639	46.39
1993	595	312	415	14 603	15 330	3 659 484	25.76
1994	218	648	2 509	4 564	7 721	456 385	35.42
1995	280	1 370	2 055	7 285	10 710	1 117 891	38.25
1996	194	5	891	4 568	5 463	2 454 792	28.16
1997	147	410	372	2 780	3 561	1 236 999	24.23
1998******	941	17 044	18,894	18 894	54 832	4 777 659	58.27
1999	36	257	3 500	2 344	6 102	720 109	169.49
2000	38	829	1 123	1 186	3 137	120 284	82.56
2001	26	129	700	753	1 582	418 615	60.83
2002*	180	1 971	2 238	16	4 224	1 056 385	23.47
2002**	227	1 983	2 619	4 147	8 749	1 303 421	38.54
2003	208	58	507	5 236	5 800	664 419	27.89
2004	46	20	764	656	1 440	330 852	31.31
Total	**4 242**	**30 098**	**50 990**	**98 873**	**179 961**	**22 408 935**	

*Statistics from 1992 to 2002 are sourced from data submitted by regional offices compiled and consolidated by the Special Action and Information Division (SAID).
** Statistics from 2002 to 2004 are sourced from submitted reports by regional offices in compliance with the Office of the Undersecretary for Field Operations (OUFO) Memo dated 27 April 2004. Data for 2004 cover January to April 2004 only.
***El Niño years.
Source: USAID, Special Concerns Office; DENR (2004).

The concept of plant succession is the fundamental basis of ANR. Sajise (1989) described ecological succession as an "orderly process of community changes, which is directional and often predictable. If it is described in terms of plant community changes, then it is referred to as plant succession". The basic ecological processes of species replacement through time as a result of modification of the environment by pioneer plant species that are favourable for the recruitment of climax species are central to ANR.

ANR as a rehabilitation process is defined by Sajise (1989) as a "reforestation strategy that makes use of advanced stages of plant succession characterized by the presence of sufficient numbers of tree seedlings, mother trees, favorable soil and microclimatic conditions as a starting point by which enhancement activities of seedling 'liberation', protection, and enrichment planting is conducted".

As a science it could be defined as a systematic integration of biophysical, technological, socio-economic and cultural information to meet the objectives of forest rehabilitation. This definition implies that successful attainment of ANR objectives requires a thorough understanding of the prevailing biophysical characteristics of the site, the prevailing socio-economic and cultural traditions or indigenous knowledge of the local people to be involved and the acceptability of the technology that will be introduced in the area. Therefore, ANR is site-specific and requires some modifications of the current implementing guidelines or policies to make it suitable to ranges of conditions prevailing in the country.

Since the concept evolved, not much research has been conducted to test the effectiveness of the strategy. Because of the need to improve knowledge on ANR, such research was implemented with the objectives of: (a) analysing the effectiveness of *Gliricidia sepium* cuttings as planting material for grassland rehabilitation by quantifying its survival and growth performance after planting and burning; (b) quantifying plant diversity (plant species composition) and physical (soil chemical) changes under the established stand of *Gliricidia*; and (c) assessing the carbon stock of the 20-year-old ANR site planted with *Gliricidia.*

The Research Site

The research site was formerly the fire ecology study area of the Upland Hydroecology Program (UHP) of the University of the Philippines at Los Baños in 1979. It is situated at an elevation of between 390 and 400 metres and was believed to be a Dipterocarp forest that had been subjected to swidden farming after the Second World War. It had been abandoned for almost 20 years and with regular burning every year, grass dominance had been maintained. The soil in the area is Macolod Clay Loam (UHP 1979). It is under the Type 1 climate of the Corona classification system, with almost 94 percent of the total annual rainfall occurring in May to October. The fire ecology research team under the UHP conducted the following studies in the area: (a) effects of fire on soil temperature at two depths (2.5 and 6 cm); (b) effects of fire on soil temperature; (c) effects of fire on some soil chemical properties; (d) effects of fire on the Acarine fauna of the grassland; (e) influence of fire on soil fungal populations in the grassland; (f) effects of fire on grassland vegetation; (g) effects of grass management on the bacterial and actinomycete populations and on nitrogen availability; (h) runoff and sediment load; and (i) chemical composition of the runoff water from grass-covered plots subjected to different types of grass management and times of burning. The size of the study site is about 2 500 m^2 bounded by secondary forest and fallow kaingin (a shifting cultivation area). The secondary forest here could serve as source of propagules for plant succession (Plate 1).

Materials and methods

Vegetation and soil sampling

Initial vegetation composition was determined by the harvesting method in a 1 m^2 quadrat on 6 April 1989. Twelve 1 m^2 quadrats were randomly chosen along the ridge and another 12 below the ridge. The harvested above-ground biomass was placed in plastic bags and later brought to the School of Environmental Science and Management's analytical laboratory for segregation by species; it was then placed in paper bags for oven drying for 48 hours at 105^0C. The Importance Value (IV) for each species was determined using the dry weight as basis for computation..

Twelve composite soil samples were also taken randomly for soil pH, nitrogen, phosphorus, potassium and organic matter determination. These processes were then repeated in August 1996 and February 2009 or seven and 20 years after, respectively.

Land preparation and planting material

Burning was used for clearing the whole site. This was done on 10 April 1989 or after the vegetation sampling was completed. Before burning, the grasses were lodged to achieve a good burn or complete removal of above-ground biomass. Stems of talahib (*Saccharum spontaneun*) constituted most of the unburned material because of its high moisture content and the woody nature of its stem.

Gliricidia sepium (kakawate) cuttings were used considering the good sprouting ability of the species when used as pegs or posts for fences. Cuttings as planting stock are advantageous over seedlings because of larger diameter size compared to potted seedlings, they eliminate the need for nursery operation, they are easy to haul (about 100 cuttings per person) and have a faster rate of planting (about 150 cuttings per person). Moreover, *Gliricidia*: (a) is a socially acceptable among farmers; (b) although exotic, it has already adapted to local conditions; (c) is a multipurpose species; and (d) it coppices readily. The cuttings were 0.5 m in length and were planted at 1 x 1 m at a depth of 0.25 m. Cuttings were sharpened (like sharpening a pencil) using a machete and care was observed not to split the bark. This was done by digging a hole using a rounded iron bar at a depth of 0.25 m before inserting the stem cutting.

Experimental design and treatments

The study occupied a total area of 2 500 m^2. The experiment was laid out in a completely randomized design with diameter class as the main plots and length of storage of cuttings as subplots. The following treatments were used:

T_1 or 2A: Cutting diameter class 1.5-2.99 cm and cuttings stored for 1 week, and site burned the following year;
T_2 or 2B: Cutting diameter class 1.5-2.99 cm and cuttings stored for 2 weeks, and site burned the following year;
T_3 or control: Cutting diameter class 1.5-2.99 cm, cuttings not stored, and no site burning;
T_4 or 4A: Cutting diameter class 3.0-4.99 cm, cuttings stored for 1 week, and burned the following year;
T_5 or 4B: Cutting diameter class 3.0-4.99 cm, cuttings stored for 2 weeks, and site burned the following year;
T_6 or control: Cutting diameter class 3.0-4.99, not stored, and no site burning.

The cuttings were sharpened at the base at the time of collection; then they were immediately stored in the shade. The treatment that needed no storage was planted the following day. Length of storage for one treatment was assessed to determine the effect of storage on survival for the practical reason that collection and hauling will require some time to accomplish under actual field conditions. Similarly, diameter size indicates the age or maturity, and therefore is a critical variable in the survival of cuttings. Planting commenced on 5 May 1989, then 12 May and 19 May for no storage, 1 week storage and 2 weeks' storage, respectively. There were 20 sample plants per treatment replicated six times. Survival was monitored quarterly during the first two years and the final determination of survival was conducted in August 1996.

A multifactor analysis of variance (ANOVA) was used to determine the effects of fire treatment, diameter size and length of storage on survival of cuttings; significant differences were analysed using the Tukey test. A one-factor ANOVA was used to analyse the initial and final sampling of soil variables.

Measurement of carbon stock

The field methods used by Banaticla (2003) in estimating the C pools for various land-use types in Putting Lupa, Mt. Makiling Forest Reserve were adopted in this study. The C stock in the following pools was measured:

- Above-ground biomass – all vegetation in the understorey layer.
- Below-ground biomass – coarse and fine roots found at depths of up to 5 cm.
- Necromass – coarse woody debris and standing litter (fallen leaves, twigs and branches, fruits and flowers on the forest floor).
- Soil organic C – up to 30 cm depth.

The method of estimating biomass and necromass was expressed in terms of dry matter per unit area (megatons per hectare) (Mg/ha) and was determined by obtaining the dry weights of the vegetation. Dry matter was then converted to the equivalent amount of C by multiplying the dry matter weight by 45 percent which is the average content of plant tissue samples taken from different areas in the Philippines (Lasco *et al.* 2002).

The total system C stock of each land cover type was calculated based on the following equation:

$$\text{Total system C stock (Mg/ha)} = \frac{\text{Biomass C + necromass C+ soil C}}{\text{Area of land (ha)}}$$

Sampling procedure

Three rectangular plots measuring 5 x 30 m (150 m2) were established from the ridge down the lower slope of the ANR site. Within each plot, a 30 m central transect line with 2.5 m perpendicular lines on both sides were established and a 1 x 1 m square plot was determined for sampling of understorey vegetation, litter, underground roots and soil for analysis (Figure 1).

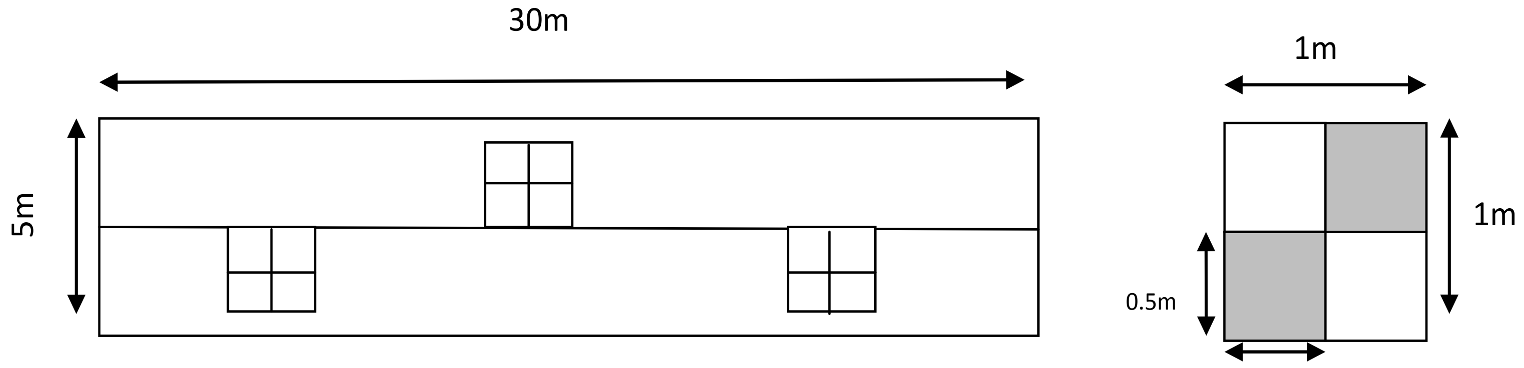

Figure 1. a. The main 150 m^2 plot for sampling trees. Within the plot are randomly located sampling quadrats for understorey vegetation, litter, roots and soil. b. Sampling quadrats for understorey vegetation (1 x 1 m) and litter/soil/roots (0.5 x 0.5 m). The shaded quadrats are for sampling litter. There were 3 samples for understorey vegetation and 6 samples for litter, roots and soil.

All trees within the 5 x 30 m rectangular plot with diameter at breast height (dbh) of ≥10 cm and palms live or dead were identified and their dbh was measured using a digital caliper. Tree height was measured using a Haga altimeter.

In estimating individual above-ground tree biomass the regression equations shown in Table 2 were used (Banaticla 2003). For sampling understorey biomass and the litter layer, a quadrat measuring 1 x 1 m and subdivided into four equal sections was established. All plants with less than 5 cm in diameter found inside the quadrat were clipped, weighed and brought to the laboratory for oven-drying at 60ºC until constant weight was achieved.

