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USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin

Non-Timber Forest Products and Crop Wild Relatives

February 2014

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Non-Timber Forest Products and Crop Wild Relatives

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The USAID Mekong ARCC project is a five-year program (2011–2016) funded by the USAID Regional Development Mission for Asia (RDMA) in Bangkok. The larger project focuses on identifying the environmental, economic, and social effects of climate change in the Lower Mekong Basin (LMB), and on assisting highly exposed and vulnerable rural populations in ecologically sensitive areas adapt to climate change impacts on agricultural, fisheries, livestock, ecosystems, and livelihood options.

This phase of the project was led and implemented by ICEM, and focuses specifically on predicting the response of the key livelihood sectors—agriculture, livestock, fisheries, rural infrastructure and health, and natural systems—to the impacts associated with climate change, and offering broad-ranging adaptation strategies to the predicted responses.

This volume is part of the USAID Mekong ARCC study set of reports:

1. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin: Summary
2. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin: Main Report
3. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Agriculture
4. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Livestock
5. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Fisheries
6. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Non Timber Forest Products and Crop Wild Relatives
7. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Protected Areas
8. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin: Socio-economic Assessment

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INTRODUCTION

This comparative analysis of the vulnerability of Non-Timber Forest Products (NTFPs) and Crop Wild Relatives (CWRs) is part of the wider Climate Change Impact and Adaptation Study of the USAID Mekong ARCC project. The Climate Study involved a basin-wide analysis of farming systems – the principal agricultural crops, livestock, capture fisheries and aquaculture, natural systems, protected areas, and the socio-economic features that integrate them.

NTFPs make a significant contribution to national and local economies and may make up over 30% of the income of individual farming families. They are essential for food security, medical remedies, fiber and furniture, and provide resins and essential oils - the raw materials for pharmaceuticals, fragrances, and other chemicals. Pressures upon land and natural resources have meant that the remaining sources for these natural products are protected areas. There is a strong financial incentive for sustainable management of this resource.

Crop wild relatives by comparison are often forgotten by all except the agricultural crop researchers. They do not necessarily have the same immediate value as NTFPs for small-scale farmers, but provide an important source of genetic materials for the improvement of existing crops, including the development of resistance to disease and extremes of temperature and drought. CWRs exist side by side with NTFPs in forests and in small patches of unused land.

The Climate Study downscaled global climate models to make predictions of changes in seasonal temperatures and rainfall, and associated characteristics such as seasonal soil moisture availability, the increased risk of floods and storms, and the timing and extent of the drought period. A number of "hotspot" provinces and ecozones have been identified within the region and these have provided the focus for this review.

This review considers the vulnerability of a few selected NTFPs and CWRs as examples from these hotspot areas. It uses a vulnerability assessment method considering the biological and climate tolerances of these species; comparing these first to the existing conditions and "comfort zones" of these hotspot areas, and then to the predicted climatic conditions.

Adaptation recommendations for each of the selected species have been developed as a component of this review, either in the context of distinct hotspot areas or sometimes more generally. These were then synthesized into a set of different approaches for encouraging greater resilience amongst the NTFPs and CWRs found in the region.

1 METHOD

1.1 CHOICE OF SPECIES

1.1.1 NTFPS

Because of the vast range of plant and animal species that are used in different ways by the people of the Lower Mekong Basin (LMB), it has been necessary to focus on a relatively small number of these in order to develop a representative set of NTFPs that can be examined for their tolerance and responses to climate changes.

Thus criteria for selecting representative NTFPs included:

- Plant type
- Economic or livelihood importance
- Distribution in different ecological zones
- Availability of information on ecological and climate preferences

NTFPs have been selected because they fall into the following plant types or form:

- Fungi – mushrooms
- Grasses and herbs
- Aquatic plants
- Climbers
- Orchids
- Bamboos and rattans
- Shrubs
- Trees

Several species of invertebrates including insects and earthworms have been selected, representing animal NTFPs. They also have an ecological importance providing services such as pollination and breakdown of organic materials in the soils.

Baseline information on the species selected has then been collated into a simple database that describes:

- Common name, Latin names, Family, Type of plant
- Description, Flowering period, Fruiting period
- Use and Parts used, Harvesting and processing, Importance and Value
- Ecological requirements - Latitude range, Elevation range, Soils preference, Forest type
- Climate requirements - Temperature range, Rainfall range
- Distribution: Cambodia, Lao PDR, Thailand, Vietnam
- Trends and Threats
- Sources of information

The information is generally quite patchy and not always available. Where ecological information is available on similar species or species in the same family, databases such as FAO's Ecocrop[1] have been used to fill in gaps where possible. This database of the selected species has then been used to provide the information for the vulnerability assessments and narrative discussions found in other sections of this report. Typically one species has been selected as an example (but not as representative) of the plant type and a vulnerability assessment carried out on this species.

One of the limitations to this analysis is the identification of specific ecozones where the different NTFPs are found. By their name, Non-Timber Forest Products are generally found in forests and while the habitats may be given as evergreen or secondary mixed deciduous or dipterocarp forests, it may be difficult to attribute these broad forest types to the more specific LMB ecozones determined by the study. Thus a certain amount of comparison of locations within a country or altitude ranges may be necessary in order to get an approximation for the ecological zone where they are found. In addition some NTFPs may be found in association with cultivated areas and so have a wider distribution. The aquatic plant NTFPs found in the Mekong Delta are easier to locate.

The approach taken therefore has been to describe NTFPs more generally in terms of:

- Important species (economic and food security)
- Important areas and habitats
- Gathering systems (commercial, small-scale)
- Tolerances and growing conditions
- Trends, threats, and opportunities

Then where there are specific differences or unique species found in the different ecological zones, these are highlighted under the different ecozone descriptions.