Table 2. Biomass regression equations for estimating individual above-ground tree biomass

Species	Equation (biomass in kg)	n	r^2	dbh range (cm)	Height range (m)	Source
Palms	Biomass = 0.3999+7.907 *total height	-	0.75	-	1-33	Teopolo *et al.* (2002)
Ipil-ipil	Biomass = 0.08771*dbh2.13 * total height$^{0.36}$	18	0.98	5.40-21.0	5.70-16.30	Tandug (1986)
General	Biomass = 0.068xdbh2.5	39	0.99	4.10-36.1	-	Banaticla (2003)

Note: n = number of tree samples; r^2 = correlation coefficient; ρ = wood density in g/cm^3).

For the necromass, all undecomposed materials or crop residues from the randomly chosen 0.5 x 0.5 m quadrats within the understorey quadrats were collected, sieved, weighed and oven-dried in the laboratory at 60ºC until constant weight was achieved.

The biomass/necromass and equivalent C stored in the understorey vegetation and litter were calculated using the following equations (Banaticla 2003) as follows:

$$\text{Total dry weight (kg/m2)} = \frac{\text{Oven-dry weight (g)/1 000(g/kg)}}{\text{Area of quadrat (m}^2\text{)}}$$

$$\text{Biomass/necromass dry weight (Mg/m}^2\text{)} = 10 \times \text{total dry weight (kg/m}^2\text{)}$$

$$\text{C stock} = \text{biomass/necromass dry weight (Mg/ha)} \times 45\% \text{ C content/100}$$

For the below-ground C pools, the live and dead roots in the upper 5 cm soil layer and soil up to a 30 cm depth were collected. Then, from the 0.5 x 0.5 m sampling site for necromass/biomass, a 0-5 cm soil layer was excavated, coarse-sieved for roots and soil samples, transferred to a plastic bag and brought to the laboratory for air-drying and dry-sieving of roots. Digging was continued for sampling of roots and soil at depths of 5-15 cm and 15-30 cm (Banaticla 2003).

The collected soil samples with roots were air-dried in the laboratory and dry-sieved with a 2 mm sieve. The collected roots with soil particles were washed to get rid of the adhering soil particles, air-dried, weighed and oven-dried at 60ºC until constant weight was attained. Total root dry matter and C were calculated using the same formula used for the understorey and litter pools.

Composite air-dried soil samples that passed through the sieve during the processing of roots for the 0-5 cm, 5-15 cm and 15-30 cm layers were later sent to the UPLB-ASC Soil Analytical Laboratory for pH and organic matter analysis using the Walkley-Black method.

Results and discussion

Survival of stem cuttings

The initial mean survival of *G. sepium* cuttings six months after planting (November 1989) for all treatments was 64 percent (Table 3). This may be low because planting was delayed for two weeks. The best time for planting of *G. sepium* stem cuttings as experienced by many farmers in the uplands is before the onset of the rainy season or in mid-April. Although the highest survival rate (78.33 percent) was observed in Treatment 4B or diameter size of 4 cm stored for two weeks and the lowest was in Treatment 1 or 2A at 48.33 percent, their differences were not significantly different. This implies that either sizes may be utilized as planting material and that planting may be delayed for two weeks as long as the cuttings are stored under shade and abrasions on the bark at the base are avoided.

Table 3. Mean survival (%) of *G. sepium* stem cuttings for two sampling periods

Treatment	22 November 1989* % survival	17 July 1996* % survival
T1 or 2A	48.33a	18.33a
T2 or 2B	63.33a	33.33ab
T3 or 2 control	56.67a	38.33ab
T4 or 4A	65.00a	40.83ab
T5 or 4B	78.33a	41.67ab
T6 or 4 control	71.67a	50.00b
Mean	**64.00a****	**37.00b****

*Mean survival rates along columns with the same superscripts are not significantly different at the 5 percent level by the Tukey test.

**Survival rates across columns are significantly different at 5 percent.

The mean survival rate in August 1996 or after about seven years was 37 percent (Table 3), which is significantly different ($p<0.05$) from that of the initial survival rate. The very low survival rate after seven years was attributed to the fire generated in the second year (April 1990). The relatively higher survival rate of cuttings in the bigger size class implies that diameter size is indeed an important factor of survival. Therefore, for the plantation to be successful, fire prevention, control and maintenance activities must continue until such time that the diameter of seedlings or stocks has reached a ground-line diameter (gld) of at least 5 cm. To attain this size, would require about five years or more. The current project reforestation budget allotment is only good for three years, and therefore seedlings will only be about 2-3 cm gld; thus they could still be easily killed by wildfire. Survival, however, is dependent also on species. Fire-intolerant species (e.g. *Acacia auriculiformis*) would still be killed by fire at 10 cm gld while fire-tolerant species at 5 cm gld would survive high fire intensity levels either through basal or epicormic sprouting (Florece and Methven 1996).

Vegetation composition

The initial vegetation sampling in April 1989 showed a total of 16 plant species with *Saccharum spontaneum* and *Imperata cylindrica* being the two most dominant grasses – an IV of 47.1 and 41.5 percent, respectively (Table 4). There were no wildlings of trees recorded despite the secondary forest that surrounds the site. The regular fire set every year by farmers surrounding the site might have eliminated the wildlings of broadleaved plants since the time of its abandonment by the UHP in 1979.

Table 4. Vegetation composition of the site during initial and second samplings

6 April 1989 (Initial)			August 1996 (second)		
Species	**O.D. wt.(g/m²)**	**IV (%)**	**Species**	**O.D. wt.(g/m²)**	**IV (%)**
*S. spontaneum**	1 472	47.1			
O. corniculata	0.4	0.01			
*D. triflorum**	15.4	0.49			
*A. mutica**	39.6	1.27			
Cyperus sp.	1.2	0.04			
*I. cylindrica**	1 296	41.48			
*D. bulbifera**	0.2	0.006			
E. oryzoides	100.8	3.23			
C. pubescens	0.4	0.01			
*L. circinatum**	5.2	0.17			
Ipomoea sp.	9.6	0.31			
*M. cordata**	18.7	0.59	*M. cordata*	29.6	4.82
*E. tomentosus**	3.1	0.09	*E. tomentosus*	13.2	2.15
P. conjugatum	105.8	4.83	*P. conjugatum*	225.5	36.7
C. patens	9.2	0.294	*C. patens*	206.7	33.64
C. acrescens	1.8	0.064	*C. acrescens*	4.1	0.67
			S. nodiflora	2.1	0.34
			N. cordifolia	32.6	5.3
			L. camara	7.5	1.22
			C. odorata	56.2	9.13
			C. asiatica	0.1	0.02
			A. conyzoides	0.5	0.08
			Trees/shrubs		
			L. leucocephala	19.8	3.22
			F. hauili	4.3	0.7
			F. ulmifolia	11	1.79
			C. philippensis	0.2	0.03
			B. javanica	1.2	0.19
Total	**3 124.4**	**100**		**614.6**	**150.49**

*Species present during the Fire Ecology Study of the UHP in 1979.

The result of the sampling conducted in August 1996 or seven years later showed a completely different vegetation type dominated by *Paspalum conjugatum* and *Cyrtococcum patens* with IVs of 36.7 and 33.6 percent, respectively (Table 4). It is surprising that the two most dominant species encountered in the initial sampling no longer existed. Out of the 16 species recorded in 1989, only five were encountered in the August 1996 sampling. These were: *Mikania cordata*, *Elephantopus tomentosus*, *Paspalum conjugatum*, *Cyrtococcum patens* and *C. acrescens*. New species have emerged such as *Synedrella nodiflora, Lantana camara, Chromolaena odorata, Centella asiatica* and *Ageratum conyzoides.* The dominant grasses in the August 1996 sampling such as *P. conjugatum* and *C. patens* had a very low IV during the initial sampling but became the dominant species after seven years, which indicated that these species were shade-loving (Table 5). It is notable that during the initial sampling the total above-ground biomass was 3 124 g/m2 with almost 88 percent of the biomass contributed by *S. spontaneum* and *I. cylindrica* as against the second sampling of only 615 g/m2 mostly from the biomass of *P. conjugatum* and *C. patens* or a marked decrease of 80 percent above-ground biomass (Table 4).

Table 5. Other tree species present in the area during the August 1996 sampling or species not captured by the sampling method used

Common name	Scientific name	Family
Paguringon	*Cratoxylum sumatranum* (Jack) Blume	Clusiaceae
Tibig	*Ficus nota* (Blanco) Merr.	Moraceae
Banaba	*Lagerstroemia speciosa* (L.) Pers.	Lythraceae
Salago	*Phaleria capitata* Jack	Thymelaeaceae
Matang-araw	*Melicope triphylla* (Lam.) Merr.	Rutaceae
Mamalis	*Pittosporum pentandrum* (Blanco) Merr.	Pittosporaceae
Hamindang	*Macaranga bicolor* Muell-Arg.	Euphorbiaceae
Bogus	*Acalypha stipulacea* Klotz.	Euphorbiaceae
Kalingag	*Cinnamomum mercadoi* Vid.	Lauraceae
Tangisang bayawak	*Ficus variagata* Blume	Moraceae
Bignay pugo	*Antidesma pentandrum* (Blanco) Merr.	Euphorbiaceae
Tirukan	*Beilschmiedia glomerata* Merr.	Lauraceae
Matang hipon	*Breynia rhamnoides* (Retz.) Muell-Arg.	Euphorbiaceae
Putat	*Barringtonia racemosa* (L.) Blume ex DC	Lecythidaceae

Moreover, a complete enumeration in 1996 of tree species within the site or those that were not captured by the sampling method used revealed 14 species, which indicated that the site had shifted into an advanced stage equivalent to a secondary forest ecosystem (Table 5). This could be explained by the following conditions: (a) *G. sepium* plantation provided a conducive microclimate for the recruitment of tree species; (b) the exclusion of fire allowed for the entry of fire-sensitive species; and (c) the presence of mother trees surrounding the site as sources of seeds.

Recently, a complete enumeration of plants contained in the ANR site revealed a total of 29 species of trees, palms and shrubs and eight species of grasses, herbs and vines (Table 6), which is considerably different and more diverse compared with the initial vegetation where grasses dominated (Plate 1).

Plate 1. The ANR site in 2009 or about 20 years after establishment (courtesy Leonardo M Florece)

Table 6. Plants at the ANR site as of June 2009

Local name	Scientific name	Family
Grasses/herbs/vines		
Bikal babui	*Dinochloa luconiae* (Munro) Merr.	Poaceae
Bikal	*Dinochloa acutiflora* (Munro) S. Dransf.	Poaceae
None	*Cyrtococcum patens* (L.) A. Camus	Poaceae
Cyperus sp.	*Cyperus* sp.	Cyperaceae
Devil's grandmother	*Elephantopus tomentosus* L.	Astraceae
Uoko	*Mikania cordata* (Burm. F.) B.L. Rob.	Asteraceae
Litlit	*Piper interruptum* Opiz var. loheri (C.DC.) Quis	Piperaceae
Bamban	*Donax cannaeformis* (G. Forst.) K. Schum.	Maranthceae
Trees/palms and shrubs		
Subiang	*Bridelia insulana* Hance	Phyllanthaceae
Paguringon	*Cratoxlum sumatranum* (Jack) Blume	Clusiaceae
Kaong	*Arenga pinnata* (Wurmb) Merr.	Arecaceae
Amugis	*Koordersiodendron pinnatum* (Blanco) Merr.	Anacardiaceae
TibigIpil-ipil	*Ficus nota* (Blnco) Merr.	Moraceae
Hauili	*Leucaena leucocephala* (Lam) de Wit	Fabaceae
Matang araw	*Ficus septica* Burm. F.	Moraceae

Bayanti	*Melicope triphylla* (Lam.) Merr.	Rutaceae
Tagbak	*Aglaia rimosa* (Blnco) Merr.	Meliaceae
Coronitas	*Alpinia elegans* (Presl.) K. Schum.	Zingiberaceae
Hagimit	*Lantana camara* L.	Verbenaceae
Takipan	*Ficus minahassae* (Teysm & de Vriese) Miq.	Moraceae
Lago	*Caryota rumphiana* Mart. var *philippinensis* Becc.	Arecaceae
Tamayuan	*Prunus grisea* (C. Muell.) Klkm.	Rosaceae
Balingayo	*Strombosia philippinensis* (Baill.) Rolfe	Olacaceae
Kayumanis	*Erythropalum scandens* Blume	Olacaceae
Alasiis	*Clausena anisum-olens* (Blanco) Merr.	Rutaceae
Lamog	*Aphananthe philippinensis*	Ulmaceae
Putat	*Planchonia spectabilis* Merr.	Lecythidaceae
Namot	*Barringtonia racemosa* (L.) Blume ex DC.	Lecythidaceae
Kalingag	*Cynometra bijuga*	Fabaceae
Ligas	*Cinnamomum mercadoi*	Lauraceae
Strophanthus sp.	*Semecarpus cuneiformis*	Anacardiaceae
Duyok-duyok	*Strophanthus* sp.	?
Matang-hipon	*Manilkara fasciculata*	Sapotaceae
	*Breynia rhamnoides (*Retz.) Muell-Arg.	Euphorbiaceae

Soil chemical changes

Soil chemical analyses of samples taken on 6 April 1989 (initial) and the sampling conducted on 12 March 1997, revealed higher values in the later sampling in all variables, except for organic matter percentage and nitrogen where no significant differences were detected (Table 7). Phosphorus, potassium and pH values during the initial and second sampling were significantly different at the 5 percent level of significance (by the Tukey test). Though nitrogen was not significantly different after seven years, the increase in the levels of soil chemical properties indicated that *G. sepium* could be a good fallow crop for marginal lands or swidden agriculture. Grist *et al.* (undated) also observed an increasing fertility over time when *G. sepium* was used as a fallow crop. Simons and Stewart (1994) revealed that the leaves of *G. sepium* when used as mulch decomposed in 40 days, hence allowing for rapid recycling of soil nutrients.

Soil analysis after about 20 years showed a slight improvement in soil chemical properties compared with the initial soil analysis especially in terms of soil organic matter and nitrogen content except for pH where the sampling in June 2009 showed a much lower value of 5.3 (Table 7).

Table 7. Results of chemical analysis of soils taken on 6 April 989 (initial), 12 March 1997 and 30 June 2009 sampling in the area.

Variables	6 April 1989	3 March 1997	30 June 2009
pH	5.34 a	5.86 b	5.3
%OM	5.72 a	5.93 a	6.73
Nitrogen	0.243 a	0.276 a	0.337
Phosphorus	0.219a	1.311b	
Potassium	1.78a	2.86b	

Superscripted values with different letters between columns are significantly different at the 5 percent level of significance (Tukey test).

Estimated C stocks

Results of carbon stock estimation in the ANR site 20 years after the initial activity in the area are shown in Table 8. Initial carbon stock was not estimated prior to ANR activities in the area, but as the area was formerly grassland dominated by *Imperata cylindrica* and *Saccharum spontaneum*, the estimated C stocks would not differ greatly with the study of Lasco and Pulhin (2000) or other authors for this type of vegetation.

Table 8. Estimated C stocks in the ANR site

Plot no.	Estimated C stored in live trees (Mg/ha)	Estimated C from above-ground biomass (Mg/ha)	Estimated C from necro-mass (Mg/ ha)	Estimated C from soil (Mg/ha)	Estimated total C stock (Mg/ha)
Plot 1	807.70	0	4.58	115.03	119.61
Plot 2	576.48	5.13	5.64	115.03	125.8
Plot 3	105.43	3.81	4.70	115.03	123.54
Mean	496.54	2.98	4.97	115.03	122.98
SD	357.89	2.66	0.58	0.0	3.13
CV (%)	128 087	7.09	0.34	0	9.81

The mean C stock of live trees is 496 Mg/ha, 2.98, 4.97 and 115 Mg/ha for above-ground biomass, necromass and C from the soil, respectively. The ANR system today as a whole has a mean C stock of 123 Mg/ha (Table 8).

The mean C stock (123 Mg/ha) of the ANR site today is much higher compared with the study of Banaticla in 2003 (Table 9) in the same area under abandoned shifting cultivation with only about 56 Mg/ha. This means that ANR has the potential to increase C stock when properly managed and protected from human activities. Differences in C stock values of the ANR site and that of Banaticla (2003) were not statistically analysed due to differences in sampling size.

Table 9. Comparison of estimated average C stock Banaticla (2003)

	C stock (Mg/ha) for the 22-year abandoned *kaingin*	This study C stock (Mg/ha) for the 20-year ANR site	Banaticla (2003) C stock (Mg/ha) for open *kaingin*
Tree biomass	84.44	496.54	89.17
Above-ground biomass	2.01	2.98	0.05
Necromass	3.038	4.97	1.352
Soil C	50.74	115.03	42.11
Estimated total C stock	55.788	122.98	43.512

Conclusion and recommendations

Rehabilitation of degraded forest lands through conventional and ANR approaches is a complex matter that needs a thorough understanding of the biophysical, technological, socio-economic and cultural conditions prevailing in the area. There are no short cuts to forest rehabilitation work as evidenced by the long process that occurred in Mt. Makiling. Although the socio-economic and cultural dimensions of ANR were not taken into account, it is still possible to test the technology in some parts of the country by asking people whether they are willing to try the technique. With the ailing economy, a cheaper version of rehabilitation must be developed. And the use of stem cuttings as described deserves a second look if it is possible in some other sites similar to the conditions at Mt. Makiling. We must endeavour to properly set up ANR sites and to document the process from the beginning to the end. Allowing an area to become marginal, such as a grassland, will entail more resources to reforest and will be more difficult because of the recurrent fire that inhibits the growth and survival of trees. But if tree species planted are fire-resistant and fast growing, grassland species will be gradually eliminated because they are shade-intolerant.

The following actions are recommended: (a) identification and characterization of ANR sites under various climatic zones in the country; (b) revision of MC No. 17 to suit the varying conditions of ANR sites; (c) research-based implementation of ANR in various sites; (d) graduate student support for those interested in research on ANR; and (e) local government participation in the implementation of ANR.

Imperata–Saccharum–Themeda-dominated grasslands abound in the country. Grasslands and marginal areas in the country are estimated to cover about 2 million hectares, all of which need immediate rehabilitation to relieve rural poverty and enhance environmental stability. As fire is the limiting factor in the rehabilitation of fire-dominated ecosystems, the following actions are recommended: (a) development of a fire management system for regions (Cordillera Administrative Region, Regions 2 and 3) and its institutionalization at all levels; (b) fabrication of fire-fighting tools and equipment to avoid relying on imported products that are often expensive; (c) support for research on fire ecology/fire management, especially on fire effects on forests at the margins of grassland areas; (d) regular monitoring and evaluation of fuel moisture under forest ecosystems during times of drought and an information, education and communication campaign in rural communities on the effects of fire on biodiversity; (e) development of a fire database system and fire-risk maps using GIS for fire-prone ecosystems; (f) formulation of a workable incentive system to encourage rural people to participate in forest fire prevention and control; and (g) regular training on fire management among DENR field staff and volunteers in villages that host fire-prone ecosystems.

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Overcoming bracken climax to assist forest regeneration in Mindanao

Lucy Linantad,[1] Rufino Sagula,[2] Eric Bruno[3] and Pedro Walpole[3]

Introduction

Mindanao's tropical rain forest lies below the typhoon belt with rainfall ranging from a distinctly dry season to rain throughout the year. The greatest area and range of forest cover are found on the slopes of the different mountain ranges that are habitats for unique species of fauna. The northern part of Mindanao has been predominantly 'Manobo', a loosely related polyglot culture of over 20 languages. The Pulangiyen, one of these communities, live along the upper reaches of the Pulangi River in Bukidnon Province and they have traditionally been associated with the local river systems. Bendum, their main village, is located at 650 metres above sea level (masl) on the western slopes of the Pantaron Range which experiences drier months from March to May.

The Pulangiyen community has an ancestral domain of 2 600 hectares that reaches the mountain ridge. There are about 80 households in the village, 20 percent being migrants. A council of elders leads the community; there are *sitio* (small settlement) leaders, some being Pulangiyen, connected to the *barangay* (village) of Busdi across the Pulangi. Helping the tribal council in the management of the domain are several committees. The Water Committee was established in 1995 and is tasked with managing the water system and its source. The committee encourages forest regeneration activities in areas of concern especially above the source. The Livelihood Committee is the trading arm of the community. The committee links the community to markets by facilitating the trading of abaca fibres and basic commodities that are not locally produced such as salt, dried fish, cooking oil, canned goods and snack foods. The committee also initiates planting of abaca to ensure the sustainability of the resource base for trade and for weaving.

Land use

Traditionally people have hunted and practiced swidden agriculture while gathering *alamay* (wild abaca) and rattan. Logging was heaviest in the area in the 1980s but has now stopped leaving the difficult forested slopes and higher elevation mossy forest unlogged. The rattan stock is now exhausted after extraction was exacerbated by many outsiders. People tried to cultivate coffee for a while and intensive maize cultivation

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was introduced by the migrants, but in the last ten years abaca has been planted and provides a variable income for many people along with less intensive farming that involves a rotation of fallow lands. Abaca is a banana-like plant (*Musa textilis*) and fibres obtained from its stalks are used to make cordage, fabric and paper.

The community has harvested forest products for a long time and has maintained much of the forest abandoned by logging companies. Young people take a particularly active role in monitoring activities in the area. The community understands that forest cover is responsible for clean water in the area. Basically, this is a community that wants to secure its domain and central to the present discussion is the water source and its system of management. The community has had to struggle with its own needs for food, for cash during emergencies and for supporting children's education. Decisions were made over a decade ago when there were external pressures to cut the forest to find other ways to support their needs other than timber extraction and forfeiting their children's inheritance. The community sought greater security in resources by establishing agreements with neighbouring communities and a formal agreement with the government regarding their ancestral domain. Their affiliation with the land and importance given to cultural identity and language has strengthened their approach to area management.

Abaca

The Pulangiyen have cultivated abaca traditionally; the women dye and weave it into *kumuyut* (cloth). *Kumuyut* is culturally important as gifts for visitors and as tokens during conflict resolution. It is also entwined into rope. With the onset of commercialization, abaca as a basic fibre is now sold and has become a reliable source of cash for the community.

To strengthen the quality of existing wild abaca stocks, new corms have been brought from Agusan. The Pulangiyen plant abaca in semi-open canopy forest; this also protects it from mosaic disease that aphids bring from the maize. In 2004, as part of a land management strategy, the committees, in cooperation with the Apu Palamguwan Cultural Education Center, started to plant abaca. Quarterly maintenance of the area is carried out via weeding and cutting of dead leaves along with the maintenance of the spring box. Planting is becoming an annual activity and is extending the original area. Abaca fibres can be extracted within three to four years after planting. The current practice employs manual stripping although a mechanized stripping machine would be more efficient. However this has not been realized yet as it may overexploit the existing resource.

Bracken climax

The natural vegetation at 600 to 700 masl is submontane forest with a significant presence of upilon or salumayag (*Agathis philippensis*) lawaan (*Shorea* sp.) and dangulog (*Dipterocarpacea*). When this land is cleared and then eroded by intensive logging activities or intensive maize production by migrants, soil nutrients are depleted and agsam or bracken (*Pteridium* sp.) dominates the vegetation more than cogon grass (*Imperata cylindrica*) or boyo-boyo (*Piper arborecens*) found at lower elevations. The bracken grows to 3 metres in height and may burn during dry periods. With such thick growth it is very hard for other species such as labagti (*Macaranga* spp.) to compete. Bracken becomes the false climax, while the true Dipterocarp climax is lost.

Forest regeneration

Formerly, water to Bendum village was delivered by split bamboo conduits but with frequent sickness and interruption of supply a safer and more permanent source was identified. A spring box was built around an exposed source adjoining cultivated land and the water was piped to the community 0.75 kilometre away on the opposite slope. The area around the spring box – about half a hectare – has since been planted with giant bamboo (*Dendrocalamus asper*) and mahogany (*Swietenia macrophylla*), both non-native species to the area as well as *Shorea*; exposed soil is now no longer found. The committee clears the spring box, mainly of roots, every three months and is also responsible for distribution and maintenance of pipes and collection of a small fee.

Above the spring box the initial cutting of some abaca and clearing of bracken in a small area allowed the growth of labagti and other noted pioneer species. Under the emerging shade of this growth, after four years new abaca corms were planted in 2006. Every school year, students collect salumayag and lawaan seedlings from the forest and plant them in the area. The livelihood and water committees along with the younger generation now want to establish more permanent cover on a neighbouring area previously cleared for agriculture and left fallow. The initial one hectare is now being extended to approximately four hectares.