1.1.2 CROP WILD RELATIVES

Crop wild relatives require a slightly different approach to NTFPs, largely because they are not specifically targeted for economic or livelihood use. While there are a large number of CWRs found within the LMB, the focus for this study was on the different species of wild rice. The rationale for this is that these wild rice species are found throughout the region with different species in the ecozones and because there is more information about ecological and climate tolerances than about other CWRs.

The region also has a wide range of wild fruit trees, landraces, and relatives of many economic fruits that are well-known as the region's exports in the world market such as durian, mangosteen, rambutan, jackfruit, and mango. A landrace is a local variety of a domesticated animal or plant species that has developed largely by natural processes, i.e., by adaptation to the natural and cultural environment in which it lives. It differs from a formal breed, which has been selectively bred deliberately to conform to a particular formal, pure-breed standard of traits. Landraces are usually more genetically and physically diverse than formal breeds.[2]

Fiber crops are also important for local, national, and regional uses. Demand has been increasing, but local production by countries in this region has never met the rising needs. This study covers a fiber

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[1] http://ecocrop.fao.org/ecocrop/srv/en/home
[2] http://en.wikipedia.org/wiki/Landraces#Plants

species of kenaf/roselle, which has been grown and used in the region for over 700 years and is considered as a neglected and under-utilized crop.

The vulnerability assessment has been carried out on three of the wild rice species and one landrace – floating rice – as an example of CWRs.

1.2 VULNERABILITY ASSESSMENT METHOD

The vulnerability assessment method used for NTFPs and CWRs is based on a method that had been developed by ICEM in 2012 for the Mekong River Commission (MRC) as part of a study on the climate change vulnerability of wetlands in the LMB.[3] It was developed to consider the vulnerability of individual wetland species and habitats and it was found to be readily adaptable for the consideration of NTFP and CWR species.

It is a rapid method that consists of a series of questions about a) the conservation status and existing threats of the species and b) the climate change threats, habitat protection, sensitivity, and adaptive capacity. Answers to the questions are scored on a simple range (1 - 3) according to the contribution made to the existing and future climate vulnerabilities, and the results of all the two sets of questions are averaged to give overall scores for the current conservation status and future climate vulnerability. Division of the scores into ranges from Very Low, Low, Moderate, High to Very High vulnerability (Table 1) enabled the plotting of each species considered in a quadrat diagram, as illustrated in Figure 1 and in each profile of the species assessed. This quadrat diagram provides a visual of where the species stands in terms of its current conservation status and its future climate change vulnerability. Comparison of the quadrat diagrams in different provinces where the species occurs allows an understanding of the differences between hotspot provinces.

Table 1: Scoring intervals for climate change vulnerability

Category interval 0.4	Low	High
Very Highly Vulnerable to climate change	2.7	3
Highly Vulnerable to climate change	2.3	2.6
Moderately Vulnerable to climate change	1.9	2.2
Low Vulnerability to climate change	1.5	1.8
Very Low Vulnerability to climate change	1	1.4

The questions are shown in Table 2 with the format of the questionnaire provided in Annex 1. The questions about baseline conservation status relate to aspects of the basic biology and distribution of the species, existing threats, and protection or management afforded it in protected areas. This part of the questionnaire is unlikely to change in different parts of the LMB. However, the non-climate change vulnerability was later adjusted for each of the hotspot provinces according to the perceived degree of threat in protected areas in these provinces. In many cases the non-climate vulnerability was adjusted upwards because of continuing trends in loss of habitat.

The second section assesses the climate vulnerability of the species. The first part of this section interprets the threats to this particular species from the climate changes predicted for the particular

[3] ICEM 2012. Rapid climate change assessments for wetland biodiversity in the Lower Mekong Basin. Consultant report prepared for the Mekong River Commission, Hanoi, Vietnam.

province or protected area (these are described in further detail within the USAID Mekong ARCC Climate Change Impact and Adaptation Study Main Report). It uses the information on the biology of the plant related to temperature, rainfall, floods, drought, etc. to interpret the local degree of the threat to the species in that province or protected area. This is the part of the questionnaire that changes significantly between areas with different climate predictions.

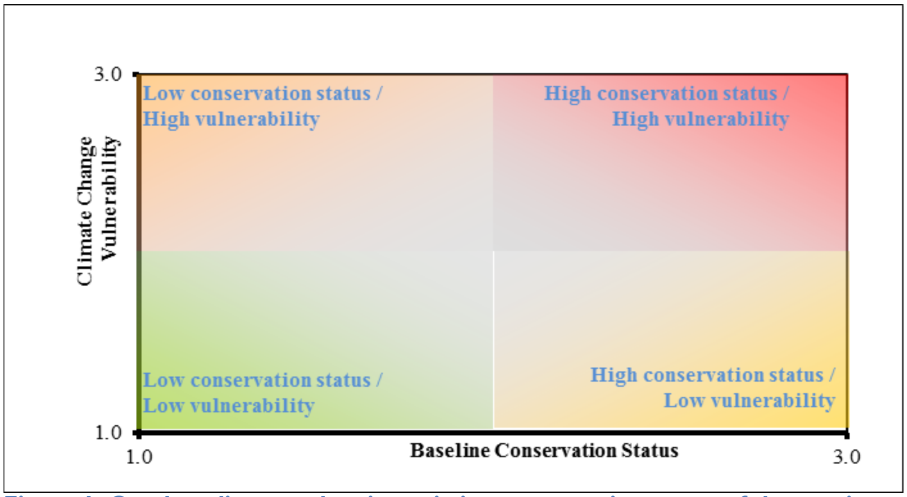

Figure 1: Quadrat diagram showing existing conservation status of the species and climate change vulnerabilities of the species

Protection from the extremes of climate are considered based upon the habitat where the species is found and includes moderating influences such as the requirement for forest cover. Sensitivity to climate change covers the basic biological tolerances, and adaptive capacity covers the biological, reproductive, and behavioral mechanisms that the species may adopt to avoid or manage extremes of climate.