Meanwhile, the lower stream banks towards the village are maintained with natural vegetation of about one hectare. A further three hectares between the village and the water source is naturally regenerating and the original vegetation is creeping back, dominated by tree ferns (*Cyathea* sp.) and some self-seeding falcata (*Albizia falcataria*). The wet area has not been successfully managed as a fishpond and has been planted with a rush (*Fimbrystilis globulosa*) that is cut and woven into soft mats. The degraded old forest is being rehabilitated and the school has about half a hectare of recently replanted *lawaan*. Burning is prevented in the area due to general awareness of the disastrous results this wrought during the drought of 1997.

The regeneration efforts are patchy with different reasons for different areas but there is an awareness of assisting natural regeneration as a strategy of particular importance to the culture. In total 12 hectares under various forms of utilization assist natural regeneration. In this way basic resources, while being productive in terms of people's livelihoods, are self-sustaining – in this case through abaca growth and water security.

This regenerating corridor links the higher tangile-oak (*Shorea polysperma* and *Lithocarpus* sp.) and mossy forests with the village and is becoming a learning ground for the education center that uses the language and culture of the Pulangiyen to strengthen their identity and negotiation powers in the valley.

Charting partnerships and possibilities for upscaling assisted natural regeneration

Rowena Soriaga[1]

Getting humans to assist natural regeneration needs to happen 'naturally'. The forest will come back if the land is not perceived as government-owned, but as a locally managed resource. The activities will continue if they are viewed as part of the stakeholders' way of life and not belonging to a project, a government programme or an NGO.

One example of upscaling assisted natural regeneration (ANR) is the 'No-Fire Bonus' Scheme in Mountain Province, the Philippines. The scheme was a provincially funded initiative from 1996 to 1998 that tapped 'natural' motivations and relationships. The Community Environment and Natural Resources Office (CENRO) desperately wanted to address the intense fires after the 1993-1994 El Niño but did not have the funds. The *barangay* (village) governments had village development plans but did not have funds for implementation. The *dap-ay* (tribal council) had a cultural system to care for forests (including fire protection) but was concerned that the system was breaking down as the sense of ancestral domain and cultural cohesion faded away. The congressman had the Countryside Development Fund that was mainly used for infrastructure projects that contributed to their political visibility. Combining all of these factors, the scheme involved the congressman awarding a PHP100 000 infrastructure project to each *barangay* government that had not incurred any fire (or made efforts to suppress escaped fires). *Barangays* that obtained a 'certificate of no-fire occurrence' from CENRO based on fire monitoring reports could claim their award from the Department of Public Works and Highways. Some municipal governments helped the *barangays* to claim the awards by covering transaction costs. The governor promised to contribute funds to the scheme, but he was not able to deliver on his promise.

The incentive scheme successfully prevented fires in 97 percent of the 124 target *barangays*. A recent impact study found a declining trend in fire occurrence even after the scheme stopped. The scheme prompted speculative behaviour among communities – they continued fire protection in anticipation of another round. In the subsequent elections, the congressman won and the governor lost. Village infrastructure projects funded through the scheme are still operational and continue to be maintained by the communities. This scheme may be likened to payment for an environmental service. Partnerships and collaboration in society happen when people are clear about each other's motivations, i.e. what's in it for them.

Another example is an effort by an urban family that owns an abandoned fishpond in Batangas to revert the area back to mangrove forest. The family sees the mangrove

1. Asia Forest Network

planting effort as a way to get families and friends together. Monitoring happens 'naturally' as the family and their friends now have a reason to frequently visit the area.

Several ANR examples exist in Bohol of families who obtained Certificates of Stewardship contracts in the 1980s under the Integrated Social Forestry Program, of people's organizations who obtained Community-based Forest Management Agreements and of households who now depend on income not from farming but from overseas remittances.

Trust in the partnership is maintained when expectations of the collaborating parties are met. Previous reforestation projects of the Department of Environment and Natural Resources raised expectations among local people that they would become millionaires if they planted falcata, mangium and mahogany, only to find when the trees had grown that either they were not allowed to harvest them or the transaction costs were very high. It takes more effort to win back trust once broken, especially when broken many times.

If policies are tools for applying the carrot and stick approach to make things work in society, then Philippine forestry policies have more sticks than carrots. The continuous decline in forest cover indicates that this does not work. Moreover, policy-makers are presently weak at using the 'delete function' for outdated policies that provide more sticks than carrots.

The most viable way to upscale ANR is to allow space for diversity. This diversity should occur not just in the species allowed to regenerate on the land, but also in the people who are given the opportunity to benefit from the land. As yet, policies and programmes in the Philippines do not provide enough space for these diversities to occur and lead to synergy among different sectors of society and line agencies of the government. Payment for environmental services will have a better chance of getting off the ground when this synergy happens.

When talking about forest rehabilitation in many parts of Asia, water is a more practical and tangible entry point than carbon. Local governments know the strain when disasters strike as a result of extreme weather events. Under pressure to contribute to the Millennium Development Goals, their concern about delivery of basic services, including water, has increased. ANR as an approach to forest rehabilitation has a better chance of getting public attention if it is tied first to water issues. Expectations may be better managed if carbon is only introduced later on as an added value.

Who are the most viable partners to upscale ANR?

- Community-based organizations and small-scale farmers favour land diverse in species and adapt well to diverse sources of livelihoods. The Philippines has over 4 800 community-based forest management organizations and several more holders of certificates of ancestral domain claims/titles. Thailand has over 10 000 community forestry networks. Viet Nam has over 2 000 village forest communities. Cambodia has over 700 community forestry committees. The cost of getting them to assist natural regeneration depends not only on the strength of the organization but also on their level of trust in the institution selling the idea. The stronger the organization, the lesser the cost. The lesser the trust, the greater the cost. As the Vietnamese 5 Million Hectares Reforestation Programme case shows, villagers needed to believe that they would benefit not only in terms of labour employment, but also in terms of forest by-products.

- Owners of abandoned fishponds who seek psychological and social rewards from caring for the environment by restoring mangrove forests.
- Families who now rely on overseas remittances and do not have time for farming but need ways to make their land more productive without much labour involved.
- ‘Gentlemen farmers’ – retired people who want to reconnect with the land (e.g. those who bought shares in Leisure Farms in Batangas).

Where best to apply ANR?

- The Vietnamese experience and inputs from the commercial forestry sector indicate that the most viable and appropriate option is on lands allocated for protection and conservation forests where diversity is appreciated and trees are more valued when left standing (national parks, watershed areas).

Who are possible supporters to mainstream ANR?

- Local governments (mayors, governors, councillors, congressional representatives) who have access to development funds and can use them as incentives for communities and villages assisting natural regeneration, e.g. through fire protection and/or overcoming species hindering succession.
- Industries using forest by-products who are interested in having a stable supply of raw materials (e.g. handicraft industries, designers of native fashion accessories, abaca processors).
- Socially and environmentally responsible corporations who have tree planting projects or subscribe to adopt-a-watershed or adopt-a-mountain programmes.
- Local and national media that have historically featured socio-environmental stories in their environment, lifestyle or business sections.

Looking forward and looking further - regional and global perspectives for ANR application

Assisted natural regeneration: global opportunities and challenges

Patrick B. Durst and Marija Spirovska-Kono[1]

Ultimately, the future of the natural ecosystem depends not on protection from humans but on its relationship with the people who inhabit it or share the landscape with it. William R. Jordan III (founder of ecological restoration)

Introduction

Forests are increasingly recognized for the ecological services and economic opportunities they provide, as well as for their social and cultural values. More than ever before, forests are seen as being intricately linked with many of the world's most pressing global environmental and social concerns, such as climate change, loss of biodiversity, water issues and rural poverty.

Despite increased recognition and appreciation of forest values, deforestation rates remain high, estimated at 13 million hectares per year, according to the latest Global Forest Resource Assessment in 2005. In aggregate numbers, the Asia-Pacific region has recently registered a positive reversal of trends related to forest area, reflected by a three million hectare net gain in forest cover from 2000 to 2005. This apparent regional turnaround, however, is due primarily to the large reforestation achievements of the People's Republic of China and Viet Nam, which mask the otherwise rather disappointing performance of much of the rest of the region. Collectively, the other countries of Asia and the Pacific lost about 3.7 million hectares of natural forest during the same period (FAO 2006).

Rising concerns over forest loss and enhanced appreciation of forest values are giving new impetus to forest restoration and rehabilitation initiatives throughout the world. Although monocultures of exotic timber species continue to be favoured for commercial plantations, there is increased recognition of the need to integrate and complement commercial plantations with enhanced biodiversity conservation and landscape restoration (Shono *et al.* 2007; Chazdon, 2008). Reforestation efforts throughout the world are therefore increasingly focusing on restoring forests' ecological functions and providing the means for sustainable rural livelihoods.

Given the scale of reforestation and forest rehabilitation needs around the world, a range of low-cost approaches needs to be considered. Assisted natural regeneration

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(ANR) is one such approach. As practised and promoted in the Philippines over the past 30 years on a limited scale, ANR emphasizes fire management, protection against destructive grazing, control of invasive grass species and assisting the growth of naturally occurring tree seedlings. Similar principles have been applied in various forms or in combination with other methods elsewhere in the world (Chazdon, 2008).

ANR has demonstrated promising results when applied at small scales, as in the case of pilot sites in the Philippines. For ANR to deliver substantial contributions toward global efforts in combating deforestation and enhancing environmental and social conditions, however, opportunities for replicating, up-scaling and mainstreaming ANR must be identified and promoted at many levels. Although local, site-specific conditions will inevitably be most critical in determining the success or failure of ANR approaches, it will be increasingly important to relate local forest rehabilitation efforts to pressing global concerns and the support mechanisms that are emerging to address these issues.

Global opportunities and challenges

Deforestation and forest degradation are undeniably interlinked with various problems extending far beyond the immediate sites where tree felling occurs. Clearing of large areas of forests and failing to substitute for the loss of their functions has led to devastating environmental, social and economic consequences, thus exacerbating some of the most pressing concerns of modern society.

Climate change is currently at the highest levels of the international environmental agenda. The recognition of the vital roles that forests play in the global carbon cycle has driven efforts to include forestry in various climate mitigation measures, including Reducing Emissions from Deforestation and Forest Degradation (REDD) and enhancing the role of forests as carbon sinks.

Forest ecosystems are estimated to contain about 80 percent of the world's above-ground terrestrial carbon and about 40 percent of below-ground carbon. At present, approximately 50 percent more carbon is stored in the world's forests than in the Earth's atmosphere (FAO 2006). The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007) indicated that deforestation and forest degradation contribute about 20 percent of global greenhouse gas emissions. Approximately 90 percent of this is accounted for by the conversion and degradation of tropical forests.

Natural regeneration of forests, including ANR approaches, can play a significant role in mitigating climate change, especially by promoting growth of long-lived shrubs and tree species with dense wood and slow turnover of woody tissue (Chazdon 2008). Restoring degraded forests can increase carbon storage on land by 120 tonnes per hectare or more (DiNicola *et al.* 1998). A clear advantage of ANR is the steady accumulation of carbon, while simultaneously generating a wide range of other forest benefits and values.

Biodiversity loss is a second area of major global concern. Some estimates suggest that overall species extinction is now occurring at 1 000 times the historical rates indicated by fossils records (CBD 2006). Habitat destruction and fragmentation are clearly among the most important contributing factors.

The complexity involved in identifying and reporting on biological diversity loss remains challenging for many countries. However, available data indicate unsettling developments, beginning with the alarming loss of 6 million hectares of primary forest each year due to deforestation and as a result of modification of forests from logging and other disturbances. In responding to surveys conducted by the Global Forest Resources Assessment, countries have classified an average of 5 percent of the tree species native to their countries as 'vulnerable', 'endangered' or 'critically endangered' (FAO 2006). There is little doubt that the loss and major modification of forest ecosystems are taking a serious toll on species and terrestrial biodiversity.

By enhancing the regeneration of native vegetation already growing and adapted to local sites, ANR offers considerable potential for restoring some of the lost biodiversity values. From a biodiversity perspective, ANR offers strong biodiversity benefits relative to conventional single-species plantation forestry.

Although ANR is sometimes criticized for producing forests that are initially dominated by a few pioneer species (Shono *et al.* 2007), it is important to recognize that the secondary forest established through ANR can be further managed for specific objectives, according to available resources, including for promotion of increased species diversity. Enrichment planting is a commonly used method to augment basic ANR techniques.

Water resources and their relation to forests have long been shrouded in misunderstanding and misinformation, especially with regard to water availability and mitigation of macrolevel floods and droughts. The importance of forest cover in regulating hydrological flows has often been overestimated (FAO and CIFOR 2005; FAO 2008). However, at local levels, forest cover undeniably plays a crucial role in preventing or reducing local downstream flooding. More importantly, forest cover has significant influence on water quality and is therefore an essential element for maintaining the hydrological balance of watershed ecosystems.

Watershed management encompasses a complex set of measures and actions that are necessary to address the interlinked ecological and social processes occurring in water catchment areas. Forest restoration in degraded watersheds needs to consider the complexity of each site and work to provide long-term solutions for maintaining and restoring ecological services and people's livelihoods.

ANR offers great potential for restoring watershed functions because it places heavy emphasis on restoration of natural processes and steady improvement of soil productivity and water quality.

Sustainable livelihoods and the role of forests in contributing to the income and well-being of local people have gained global prominence in recent years as forest policy-makers broaden their expectations and demands on forests. Nevertheless, adequately addressing the rights and responsibilities of forest-dependent people remains a significant challenge.

The current economic crisis vividly demonstrates the interconnected nature of today's society. The collapse of the housing sector in many developed countries has greatly reduced demand for wood products. The reduced ability and willingness of buyers to pay has negatively affected the demand for environmental services. Markets for carbon and environmental services have witnessed a plunge in prices and demand similar to other commodities. Forestry jobs have been slashed and investment in the forestry sector has declined dramatically.

At the same time, the crisis has opened new opportunities for 'greener' paths of development, with some countries (e.g. Japan, the United States of America, the Republic of Korea) including forestry-related measures in their economic stimulus programmes. Incentives and opportunities for forest communities to engage in sustainable forest management will hopefully be a lasting legacy of the 'green development' approaches emerging from the current economic crisis.

Local communities are at the core of successful ANR application. Initial experience with ANR in the Philippines demonstrated a wide variety of ways for effectively involving and empowering local people. However, up-scaling of ANR requires the identification of additional innovative approaches for up-scaling and strengthening community involvement (Table 1).

Table 1. Incentives for community involvement in ANR activities

Examples of observed incentives	Possible incentives for future ANR up-scaling
Contributing to local pride and sense of accomplishment	Strengthening the security of land and resource tenure
Fire management (demonstrating zero fire occurrence on formerly fire-prone sites and witnessing resulting regrowth of vegetation)	Zero-fire cash bonuses
Income opportunities through salaries for ANR work	Payment for environmental services (PES), including carbon financing
Approval to grow cash crops and trees producing non-wood forest products (NWFPs) in fire breaks	Improved market access for cash crops and NWFPs

Land and resource tenure are the central issues for ensuring local commitment to sustainable land management beyond the duration of finite projects. Policies need to be developed or revised accordingly, to provide a secure sense of ownership of restored forest areas and ensure sustainable long-term resource management.

Secure land and resource tenure is a necessary prerequisite for local communities to access innovative new sources of financing such as PES and emerging carbon markets (Leimona *et al.* 2009). However, many other elements also need to be addressed before communities practising ANR will be able to fully tap the potential of PES and carbon-trading schemes. Among the priorities is generating more detailed documentation of the long-term impacts of ANR practices *vis-à-vis* local biodiversity, water quality and carbon sequestration. To advance this agenda, there is a strong need for developing simple, practical and low-cost community-based monitoring tools.

Experience from the Philippines demonstrates that there are various private companies seriously committed to offsetting their negative environmental impacts by supporting forest rehabilitation and restoration. Social corporate responsibility is becoming increasingly important for many companies. At the same time, many governments in the region are also developing schemes for remunerating communities for providing various environmental services. These developments offer potential for attracting greater support for ANR activities from both the private and public sectors in the future.

ANR's niche in restoring degraded lands

Given the scale of reforestation and forest rehabilitation needs around the world, it is necessary to consider all available opportunities and approaches for addressing the challenges. The costs are daunting. Conventional reforestation can easily cost US$1 000 per hectare, suggesting a hefty bill of up to US$13 billion per year just to offset current forest losses, using conventional plantation reforestation methods (Dugan 2009).

Plantations currently comprise about 4 percent of the total global forest area, with a steady expansion of about 2.8 million hectares per year globally, much of it in Asia (FAO 2006). Data on the areas where forests are regenerated naturally are far less certain, but many of the more successful techniques are evident. These include 'mountain closure' in China, the inclusion of natural regeneration as a key element of the Five Million Hectare Reforestation Program in Viet Nam, natural regeneration in community forests in Nepal and ANR in the Philippines. There are also important opportunities to rehabilitate lands using agroforestry, farm forestry and other approaches.

It is not appropriate to blindly advocate one approach over others, but rather to carefully assess the costs and benefits of different options against desired objectives and local conditions.

The case of grasslands dominated by *Imperata cylindrica* is a particular challenge for much of the Asia-Pacific region. Sheet *Imperata* (meaning very large expanses of *Imperata*-dominated grasslands) covers 35 million hectares across the region – an area larger than all of the Philippines. When other areas where *Imperata* is mixed with various low-productivity species are included, the total affected area exceeds 57 million hectares (Table 2). Due to frequent and repeated burning and progressive degradation, these areas are generally unproductive, harbour relatively little biological diversity and offer few opportunities for local livelihoods.

Table 2. Estimates for Imperata areas in Asia

Country	Area (million ha)
Indonesia	13.5
India	12.0
Philippines	6.0
Viet Nam	5.0
South China	5.0
Thailand	4.0
Myanmar	3.0
Lao PDR	2.0
Sri Lanka	2.0
Malaysia	0.5
Cambodia	0.3
TOTAL	**57.2**

Source: Garrity *et al*. (1997).

The scale of the *Imperata*-dominated areas represents both a challenge and an opportunity for forest restoration. ANR – as practised in the Philippines – has developed specific approaches for rehabilitating *Imperata* areas (especially with respect to fire management and control); they offer excellent potential for application in other countries with large areas of *Imperata*.

Conclusions

Despite ongoing and intensified efforts to restore forests, ecosystem services and biodiversity throughout the world, a massive area of degraded land and forests remains, particularly in the tropics. Policy-makers – even when they are sympathetic to the problems – are generally constrained by a lack of funding and resources to fulfil ambitious forest restoration goals.

Restoration of degraded lands and forests is evolving to increasingly consider the complex ecological, economic and social values of each locale. Different approaches are being applied with varying degrees of success around the world, but an unbalanced emphasis on single-species plantation development in many areas remains.

It is therefore important to strengthen awareness-raising efforts to highlight the potential of simple, low-cost alternatives for forest restoration, such as ANR. At the same time, it is critically important to identify conditions and factors necessary for successful application of ANR, and to be realistic about the expectations and potential for ANR to meet management objectives. The costs and benefits of various forest restoration methods must be assessed in more detail to help policy-makers in identifying the most effective methods for achieving desired objectives.

Detailed documentation of the effects on local biodiversity, water quality and carbon storage capacities is also required if ANR is to seize emerging opportunities for capturing innovative new financing through carbon markets and PES.

Forest restoration is a long and complex process, which needs to take into account a wide array of environmental, economic and social factors. ANR offers practical options for complementing large-scale conventional reforestation efforts and provides effective low-cost solutions for increasing the social values of formerly degraded areas.

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Capturing the value of forest carbon: C sequestration through ANR practices

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Introduction

The last century has witnessed massive deforestation in the tropics and the Philippines has been no exception. When the Spanish colonizers first set foot in the Philippines in 1521, 90 percent of the country was covered with lush tropical rain forest (approximately 27 million hectares out of 30 million hectares of total land area). By 1900, there was still 70 percent or 21 million hectares of forest cover (Garrity *et al.* 1993; Liu *et al.* 1993). However, by 1996 there were only 6.1 million hectares (20 percent) of forest remaining (FMB 1997). Thus, in the last century alone, the Philippines lost 14.9 million hectares of tropical forests or an average of about 150 000 hectares/year (Table 1).

Table 1. Deforestation rates in the Philippines in the twentieth century

Period	Years	Forest loss (ha)	Rate (ha/yr)
1900-1934	35	4 000 000	114 286
1935-1988	54	9 700 000	179 630
1989-1996	8	1 200 000	150 000
Mean			147 972

Source: Forest loss data adapted from various Forest Management Bureau (FMB) statistics.

Reforestation work in the Philippines started during the first decade of the twentieth century. A recent review of reforestation in the Philippines showed that the reforestation rate significantly lagged behind the deforestation rate (Carandang *et al.* 2004). From 1960 to 2002, the annual average area planted was about 41 000 hectares per year, which is less than 50 percent of the annual deforestation rate for the same period. More importantly, the actual success rate of the reforestation effort could be less than 30 percent in many cases. Official statistics report the area planted for the year but do not track what portion still exists. This is validated by the fact that available maps do not show where the reforested areas are.

The cost of reforestation is not cheap. Between 1988 and 1992 the Asian Development Bank (ADB), the World Bank and the Japanese Government lent US$731 million for forestry projects in the Philippines (Korten 1995). With such a low rate of success, much of these funds have been wasted. In future, reforestation of the country's 8.4 million hectares of denuded forests could cost the government some PHP361 billion (US$6.6 billion).

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There have been attempts to find more cost-effective alternatives to conventional reforestation approaches, one of which is assisted natural regeneration (ANR). ANR is a flexible approach to reforestation that uses natural regeneration of forest trees (wildlings or natural seedlings, and sprouts). It 'assists' natural regeneration by preventing fire, 'pressing' *Imperata,* helping trees to grow faster and planting additional trees when needed (Friday *et al.* 1999). By the end of 1995, about 2 500 hectares of ANR areas had been developed, mostly in the Bicol region (FMB 1996).

Experience in the Philippines has shown that if grassland areas are protected from fires and other disturbances, they can regenerate back to tropical forest. ANR seeks to hasten the process of succession by protecting the area from disturbance and by planting additional trees. The success of ANR largely depends on how well the community is able to protect the growing seedlings from fires and other damaging agents (such as grazing). Firebreaks may also need to be constructed. After fire prevention, suppressing cogon and other weeds is the most important activity in ANR. This is done through 'pressing'. The grass is pressed low to the ground by trampling or by rolling a weight over it. Pressing bends the base of the cogon culm (stem) in the same way as folding a plastic water hose. The weight of the grass helps to keep it bent down and grass in the lower layers dies.

More recently, there has been a rising interest in the role of forest ecosystems to mitigate climate change through carbon (C) sequestration. A number of studies have explored the potential of forest lands in the Philippines to store and sequester carbon, including accessing the rising carbon market (Lasco *et al.* 2008; Lasco *et al.* 2007; Villamor and Lasco 2006).

This paper has two main sections. The first presents key findings of the Intergovernmental Panel on Climate Change (IPCC) report on the role of forestry in mitigating climate change. The second presents research results on carbon sequestration through reforestation activities in the Philippines.

The mitigation potential of reforestation and forest regeneration

Deforestation, degradation and poor forest management reduce carbon storage in forests, but sustainable forest management, planting and rehabilitation can increase carbon sequestration (FAO 2006). It is estimated that the world's forests store 283 Gigatonnes (Gt) of carbon in their biomass alone. The carbon stored in forest biomass, deadwood, litter and soil together, is about 50 percent more than the amount of carbon in the atmosphere.

The tropical region has the greatest potential for climate change mitigation through its beneficial forestry activities. It is difficult to quantify the total potential of the world's tropical forest to mitigate climate change. According to the IPCC's Fourth Assessment Report, available studies about mitigation options differ widely in basic assumptions on carbon accounting, costs, land areas, baselines and other major parameters (Nabuurs *et al.* 2007). There is still a need for more detailed estimates of economic or market potential for mitigation options by region or country in order for policy-makers to make realistic estimates of mitigation potential under various eligibility-rule scenarios for policy, carbon price and mitigation programmes. Initial studies indicate that the largest potential is in avoiding deforestation and enhancing afforestation and reforestation (A/R), including bioenergy.

In spite of the different approaches and methods, recent studies estimate that future deforestation will remain high in the tropics. For example, Sathaye *et al.* (2007) estimated that deforestation rates will continue in all regions. Africa and South America have high rates of loss, cumulatively about 600 million hectares by 2050. Thus, reducing deforestation is a high-priority mitigation option within the tropical region. In addition to the significant carbon gains, substantive environmental and other benefits could be obtained from this option. To counteract the loss of tropical forests, successful implementation of mitigation activities requires understanding of the underlying and direct causes of deforestation, which are multiple and locally based (Chomitz *et al.* 2006).