Together with the database for the species and a description of the climate changes predicted, the excel spreadsheets prepared for each species provide an accessible record of the assessment and the rationale for the scoring. This rationale is very important for the understanding of the assessment, and has been used in the narrative of the profiles for each species.

Table 2: Rapid Vulnerability Assessment questions

Baseline conservation status	Climate Vulnerability
1. What is the population size within the LMB?	**Climate threats**
2. What is the population's trend in the LMB in the last 50 years?	1. Is temperature change considered to be an issue?
3. What is the geographic range size in the LMB?	2. Is drought likely to be an issue?
4. What is the range size trend in the LMB in the last 50 years?	3. Is increased flooding likely to be an issue?
5. Can the species reproduce fast?	4. Is exposure to hydrological change an issue?
6. Is the species a generalist or specialist?	5. Are extreme weather events an issue such as typhoons and high winds?
7. Does the species need a lot of habitat?	**Protection from climate threats**
8. Is the species able to disperse?	7. Are microhabitats or refugia available to

Baseline conservation status	Climate Vulnerability
	reduce exposure to temperature change?
9. How does the species survive current floods?	8. Are microhabitats or refugia available to reduce exposure to drought?
10. How does the species survive current droughts?	9. Are microhabitats or refugia available to reduce exposure to flood?
11. Are there threats to survival from humans use?	10. Are microhabitats and refugia available to reduce exposure to hydrological change?
12. Are there threats to survival from non-humans interactions?	11. Are microhabitats or refugia available to reduce exposure to extreme weather events?
13. Does the protected area have effective management?	**Sensitivity**
14. Does the species have a national conservation status?	13. Does the species have a wide **heat** tolerance?
15. Does the species have an IUCN Red List status	14. Does the species have a wide **precipitation** tolerance?
	15. Does the species have a wide **hydrological** tolerance?
	16. Is the species sensitive to **associated risks** from other species?
	Adaptive capacity
	17. Does this species have **reproductive traits** that will allow it to bounce back from the new climate exposure?
	18. Does this species have **habitat traits** that will allow it to bounce back from the new climate exposure?
	19. Is the population big enough and with enough **genetic diversity** to withstand the new climate exposure?
	20. Does the species have **behavior** that will allow it to adapt to the new climate?
	21. Is there sufficient **habitat connectivity** to allow organisms to reach appropriate habitat/climate space/refugia?
	22. Is there **adequate time** to allow an individual to develop adaptive changes?
	23. Will baseline stress be increased by the new climate in the LMB?

2 NON-TIMBER FOREST PRODUCTS

2.1 OVERVIEW OF THE DIVERSITY OF NTFPS

"Non-Timber Forest Products include all the materials collected from natural or man-made forests and riverine habitats and used to support local livelihoods. These include items such as forest and aquatic vegetables, fruit, traditional medicine products, wild animals and aquatic organisms such as fish, mollusks, insects and crustaceans. While the term NTFP implies non-timber items, it does include wood products for home construction, fuel wood and charcoal and handicraft products."[4] In this study we include products collected from wetlands and cultivated lands.

NTFPs are a very important component of subsistence and livelihood activities throughout the world. In the Mekong region, NTFPs are considered to be critical for many people living in the rural areas of the basin, contributing significant proportions of food and nutrition, especially during seasons of rice shortage, and contributing to the household economy through the sale of high-value products.

NTFPs can be categorized by the use associated with different parts of the plant (or animal). A simple classification groups the uses into:

- Food
- Medicines
- Fibers (including building materials)
- Extracts
- Ornamentals
- Charcoal and fuel wood
- Animal products

Some plants have multiple uses, with different parts being collected and used at different stages of growth. Some examples of these are shown in Table 3 below, taken from Lao PDR. Many of the same or similar species are found throughout the region and are collected and used by local people in all four countries of the LMB. The diversity of NTFPs and the uses that have been found for them is so large that it is difficult to classify them easily.

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[4] NAFRI, NUoL, SNV (2007) *Non-timber forest products in the Lao PDR. A manual of 100 commercial and traditional products*. The National Agriculture and Forestry Research Institute, Vientiane, Lao PDR. Quoting Mollot et al (2004)

Table 3: Examples of NTFPs grouped by use categories

(Source: NAFRI, NUoL, SNV (2007))

A. Food	**C. Fibres**
Fruits: Baccaurea ramiflora	*Bamboo*: canes
Stems/shoots: bamboo and rattan shoots	*Rattan:* canes
Tubers/roots: Dioscorea hispida	*Leaf fibre: Pandanus* sp.
Leaves: Melientha suavis	*Stem fibre:*
Nuts/seeds: Arenga westerhouttii	*Bark fibre: Broussonetia papyrifera*
Flowers: Markhamia stipulata	*Grass: Thysanolaena latifolia*
Spices: Zanthoxylum rhetsa	**D. Extracts**
Mushrooms: Lentinus sp.	*Gums: Boehmeria malabarica*
Food oils and gums:	*Gum resin: Garcinia sp.*
Fodder (for animals): Albizia procera	*Resin: Shorea obtusa*
B. Medicines	*Oleoresin: Dipterocarpus alatus*
Fruits: Rhus chinensis	*Latex:* rubber
Stems/shoots: Coscinium fenestratum	*Tannin: Pentace burmanica*
Tubers/roots: Smilax grabra	*Dye: Diospyros mollis*
Leaves: Plumbago indica	*Essential oil: Aquilaria* sp.
Nuts/seeds: Strychnox nux vomica	*Stimulants:* betel nut
Flowers: Clerodendrum paniculatum	*Insecticides: Azadirachta indica*
Bark: Clausena harmandiana	**E. Ornamentals**
Wood: Draceaena loureiri	Orchids, ferns and curcuma flowers
	F. Charcoal and (fuel) wood
	G. Animal products (separate group)