In the short term (2008-2012), it is estimated that 93 percent of the total mitigation potential in the tropics will be through avoided deforestation (Jung 2005). In the long term, it is estimated that US\$27.2/tCO_2 is needed to virtually eliminate potential deforestation (Sohngen and Sedjo 2006). Over 50 years, this could mean a net cumulative gain of 278 000 MtCO_2 relative to the baseline and 422 million hectares of additional forests. The largest gains in carbon would occur in Southeast Asia, which gains nearly 109 000 MtCO_2 for US\$27.2/tCO_2, followed by South America, Africa and Central America, which would gain 80 000, 70 000 and 22 000 MtCO_2 for US\$27.2/tCO_2, respectively (Figure 1).[2]

Next to avoided deforestation, establishment of new forests through reforestation and afforestation offers the second largest potential to mitigate climate change through enhanced carbon sequestration. The assumed land availability for afforestation options depends on the price of carbon and how it competes with existing or other land-use financial returns, barriers to changing land uses, land tenure patterns and legal status, commodity price support and other social and policy factors.

2. tCO2 = tonnes of carbon dioxide. MtCO2 = Mega (or million) tons of carbon dioxide.

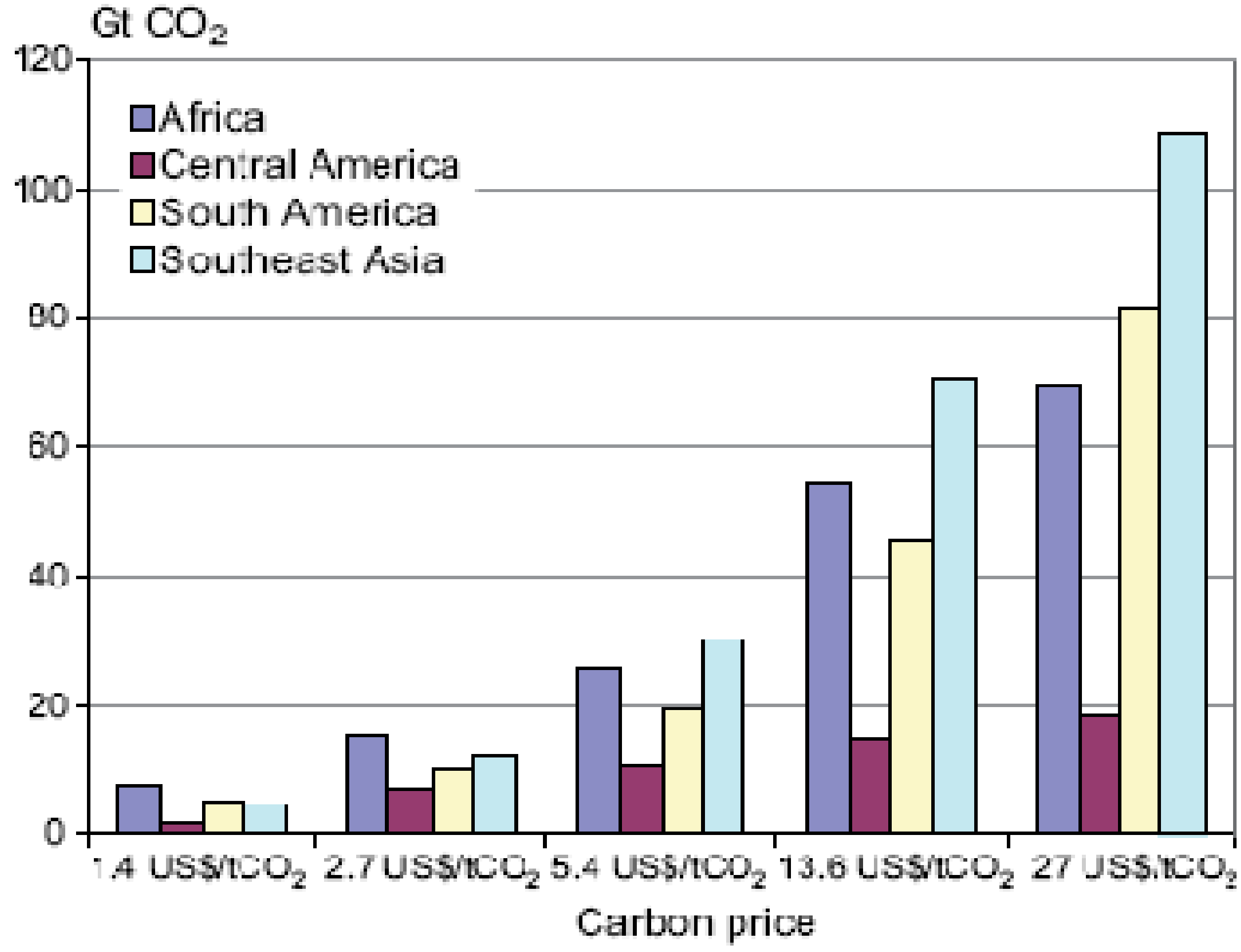

Figure 1. Cumulative carbon gained through avoided deforestation by 2055 over the reference case by tropical regions under various carbon price scenarios.
Source: Sohngen and Sedjo (2006) from Nabuurs *et al.* 2007

Cost estimates for carbon sequestration projects for different regions vary widely. For forestry projects in developing countries, the cost ranges from US$0.5 to US$7/tCO_2, compared to US$1.4 to US$22/tCO_2 for forestry projects in industrialized countries (Cacho *et al.* 2003; Richards and Stokes 2004). In the short term (2008-2012), an estimate of economic potential area available for afforestation/reforestation under the Clean Development Mechanism (CDM) would be 5.3 million hectares, an aggregate total in Africa, Asia and Latin America, with Asia accounting for 4.4 million hectares (Waterloo *et al.* 2003).

In total, the cumulative carbon mitigation benefits by 2050 for a scenario of US$2.7/t$CO_2$ plus a 5 percent annual carbon price increment for one model are estimated to be 91 400 MtCO_2; where 59 percent comes from avoided deforestation (Figure 2). From 2000 to 2050, avoided deforestation dominates in South America and Asia, accounting for 49 percent and 21 percent, respectively, of the total mitigation potential. When afforestation is considered, Asia predominates.

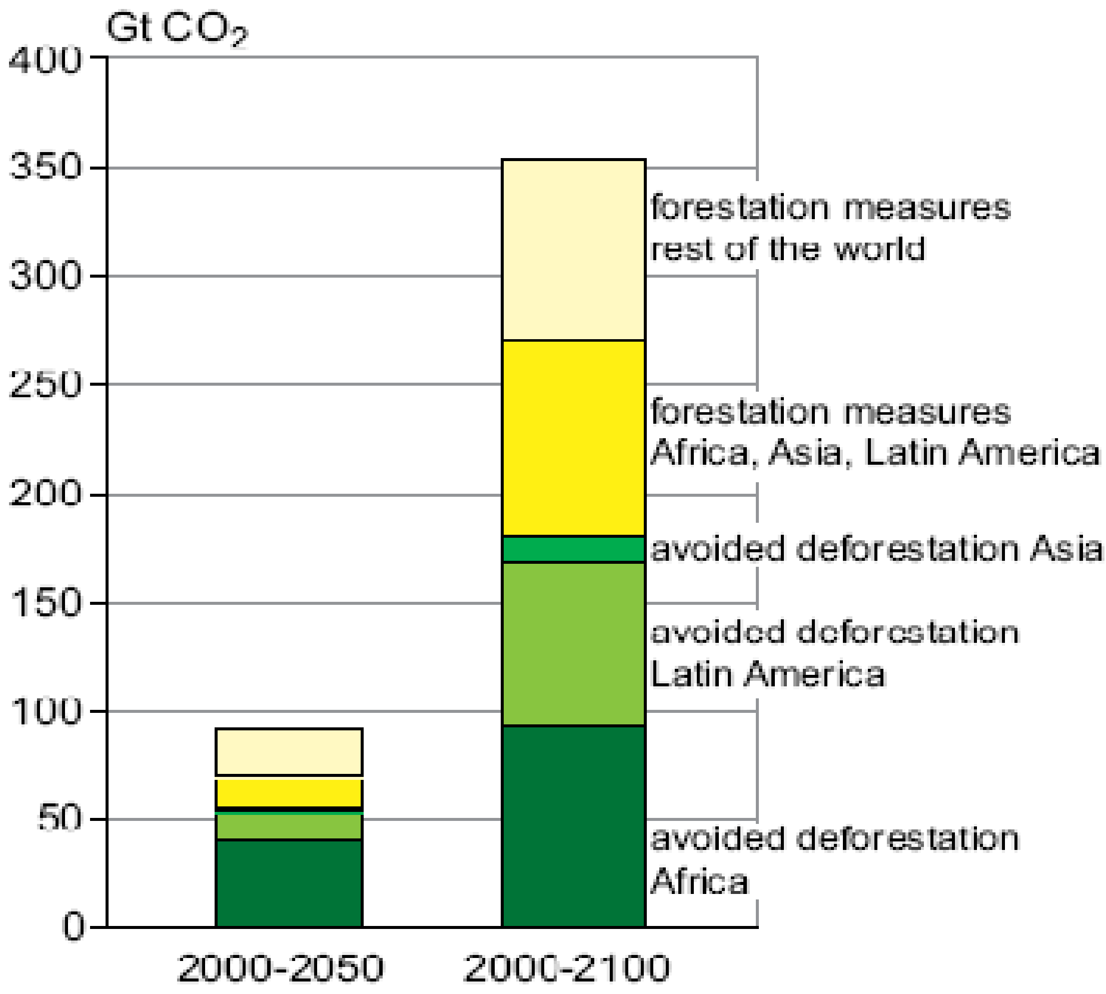

Figure 2. Cumulative mitigation potential (2000-2050 and 2000-2100) according to mitigation options under the US$2.7/t$CO_2$ +5 percent/year annual carbon price increment.

Source: Sathaye *et al.* (2007) from Nabuurs *et al.* (2007)

The IPCC 2007 report did not include the specific mitigation potential of ANR that can fall under two categories depending on the initial forest cover. If the initial tree crown cover is below the threshold forest definition (from 10 to 30 percent minimum crown cover), then ANR is a reforestation activity. However, if the initial crown cover is more than the minimum, then it becomes a forest management (regeneration) activity.

According to the IPCC special report on land-use change and forestry (IPCC 2000), forest regeneration includes activities such as changing tree density through 'human-assisted natural regeneration'; enrichment planting; reduced grazing of savannah woodlands; and better matching of tree provenances, genetic strains, or species to soils and sites. Human-assisted natural regeneration is the establishment of a forest age class from natural seeding or sprouting after activities such as selection cutting, shelter (or seed-tree) harvest, soil preparation, or restricting the size of a clear-felling stand to secure natural regeneration from surrounding trees.

Forest regeneration influences on-site carbon stocks by accelerating the return of a growing forest after harvest, altering growth rates of above- and below-ground tree biomass through better species selection and changing the potential mix of final wood products. The accumulation time of above- and below-ground biomass ranges from 5 years (for the shortest rotation times in tropical plantations) to 150 years or more in low-potential sites in boreal forests. The tree biomass carbon accumulation process is not difficult to quantify and predict where well-developed forest growth and yield models are available. However, only a few studies exist on the relationship between forest regeneration and carbon sequestration.

Potential carbon sequestration of ANR

The rapid loss of forests in many Southeast Asian countries has left millions of hectares of denuded and degraded land. In the Philippines, at least 2 million hectares of former forested lands are now grasslands. Deforested lands have much lower carbon stocks than the forests they replace. In response, countries in the region have launched massive reforestation programmes. There are very limited data in the literature on carbon sequestration rates of reforestation species in Southeast Asia. However, there is much literature on the growth performance of species planted in reforestation areas. Typically, diameter at breast height (dbh) and height are the main variables measured and reported. Through the use of allometric equations, primarily from the FAO handbook by Brown (1997), we attempted to estimate biomass and carbon stocks and their rate of accumulation based on data from existing literature. Selected results are presented below. Actual carbon sequestration rates for ANR projects may not be too far from those in reforestation projects.

In the Philippines, a reforestation project in highly degraded soil conditions using fast-growing exotic species has carbon stocks of 3.5-48.5 MgC/hectare six to 13 years after planting (Table 2). On the other hand, the rate of carbon sequestration was 0.3-3.7 MgC/hectare/year (as measured by mean annual increment [MAI]). These values are very low compared to other Philippine tree plantations because of the poor site conditions in the area that is predominantly covered with *Imperata* and *Sacharum* spp. grasses (Sakurai *et al.* 1994).

Table 2. Biomass/carbon density and MAI in Nueva Ecija, Philippines

Species	Age (yr)	Ave dbh (cm)	Biomass Mg/ha	MAI Mg/ha/yr	C density MgC/ha	MAI MgC/ha/yr
Acacia auriculiformis 1	6	5.68	7.4	1.2	3.3	0.6
A. auriculiformis 2	6	6.46	10.0	1.7	4.5	0.8
A. auriculiformis 3	9	9.62	42.5	4.7	19.1	2.1
A. auriculiformis 4	9	8.71	32.0	3.6	14.4	1.6
A. auriculiformis 5	9	10.47	46.1	5.1	20.8	2.3
A. auriculiformis 6	9	8.73	39.7	4.4	17.9	2.0
Tectona grandis 1	13	5.50	8.7	0.7	3.9	0.3
T. grandis 2	13	7.36	22.3	1.7	10.0	0.8
Gmelina arborea 1	6	7.33	17.2	2.9	7.8	1.3
G. arborea 2	6	6.80	7.7	1.3	3.5	0.6
Pinus kesiya	13	12.53	107.8	8.3	48.5	3.7
P. kesiya + broadleaf spp.	13	10.10	83.2	6.4	37.5	2.9

Note: Age and dbh data from Sakurai *et al*. (1994); biomass computed using the equation Biomass/tree in kg= 21.297-6.953*dbh+0.74dbh^2 for broadleaf species and Biomass/tree = EXP-1.17+ 2.119*LN(dbh) for conifers (from Brown 1997); %C in biomass = 45 percent (based on Lasco and Pulhin 2000).

In another part of the Philippines with similar vegetative cover but higher rainfall, carbon MAI was 6.4-7.9 MgC/hectare (Table 3). The carbon sequestration in this site was higher than the previous site most likely because of the more abundant rainwater supply. This study is also unique in that the biomass was determined directly by destructive sampling (Buante 1997). In the same island, three fast-growing species have a carbon density and MAI of 8-88 MgC/hectare and 0.7-8.0 MgC/hectare/year, respectively (Table 4).

Table 3. Biomass/carbon density and MAI in Leyte, Philippines

Species	Biomass Mg/ha	MAI biomass Mg/ha/yr	C density MgC/ha	C MAI MgC/ha/yr
Acacia mangium	56.9	14.2	25.6	6.4
Gmelina arborea	70.2	17.6	31.6	7.9
A. auriculiformis	64.0	15.9	28.6	7.1

Note: Biomass data from Buante (1997); %C in biomass assumed to be 45 percent. Tree age = 4 years.

Table 4. Carbon density and MAI of reforestation species in Leyte, Philippines (Lasco *et al.* 1999)

Species	Biomass Mg/ha	MAI biomass Mg/ha/yr	C density MgC/ha	C MAI MgC/ha/yr
S. macrophylla				
1	22.6	2.1	10.2	0.9
2	19.9	1.8	9.0	0.8
3	8.5	0.8	3.8	0.4
Mean	***17.0***	***1.6***	***7.7***	***0.7***
A. mangium				
1	220.9	20.1	99.4	9.0
2	162.9	14.8	73.3	6.7
3	203.6	18.5	91.6	8.3
Mean	***195.8***	***17.8***	***88.1***	***8.0***
G. arborea				
1	165.1	10.3	74.3	4.6
2	117.0	7.3	52.7	3.3
3	89.9	5.6	40.5	2.5
Mean	***124.0***	***7.8***	***55.8***	***3.5***

Planting trials of species not commonly growing in the Philippines but with potential for reforestation were conducted in Iloilo Province with similar grass cover as the above sites (Lachica-Lustica 1997). After four years, carbon density ranged from 0.30-70.11 MgC/hectare, while carbon MAI was generally less than 10 MgC/hectare/year (Table 5). In contrast, adjacent grassland area has only 1.68 MgC/hectare.

Table 5. Biomass/carbon density and MAI in Iloilo Province, Philippines

Species	Mean dbhcm	Biomass Mg/ha	MAI biomass Mg/ha/yr	C density MgC/ha	C MAI MgC/ha/yr
Acacia neriifolia	17.5	87.1	21.8	39.2	9.8
A. holosericea	11.9	34.4	8.6	15.58	3.9
A. crassicarpa	18.9	155.8	39.0	70.1	17.5
A. aulacocarpa	13.0	56.4	14.1	25.4	6.3
Leucaena diversifolia	3.3	0.7	0.2	0.3	0.1
Casuarina cuminghiana	3.8	3.2	0.8	1.4	0.4
C. equisitifolia	7.8	15.6	3.9	7.0	1.8
Eucalyptus citrodora	12.1	52.4	13.1	23.6	5.9
E. cloeziana	11.6	48.3	12.1	21.7	5.4
E. pellita	10.4	34.0	8.5	15.3	3.8
E. tereticornis	11.8	49.9	12.5	22.4	5.6

Note: dbh data from Lachica-Lustica (1997); tree age = 4 years; biomass computed using the equation Biomass/tree in kg = 21.297-6.953*dbh+0.74dbh^2 for broadleaf species and for conifers Biomass/tree = EXP-1.17+ 2.119*LN(dbh) (from Brown 1997); %C in biomass = 45 percent (based on Lasco and Pulhin 2000).

In terms of long-term carbon stocks after reforestation, mahogany and dipterocarp trees planted about 80 years ago are estimated to contain 126-286 MgC/hectare with an MAI of 1.6-3.6 MgC/hectare/year (Table 6). These densities and MAI are lower than the above results because mahogany and dipterocarp trees are relatively slow growing.

Table 6. Carbon density and MAI of reforestation areas 80 years after planting in Mt. Makiling, Philippines

Species	Age (yrs)	Tree/ ha	Biomass (Mg/ha)	MAI (Mg/ha/yr)	C density Mg/ha	MAI Mg/ha/yr
Swietenia macrophylla 1	80	802	565	7.1	254	3.2
Swietenia macrophylla 2	80	405	635	8.0	286	3.6
Parashorea malaanonan + *Anisoptera thurifera*	80	569	536	6.7	241	3.0
Parashorea malaanonan + *Dipterocarpus grandiflorus*	80	701	279	3.5	126	1.6

Note: Age and dbh data from Sakurai *et al*. (1994); biomass computed using the equation Biomass/tree in kg = EXP{-2.134+(2.53*LNdbh)} (from Brown 1997); %C in biomass = 45 percent (based on Lasco and Pulhin 2000).

Silvicultural treatments, such as fertilization, weeding and mycorrhizal inoculation, increase the growth of trees and thus enhance the rate of carbon sequestration.
In degraded areas in Surigao del Sur, Philippines, the inoculation of mycorrhizae increased carbon density by 32 to 237 percent compared to uninoculated treatments (Table 7). In another area of the country, mycorrhizal inoculation increased carbon density and MAI by 43 to 169 percent (Table 8).

Table 7. Effects of mycorrhizal inoculation on carbon density and MAI of tree plantations in Surigao del Sur, Philippines

Species/Treatment	Age (yr)	Diameter cm	Biomass Mg/ha	MAI Biomass	C density	C MAI
Pinus caribaea						
Uninoc	2	6.11	15.97	7.98	7.18	3.59
Inoc	2	9.17	37.74	18.87	16.98	8.49
	% difference			136		
Eucalyptus deglupta						
Uninoc	2	4.15	5.76	2.88	2.59	1.30
Inoc	2	6.3	7.63	3.81	3.43	1.72
	% difference			32		
Eucalyptus deglupta						
Uninoc	3	9.435	23.96	7.99	10.78	3.59
Inoc	3	14.26	80.69	26.90	36.31	12.10
	% difference			237		

Note: Diameter data from dela Cruz (1999); no. of trees = 1 111/hectare. Allometric equation for *P. caribaea*: Y (kg) = exp{-1.170+2.119*ln(D)} range 2-52 cm; for *E. deglupta*: Y (kg)= EXP{-2.134+(2.53*LNdbh)} (from Brown 1997)

Table 8. Effect of mycorrhizal inoculation on carbon density and MAI of tree plantations in Tarlac, Philippines

Species/treatment	Age (yr)	Diameter cm	Biomass Mg/ha	MAI Mg/ha/yr	C density (MgC/ha)	MAI C MgC/ha/yr
Acacia auriculiformis						
Uninoc	2	6	6.91	3.45	3.11	1.55
Inoc	2	7	9.87	4.94	4.44	2.22
% difference			43			
Casuarina equisitifolia						
Uninoc	2	2.7	2.83	1.41	1.27	0.64
Inoc	2	4.3	7.58	3.79	3.41	1.71
% difference			169			

Note: Allometric equation for C. equisitifolia: Y (kg) = exp{-1.170+2.119*ln(D)} range 2-52 cm; adj r2=0.98 (from Brown 1997). Allometric equation for A. auriculiformis: Y (kg) = 21.297-6.953(D)+0.740(D2) range 4-112 cm; adj r2=0.92 (from Brown 1997).

In Indonesia, a reforestation project in Sumatra produced carbon stocks of 39-76 MgC/hectare/year and a carbon sequestration rate of 4.9-6.9 MgC/hectare/year (Table 9). On the other hand, a reforestation project in Bogor produced a carbon density and MAI of 162-256 MgC/hectare/year and 3.6-8.0 MgC/hectare/year (Table 10). This carbon density is much higher than the site in Sumatra because the former is much older. However, the rate of carbon accumulation is comparable.

Table 9. Carbon density and MAI of reforestation species in Sumatra, Indonesia

Species	Age (yr)	Tree/ha	Biomass Mg/ha	MAI Mg/ha/yr	C density MgC/ha	MAI MgC/ha/yr
Swietenia macrophylla	11	940	169.24	15.39	76.16	6.92
Acacia mangium	11	912	157.34	14.30	70.80	6.44
Peronema canescens	8	1 016	87.49	10.94	39.37	4.92

Note: Age, dbh and tree/ha data from Sakurai *et al*. (1995). Allometric equation used to estimate biomass: Biomass per tree (kg)= EXP{-2.134+(2.53*LN(dbh)} (from Brown 1997).

Table 10.C density and MAI of reforestation species in Bogor, Indonesia

Species	Age (yr)	Tree/ha	Biomass Mg/ha	MAI Mg/ha/yr	C density MgC/ha	MAI MgC/ha/yr
Swietenia macrophylla	45	666	359.02	7.98	161.56	3.59
Dipterocarpus retusus	33	428	413.69	12.54	186.16	5.64
Shorea selanica	32	244	567.83	17.74	255.52	7.99

Note: Age, dbh and tree/ha data from Sakurai *et al*. (1995). Allometric equation used to estimate biomass: Biomass per tree (kg) = EXP{-2.134+(2.53*LN(dbh)} (from Brown 1997).

In Malaysia, afforestation projects have been conducted in two degraded soils: BRIS (162 000 hectares) and tin tailings (113 000 hectares) (Amir *et al*. 1994). Beach ridges interspersed with swales (BRIS) soils form an almost continuous belt in the east coast of peninsular Malaysia. Tin tailing soil is a waste product of tin mining. Soil composition is mainly sandy, with low nutrient status, inferior water and nutrient-holding capacity and poor structure. Growth rates are expected to be lower under such soils. Results of afforestation trials showed that most species accumulate less than 5 MgC/hectare/year while carbon density ranged from 7-261 MgC/hectare depending on the species and age (Table 11).