The values of these NTFPs can be considerable, both in their contributions to local livelihoods and market value when such products are exported. For instance in Lao PDR the value of NTFPs to household incomes has been estimated in various studies as shown below in Table 4. It can be seen that the average value per household is estimated at $489 per year for NTFPs and $472 per year for wild fish. Wild fish make up almost as much as NTFPs to the household income.

Table 5 uses this figure of $489 per household per year and multiplies up by the number of rural households to get a figure of $381 million for non-cash contribution from NTFPs to household livelihoods, and adds another $164 per household for cash income contributions. This gives a total of $510 million per year from NTFPs. This corresponds to 9.2 % of the GDP of Lao PDR in 2009.

Table 4: Household values of NTFPs in Lao PDR as of 2009

(Source: NAFRI, NUoL, SNV (2007))

Province	Year	Citation	Kip values			Dollar values				2009 $ values (CPI 2009=100)			
			NTFP	Wild Fish	All	$/kip rate	NTFP	Wild Fish	All	CPI 2009	NTFP	Wild Fish	All
Salavan	1998	Clendon	315,458	90,142	405,600	3,429	$ 92	$ 26	$ 118	16.33	$ 563	$ 161	$ 724
Huaphan	2001	IUCN	2,208,000	99,000	2307000	7,754	$ 285	$ 13	$ 298	50.30	$ 566	$ 25	$ 591
Sekong	2003	Rosales	3,664,282	552,656	4,216,938	8,008	$ 458	$ 69	$ 527	64.27	$ 712	$ 107	$ 819
Attapeu	2004	Mollot	2,739,400	9,504,000	12,243,400	8,405	$ 326	$ 1,131	$ 1,457	70.99	$ 459	$ 1,593	$ 2,052
Savannakhet	2004	Hansen	875,000	n.a.	875,000	8,405	$ 104	n.a.	$ 104	70.99	$ 147	n.a.	$ 147
										Average	$ 489	$ 472	$ 961

Table 5: Estimates of contribution of NTFPs to national income in Lao PDR
(Source: NAFRI, NUoL, SNV (2007))

No persons in the entire country	6,205,341
No persons/household	5.8
No households	1,069,886
% rural households	73%
Total no rural inhabitants	4,529,899
Total no rural households	781,017
Annual NTFP cash income per rural household	**$164**
Annual NTFP non-cash income per rural household	**$489**
Annual NTFP income per rural household	**$653**
Total Annual NTFP Cash Income at National level	**$128,086,797**
Total Annual NTFP Non-Cash Income at National level	**$381,917,313**
Total Annual NTFP value at National level	**$510,004,110**
GDP	$5,543,146,900
% NTFP Cash Income as % of GDP	2.3%
% NTFP Non-Cash Income as % of GDP	6.9%
% Total NTFP Income as % of GDP	9.2%

Some NTFPs are extremely valuable in their own right. For example, cardamom is the second most valuable agricultural export commodity from Lao PDR after coffee. In good masting years, malva nuts gathered from the south of Lao PDR may exceed the export value of cardamom (NAFRI, NUoL, SNV (2007)).

The species chosen as examples of NTFPs for this study have the following uses as shown in Table 6.

Table 6: Uses for the different species of NTFPs selected for this study

Group/ Species	Food	Medicine	Fiber	Extract	Ornamental
Mushrooms					
1. *Amanita vaginata, A. caesarea*	X	X			
2. *Auricularia polytricha and A. auricular*	X	X			
3. *Boletus edulis* + spp.	X				
4. *Lentinus polychrous*	X				
5. *Lentinus edodes*	X				
6. *Russula virescens*	X	X			
Grasses/herbs					
7. *Apium graveolens*	X	X		X	
8. *Amomum microcarpum* + spp.		X		X	
9. *Centella asiatica*	X	X		X	X
10. *Curcuma singularis*	X	X			X
11. *Thysanolaena latifolia*			X		X
Aquatic plants					
12. *Eleocharis* spp.	X				
13. *Ipomea aquatica*	X				
14. *Lepironia articulata*			X		
15. *Nymphaea* spp.	X				
16. *Passiflora foetida*	X	X			