Table 11. Estimated above-ground biomass of afforestation sites in Malaysia

Species	Stand age	MAI dbhcm	dbh cm	Biomass Mg/ha	C density MgC/ha	Biomass MAI Mg/ha/yr	C MAI MgC/ha/yr
Tin tailings							
1. Sandy							
Acacia aulocarpa	27	0.85	22.95	100.6	45.3	3.8	1.7
A. auriculiformis	32	0.78	24.96	123.5	55.6	3.9	1.7
A. mangium	4	2.87	11.48	15.6	7.0	3.9	1.8
Pinus caribaea	26	0.76	19.76	69.1	31.1	2.7	1.2
P. elliotii	33	0.59	19.47	67.0	30.2	2.0	0.9
Casuarina equisitifolia	30	0.78	23.4	98.9	44.5	3.3	1.5
2. Sandy slime							
A. auriculiformis	30	1.24	37.2	314.7	141.6	10.5	4.7
A. richii	28	1.02	28.56	170.5	76.7	6.1	2.7
P. merkusii	32	0.87	27.84	143.0	64.3	4.5	2.0
P. caribaea	30	1.22	36.6	255.2	114.9	8.5	3.8
3. Slime							
A. auriculiformis	32	0.99	31.68	217.5	97.9	6.8	3.1
Paraserianthes falcataria	30	1.63	48.9	580.3	261.1	19.3	8.7
Fagraea fragrans	30	0.47	14.1	28.2	12.7	0.9	0.4
BRIS soils							
A. mangium	8	2.6	20.8	78.7	35.4	9.8	4.4
Hopea odorata	6.5	0.72	4.68	2.0	0.9	0.3	0.1
Araucaria cunninghamii	29	0.65	18.85	62.6	28.2	2.2	1.0
P. caribaea	30	0.92	27.6	140.4	63.2	4.7	2.1
P. merkusii	24	0.92	22.08	87.5	39.4	3.6	1.6
P. oocarpa	24	0.91	21.84	85.5	38.5	3.6	1.6
C. equisitifolia	8	2.74	21.92	86.1	38.8	10.8	4.9

Note: Age and dbh MAI data from Amir *et al*. (1994). Spacing assumed to be 5x5 m (400 trees/ha). Biomass C content = 45 percent. Allometric equation used to estimate biomass: Biomass per tree (kg) = EXP{-2.134+(2.53*LN(dbh)} (from Brown 1997).

Potential of ANR to generate carbon credits

The Clean Development Mechanism (CDM)

The Kyoto Protocol sets emission limits for six greenhouse gases (GHGs) for developed nations, mostly industrialized countries and economies in transition, known as ‘Annex 1’ or ‘Annex B’ countries. These countries committed to collectively reduce GHG emissions by at least 5 percent relative to their 1990 emissions. To enter into force, 55 countries were required to ratify the Protocol, including at least 55 percent of emissions of Annex 1 Parties for 1990. On the ninetieth day after the ratification by the Russian

Federation, the Kyoto Protocol entered into force on 16 February 2005. The Philippines ratified the protocol in November 2003.

The Clean Development Mechanism (CDM) is one of the three flexible mechanisms established to meet the goals of the Kyoto Protocol. The dual goal of the CDM is to assist Parties not included in Annex I to achieve sustainable development, and to assist Parties included in Annex I to achieve compliance with their quantified emission limitation and reduction commitments through projects in developing countries. The CDM essentially offers opportunities for financing sustainable development projects in developing countries that could generate Certificates of Emission Reduction (CERs). It specifically presents opportunities for a developing country to host projects that rehabilitate degraded lands, among others.

Under the CDM, forestry projects are limited to A/R. A key output of COP-9[3] in December 2003 was the modalities and procedures for A/R CDM projects (Decision 19/CP9) that could serve as a workable basis for project development. Reforestation and afforestation are officially defined by the United Nations Framework Convention on Climate Change as follows (Decision 11/CP7, 2001):

- ‘Afforestation’ is the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources.
- ‘Reforestation’ is the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but was converted to non-forested land. For the first commitment period, reforestation activities would be limited to reforestation occurring on those lands that did not contain forest on 31 December 1989.

It should be noted that how a country defines a forest is very important in determining which activities qualify. Under the CDM, a ‘forest’ is a minimum area of land of 0.05-1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10-30 percent with trees with the potential to reach a minimum height of 2-5 metres at maturity *in situ*. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground or open forest. Young natural stands and all plantations that have yet to reach a crown density of 10-30 percent or tree height of 2-5 metres are included under forest, as are areas normally forming part of the forest area that are temporarily unstocked as a result of such human intervention as harvesting or natural causes, but which are expected to revert to forest. Depending on how a party chooses its definition, certain type of agroforestry systems may not be eligible for CDM. For example, if a low cover is selected (e.g., 10 percent), then many agroforestry systems, such as tree farms, will be classified as forest already and are thus not eligible for ‘reforestation or afforestation’.

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For the first commitment period, credits from CDM Land use, Land-use Change and Forestry (LULUCF) projects cannot exceed 1 percent of the total commitments of Annex 1 parties.

Our initial estimates showed that the life-cycle cost of potential forestry projects (not necessarily Kyoto Protocol compliant) in the Philippines ranged from about US$0.12/tC to US$7.60/tC (Lasco and Pulhin 2001). On the other hand, the cost of protecting a Philippines National Oil Company-Energy Development Corporation geothermal forest reservation in the island of Leyte was US$2.94/tC (Lasco *et al.* 2002). In contrast, a systematic comparison of sequestration supply estimates from national studies in the USA produced a range of US$25 to US$75/ton for a programme size of 300 million tons of annual carbon sequestration (Stavins and Richards 2005).

Areas suitable for CDM in the Philippines, which include those that need to be permanently forested for legal, ecological, or social reasons, are the most likely candidate areas for climate mitigation projects. These include:

- Critical watersheds;
- Forest reserves (including those under the management of other government agencies and government-controlled corporations, such as the Philippine National Oil Company and National Power Corporation, academic institutions and the military); and
- Forest lands under the National Integrated Protected Area System, including those with 50 percent slope and 1 000 masl elevation.

The total area of the aforesaid forest lands is about 5 million hectares (FMB 2001), a large portion of which needs to be either protected or rehabilitated.

Once new financing schemes are available, property rights issues may become important (Lasco and Pulhin 2003). Competition over who will control forest lands may intensify. In the Philippines, many upland areas are being claimed by indigenous peoples. Such claims may be ignored in favour of establishing climate-change forests. Thus, the guidelines should have adequate provisions for respecting the rights of local users. This is more easily said than done in many developing countries. These issues could be adequately addressed, however, through public consultation and participation in project planning and implementation. The environmental impact assessment system is the main mechanism for facilitating this in the Philippines. Existing policies and procedures embodied in the Indigenous People’s Rights Act should also ensure that the rights of indigenous peoples are fully safeguarded.

ANR potential for CDM and other carbon markets

For the CDM market, the selected forest definition of a country will play a critical role in whether ANR will qualify or not. ANR projects are eligible only if the project area is not forested (i.e., it does not have tree cover greater than the minimum cover for a forest as defined by the host country, which could range from 10 to 30 percent tree cover). If a country chooses 10 percent as the minimum cover for a forest, it is likely that ANR activities will not qualify. This is because one prerequisite for ANR to succeed is the presence of natural regeneration, which some recommend to be at least 200 trees/hectare (Friday *et al.* 1999). The coverage of these natural regeneration stands may exceed the threshold, making the potential project sites already 'forested'. The Philippines uses 10 percent crown cover in its forest definition, although this has not been officially submitted to the CDM Executive Board. If it sticks to this definition, there may be a very limited number of forestry projects that could be eligible. Projects such as those on ANR will be excluded. In contrast, Indonesia has chosen 30 percent as its minimum crown cover for forests, thereby allowing a greater variety of eligible forestry projects.

In any case, there are still a very limited number of approved forestry projects under the CDM, partly because of its complicated rules. To date, there are only four approved forestry CDM projects comprising about 0.2 percent of all approved CDM projects (Figure 3).

The situation in the voluntary carbon market (non-Kyoto) is slightly more encouraging. The voluntary over-the-counter markets are currently the only source of carbon finance for avoided deforestation and they have a higher proportion of forestry-based credits out of total market transactions than the CDM (36 percent vs. 1 percent for CDM) (Hamilton *et al.* 2007). Indeed, forest projects are the largest component of the voluntary carbon market, which in 2006 amounted to 23.7 million tCO_2 equivalent valued at US$91 million. This is partly because voluntary carbon markets have historically served as sources of experimentation and innovation.

Another potential barrier to the implementation of ANR carbon sequestration projects is the transaction cost. For forestry projects, it is estimated that up to US$200 000 are needed to design and register a regular-sized CDM project. This amount does not include the cost of actual tree planting and maintenance. This means that an area of several thousand hectares is needed just to break even. In most cases, the financial return from the sale of carbon credits will not be enough to offset the expenses incurred. Thus, the carbon market should be viewed as an added income stream to forestry projects.

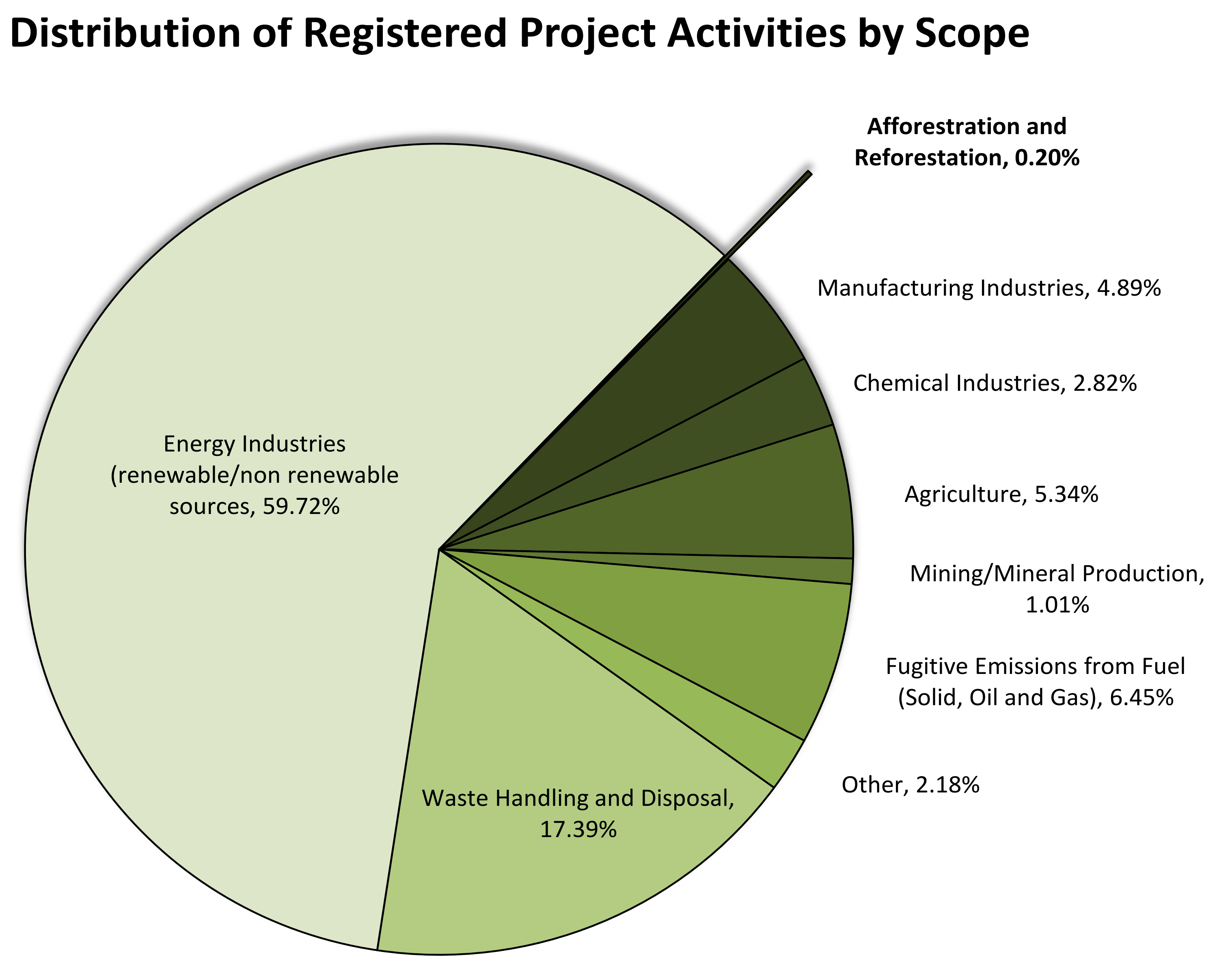

Figure 3. Forestry projects comprised less than 1 percent of all registered CDM projects as of 14 May 2009
Source: http://cdm.unfccc.int/Statistics/Registration/RegisteredProjByScopePieChart.html

Closing remarks

Climate change is one of the most pressing concerns today. One of the leading causes of GHG emissions is deforestation. Conversely, forest conservation, restoration and sustainable management are critical to mitigating climate change.

Assisted natural regeneration is one of the most effective ways to restore forest cover. One of its many ancillary benefits is increased carbon sequestration as trees grow. While this is not disputed, accessing the carbon market may be hindered by legal and financial reasons.

Several research gaps remain. Carbon sequestration rates of ANR projects in the Philippines are still lacking. Financial and economic cost and benefit data of ANR carbon sequestration projects are also missing.

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