Group/ Species	Food	Medicine	Fiber	Extract	Ornamental
17. *Sesbania sesban*	X				
18. *Stenochlaena palustris*	X				
19. *Typha orientalis*	X		X		
Climbers and vines					
20. *Cissampelos pareira*	X	X		X	
21. *Coscinium fenestratum, Fibraurea recisa*		X		X	
22. *Discorea hispida*	X	X		X	
Orchids					
23. *Dendrobium* spp.		X			X
24. *Dendrobium aggregatum or D. lindleyi*				X	X
25. *Paphiopedilum hirstissimum or P.equirolei*					X
Bamboos and Rattans					
26. *Bambusa arundinacea*	X	X	X	X	X
27. *Bambusa tulda*	X		X		
28. *Calamus caesius*	X	X	X		X
29. *Dendrocalamus latifolius*			X		
30. *Dendrocalamus lonofimbriatus*			X		
31. *Indosasa sinica*	X		X		
Shrubs					
32. *Broussonetia papyrifera*					
33. *Cratoxylum formosum*	X	X		X	
34. *Meliantha suavis*	X	X		X	
Trees					
35. *Aquilaria crasna*				X	
36. *Arenga westerhouttii*	X				
37. *Baccaurea ramiflora*	X	X			
38. *Dipterocarpus alatus*		X	X	X	X
39. *Markhamia stipulata*		X			
40. *Scaphium macropodum*	X	X		X	
41. *Shorea obtusa*		X	X	X	X
42. *Styrax tonkinensis and S. benzoides*				X	
Animal products					
43. Insects – Red Ants *Oecophylla smaragdina*	X	X			
44. Insects – Cicada *Dundubia intermerata*	X				
45. Insects – Crickets	X				
46. Insects – Scarab beetle *Holotrichia sp.*	X				
47. Insects – Bees/Honey	X	X		X	
48. Earthworms		X		X	

The gathering systems for NTFPs are as diverse as the plants, their different parts that are used, and the actual uses. These range from non-destructive gathering of the fruits, flowers, shoots, and leaves to the more destructive digging up of roots, removal of bark, and the cutting down of whole trees. The collection of whole plants, such as orchids, is also effectively destructive because it removes the gene stock from the wild. Insects such as crickets and cicadas are often attracted to lights at night and then collected as they fall in water.

Some products, such as bamboo shoots and fruits, may be used or sold fresh. Other processing may involve sun-drying or air-drying, e.g., mushrooms, and deep frying such as for the insects. More complex processes are involved for the resins and extracts, which may require steam distillation.

Probably the main threat to NTFPs is the clearance of forests and changes in land use for agriculture and agroforestry. In all the countries of the LMB, forest cover has changed dramatically over the past 50 years. In Lao PDR, for example, the original natural forest cover was over 70% in the 1940s and by 2002 was reduced to 41.5%.[5] The main drivers for this are considered to be shifting cultivation, legal and illegal logging, conversion to agriculture and forest plantations, and infrastructure development. It should be pointed out from the perspective of NTFPs, while secondary and recovering forests can be very productive sources of NTFPs, plantations for commercial crops such as rubber lead to an almost sterile environment for most NTFPs. The national targets for agricultural land expect to see an increase from 1.2 million ha in 2002 to over 2 million ha by 2020.

During the past 4 decades, Thailand has lost a total of 72 million rai of forest area or about 1.6 million rai/year on average (the country's forest area was 171 million rai or 53.3% of the total area in 1961 and remained 99.15 million rai or 30.86% in 2009).[6,7]

In the Mekong Delta in Vietnam, remaining forest estimates range from 25% to 40% of former forest cover.[8] Today the landscape has largely been turned into manmade agriculture landscape. Of the total land area of about 3.96 million hectares, 2.6 million hectares are being used for agriculture, mainly rice cultivation and aquaculture, accounting for 65% of the total land area—the rest of the area consists of waterways, residential land, roads, and a small proportion being protected areas.

The national plan to 2020 is to develop the Mekong Delta into a focal commercial agriculture and aquaculture production area with high economic growth rate. The targets to 2020 are to maintain 1.8 million hectares of rice, 0.5 million hectares of aquaculture, and to increase the forest cover to 9% from the current 5%.[9]

Apart from habitat change, overexploitation of some NTFPs has led to significant reductions of some products. This is especially a concern where destructive harvesting is practiced, since this leads to progressive loss of the natural resources.

Foppes and Ketphanh in 2000 (as quoted in NAFRI, NUoL, SNV (2007)) highlighted changes in NTFPs through discussions in a village in Champasak Province of Lao PDR over 10 years. This illustrated the increasing population pressure upon the resource, intensification of harvesting, declining availability, and increasing market prices, which all act as drivers of the trend of decreasing NTFPs.

Counter to this, there have been successful domestication or cultivation of some NTFPs, e.g., false cardamom, mushrooms (especially those that grow on decaying wood), eagle wood plantations, bong bark plantations, growing of rattan shoots, and broom grass. False cardamom gardens have been established in southern Lao PDR, which are not plantations in the strict sense, but rather clearings in the forest where wild *Amomum* is allowed to regenerate after a year of growing upland rice.[10]

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[5] Chanhsamone Phongoudome, Bounphom Mounda, Khamphay Manivong, Silavanh Sawathvong, Saykham Bouthavong and Boualy Phamuang (2009). *Report On The National Program Assessment on Forest of Lao PDR*

[6] Technical Conference organized by ONEP, 22-24 May 2011, Bangkok, on the occasion of The International Year of Forest and The International Year of Biodiversity

[7] 1 rai = 1,600 sq m; 6.25 rai = 1 ha

[8] Pamela McElwee and Micheal Horowitz (1999). Prepared for the Mekong River Basin Research and Capacity Building Initiative, Oxfam America SEA 15 197-99 by the Institute for Development Anthropology 1999

[9] Decision of the Prime Minister 939/QD-TTg dated on July 19, 2012 on approving the master plan for socio-economics development of the Mekong Delta to 2020

[10] NAFRI, NUoL, SNV (2007) *Non-timber forest products in the Lao PDR. A manual of 100 commercial and traditional products*. The National Agriculture and Forestry Research Institute, Vientiane, Lao PDR.

In Vietnam, some wetland plants have been successfully domesticated and have become an important income for farmers. While it can still be found in the wild, *Typha* has been planted for commercial purposes. Farmers in Soc Trang, Bac Lieu, and Ca Mau Provinces raise fish in their *Typha* fields fetching an income of up to $2,500/hectare/year. Pickled and fresh *Typha* can be ordered from almost any restaurant in the Mekong Delta. In low-lying areas, *Typha* has proven to be a more economically competitive crop than rice. Fresh young *Typha* shoot is sold at around $1.5/kg and pickled *Typha* fetches $2.0/kg. Tender bases of *Eleocharis* spp. is sold at $0.75 per kg. It can be an important income source for farmers in acidic areas where rice gives low yield or where only one crop of rice per year is possible.

Table 7: Changes in off-takes per effort for 3 key NTFPs in a village in Champasak Province of Lao PDR over 10 years

Source: Foppes and Ketphanh (2000)

NTFP	10 years ago	Today
Wildlife	Plenty of wildlife: turtles, monitor lizards, deer, snakes, jungle fowl, other birds. You could easily hunt them in your backyard. There was no outside market, no selling. Only our village hunted (9 families only).	Many species disappeared: turtle, deer, jungle fowl, birds. You can walk for 48 hours and still not get anything. Market demand is big, prices are getting higher (1 mouse-deer costs 12,000 kip). Many outsiders come to hunt in our forest. Village has 57 families now.
Fish	You could catch 4-5 kg within 1 hour. There were only 9 families. No selling, no destructive methods used, only traps and nets.	You can not even get 0.5 kg in 1 hour. There is not enough to feed all our 57 families. Strong outside market (2,500 kip/kg). Destructive methods used by outsiders: explosives, guns, poison. Decline: 90%
Rattan	In 1 day, you could get 300 stems, or as many as a man can carry. We used to also have big diameter rattan, now only small diameter species.	You can only get 20-30 stems in a day. Harvesting has intensified over the last 2 years. 1 stem sells for 200kip. We know there is no quota but we need to sell anyhow. Decline: 90%.

2.2 ECOLOGICAL PREFERENCES AND TOLERANCES

The description of ecological preferences of different NTFP species and the climate tolerances is important as a precursor for assessment of vulnerability of NTFPs to climate change factors. For the species that have been used as examples for this study, these have been summarized below. Very often specific details on climate tolerances are not available for the species and may only be compared to crop plants where growing conditions have been researched.

Table 8: Climate tolerances and ecological preferences of selected NTFP species

Group/ Species	Elevation range	Climate tolerance		Soil type limitation	Forest type
		Temp	Rainfall		
Mushrooms					
1. *Amanita vaginata, A. caesarea*	Not specific				Dipterocarp, open forests, woody areas
2. *Auricularia polytricha and A. auricular*	All altitudes	20 – 25 °C optimum	Humidity over 80% for fruiting	pH 6 – 6.5	Evergreen and mixed deciduous
3. *Boletus edulis* + spp.	All altitudes		Growth triggered by rainfall events		Open and dry dipterocarp and pine forests
4. *Lentinus polychrous*	Not specific			Near streams	Dry dipterocarp and mixed forest
5. *Lentinus edodes*	Not specific				Dry wood of *Fagaceae* spp.
6. *Russula virescens*	Not specific	30-38° C	1,350 mm/yr	Sandy loam, silty sand, clay, laterite, pH 5-7	Dry deciduous dipterocarp
Grasses/herbs					
7. *Apium graveolens*					
8. *Amomum microcarpum* + spp.					
9. *Centella asiatica*	Up to 700 m asl	Tropical. Tolerates down to 5 -10° C		Sandy, loamy, clay soils. Acid, neutral, and alkaline soils. Prefers moist or wet soils.	Can grow in light woodland. Prefers swampy areas
10. *Curcuma singularis*	200 – 800 m asl				Mixed deciduous, dipterocarp, dry evergreen or semi-evergreen
11. *Thysanolaena latifolia*					
Aquatic plants					
12. *Eleocharis* spp.					
13. *Ipomea aquatica*					
14. *Lepironia articulata*					
15. *Nymphaea* spp.					
16. *Passiflora foetida*					
17. *Sesbania sesban*					
18. *Stenochlaena palustris*					
19. *Typha orientalis*					
Climbers and vines					
20. *Cissampelos pareira*					Evergreen, deciduous
21. *Coscinium fenestratum, Fibraurea recisa*					
22. *Discorea hispida*					
Orchids					
23. *Dendrobium* spp.					
24. *Dendrobium aggregatum or D.lindleyi*	300 – 1,500 m asl	Cool climate with sunlight	965 – 1,550 mm/yr	Semi-epiphytic, attached with big trees	Dry evergreen, mixed deciduous
25. *Paphiopedilum hirsutissimum or P.esquirolei*	1,000-1,800 m asl	Cool climate		Humus soils	Hill evergreen

Bamboos and Rattans					
26. *Bambusa arundinacea*	Up to 2,000 m asl	22-30°C	1,200-2,500 mm/yr	Well drained (dry spells), pH 4.5-6.5	
27. *Bambusa tulda*					
28. *Calamus caesius*	Up to 800 m	23-30°C	2,500-3,200 mm/yr	Poorly drained, organic, alluvial, pH 5.5-7.0	Moist evergreen, dry evergreen, peat swamp
29. *Dendrocalamus latifolius*					
30. *Dendrocalamus lonofimbriatus*					
31. *Indosasa sinica*					
Shrubs					
32. *Broussonetia papyrifera*					
33. *Cratoxylum formosum*	<1,000 m asl			Found on many soil types	Mixed dipterocarp, dried mixed deciduous, moist mixed deciduous, peat swamp, mangrove
34. *Meliantha suavis*	300-900 m asl			Sandy loam, conglomerate	Mixed deciduous, dry dipterocarp
Trees					
35. *Aquilaria crasna*					
36. *Arenga westerhouttii*					
37. *Baccaurea ramiflora*					
38. *Dipterocarpus alatus*	100-800 m asl	22-32°C	1,000-2,000 mm/yr	Alluvial, deep soil, pH 5.0-6.5, well drained (dry spells)	Dry evergreen, dry dipterocarp, lower moist evergreen
39. *Markhamia stipulata*					
40. *Scaphium macropodum*					
41. *Shorea obtusa*	100-600 m asl (up to 1,300 m asl)	22-28°C	1,000-1,300 mm/yr with 5-6 month dry period	Loamy with laterite, conglomerate, well drained, pH 4.5-5.0	Mixed deciduous, dry dipterocarp
42. *Styrax tonkinensis and S. benzoides*					
Animal products					
43. Insects – Red Ant Eggs *Oecophylla smaragdina*	<1,000 m asl	10-40°C (optimal for feeding =30°C)	1,350 mm/yr on average	Dry with access to sunlight	Deciduous dipterocarp, fruit plantations
44. Insects - Cicada					Natural forests
45. Insects – Crickets					
46. Insects – Scarab beetles *Holotrichia sp*					Dry dipterocarp, mixed deciduous
47. Insects – Bees/Honey					
48. Earthworms	Wide distribution	4 – 35 °C Optimal temperature- 15 – 28 °C	Ave. annual: 1,260 mm/yr. Ave. relative humidity 82% Opt. moisture content: 60 – 80%.	Light loam, light sandy, medium loam, alluvium, clay soils	Dry evergreen, dry dipterocarp, forest plantations, grasslands

2.3 LINKAGES WITH OTHER FARMING SYSTEMS

NTFPs can be considered to lie at the heart of traditional farming systems in the LMB and even have strong links with more commercial farming systems. The figure below illustrates some of the linkages with the other farming systems and shows why it is essential that viable and sustainable NTFP and CWR systems are supported in the face of climate change. This figure considers that wild fish and the capture fishery to be closely related to the NTFPs.

Starting with the social components, mention has already been made to the key role of NTFPs in underpinning the livelihoods of rural communities throughout the basin. NTFPs provide food and nutrition, food security in times of rice deficit, and delicacies that are enjoyed by the farmers – including bamboo shoots, seasonal fruits, etc. In the absence, and often instead of, conventional medicines, NTFPs provide herbal remedies, supplements, and tonics for rural communities. They provide the raw materials for construction and fibers for furniture, paper making, and textiles. They provide the basic energy for cooking and warmth through firewood and charcoal. The collection and processing of NTFPs are a fundamental part of the culture of all different ethnic groups. In addition, many of the NTFP products that are collected are sold both in the local and urban markets, and to middlemen who export the products especially to neighboring countries. The value of NTFPs to the national economies in the region is very significant.

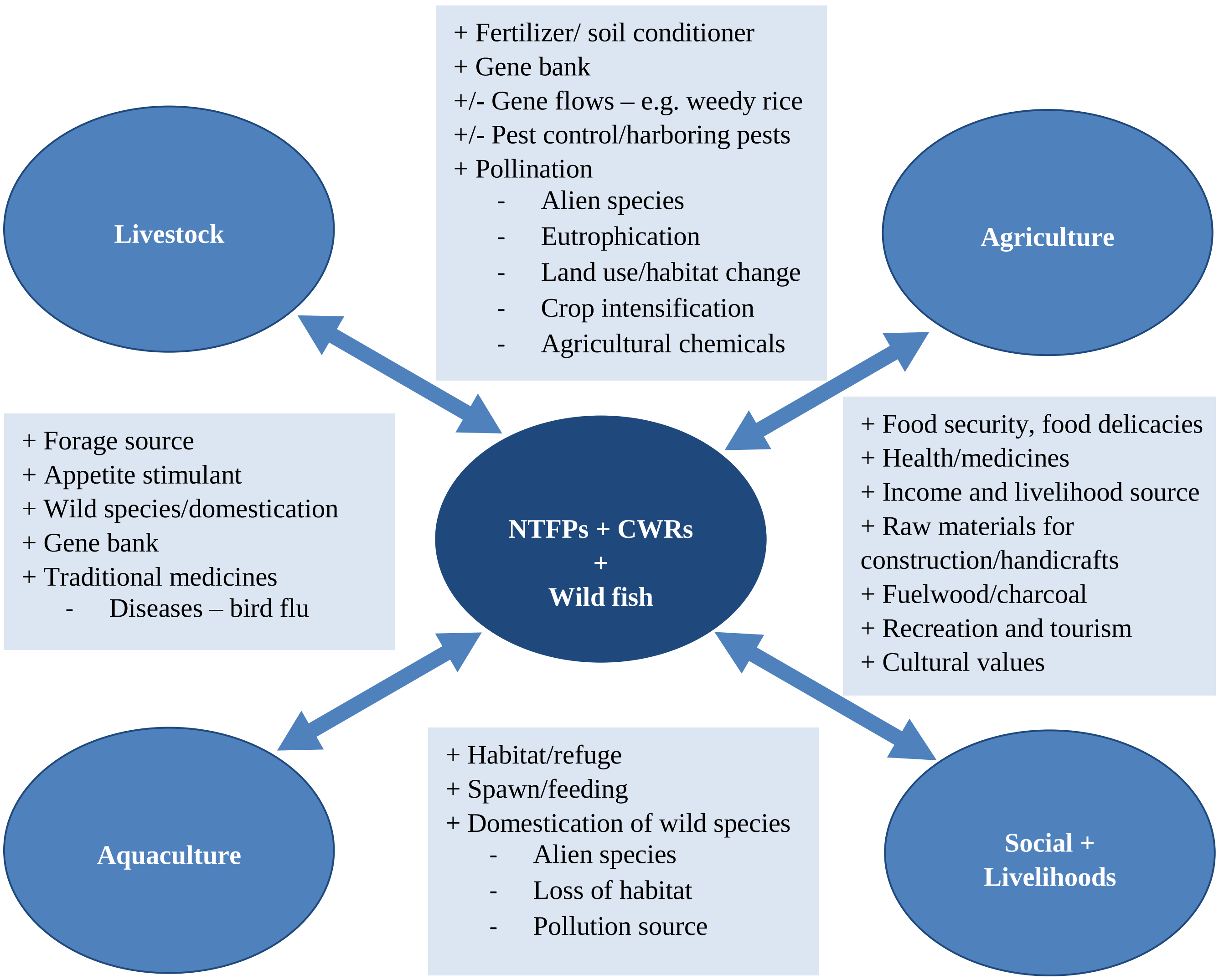
NTFPs and CWRs are also central to agricultural systems. Many of the present day crops have originated within the region – notably rice, but also vegetables such as eggplants and fruits such as mango and mangosteen. NTFPs and CWRs represent an in situ genebank, which could be tapped into for improving the existing crops. The ongoing domestication and cultivation of NTFPs is really the first step in an age-old process of crop development. Some NTFPs also have insecticidal properties and can be used for pest control, although often the forests are seen as harboring crop pests. Pollinating animals, e.g., birds, bees, and bats, are essential for successful crops, especially fruits, and forests provide the habitats for these pollinators (e.g., *Sonneratia* mangroves for dawn bat and honeybees).

However, the survival of NTFPs and CWRs is also threatened by agriculture. There is increasing pressure on land resources for more extensive and intensive forms of agriculture, and land use change and habitat conversion is perhaps the biggest threat to the viability of many NTFPs. The increasing use of agricultural chemicals also threatens insects such as honeybees and decreases populations of earthworms.

The linkages with livestock farming systems similarly have provided the wild stocks for domesticated animals, e.g., local landraces of pigs and poultry. As such, some of the wild species of animals still represent an in situ genebank, though these are increasingly under threat. Of the plant species, many NTFPs provide forage for animals and are either available as the animals graze or browse directly, or may be collected by the farmers for their animals. Examples of this are the paper mulberry and *Sesbania*, which can also act as appetite stimulants for animals. As with plants from the forest, some animal products have recognized medical properties, e.g., honey and specific products can fetch high value when exported. On the other hand, the forest also harbors animal diseases and products from the animals in the forest can help these diseases make the transition to both domestic animals and humans, e.g., SARS and bird flu.

Finally the linkage with aquaculture is strongest between wild fish and cultured fish. Although a large proportion of aquaculture species are exotic fish, there is a significant potential for the development of indigenous species for aquaculture, and research into this is progressing. Quite often the fish that are cultured come from eggs or fingerlings of wild stocks that have been collected, rather than from hatcheries. Some of the aquatic plants that are cultivated around fish ponds provide both food and shelter for the fish. As with forest habitats, the development of aquaculture ponds in many parts of the LMB has put pressure upon natural wetland areas.

Figure 2: Linkages with other components of the farming systems in the Lower Mekong Basin



3 SPECIES ASSESSMENTS

This section is divided into the different NTFP groups with an overview for the type, followed by a vulnerability assessment of the selected species. Each profile contains information on the following:

- What is the species
- How is it used (linkages with other farming systems)
- Its value and how much it is used
- Distribution
- Ecological requirements relevant to the CC aspects
- Baseline status in the hotspot areas with existing stresses and threats
- Climate change threats and vulnerability for the hotspots and the likely impacts
- Recommended adaptation measures

3.1 MUSHROOMS

Mushrooms are fungi, which are lower plants that do not photosynthesize. Several different types can be distinguished based upon their living characteristics – saprophytes that grow on raw humus, epiphytes that grow on other plants, and parasites that grow on other plants and draw their nutrients from them. The fungi consist of large root-like networks of filaments that grow underground or in the wood, and produce fruiting bodies, which are the mushrooms that are harvested. In Lao PDR there are generally two types recognized: those that grow on dead and decaying wood, and those that grow on the ground.

There are many different species throughout the region – for example in China some 375 edible mushroom species are found in the forests. In Thailand there are some 120 species in 39 families. While there are many edible species, a number of them are poisonous, some fatal. Some species are used for traditional medicines. While many are collected for home use, some have significant export value, such as *Lentinus edodes* (Shiitake mushrooms), which can be sold at 3 – 6 USD/kg dry weight. Vietnam exports around 1,000 tonnes of wild Jew's ear mushrooms (*Auricularia auricula).*[11] In Thailand, wild mushrooms are important for local food and health security and sources of supplementary occupation and income. Market price is 5 – 8 USD/kg (>150 THB/kg).

Growth and availability is associated with vegetation and undergrowth of deciduous dipterocarp forests. Leaves, branches and twigs fall in the dry season, decompose, and become nutrients and maintain soil moisture, facilitating growth of mushrooms. Mushrooms prefer high temperature and relatively high air humidity (80-90%). Availability is during June – October. Abundance increases after heavy rain in summer, throughout the rainy season, and peaks at the end of the rainy season.

Gathering for domestic consumption as well as for sale occurs during the rainy season and peaks in September. Cultivation of mushrooms that grow on humus and rotting plant materials is relatively well developed, but those that are dependent upon particular types of trees (e.g., *Russula repida* grows only

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[11]NAFRI, NUoL, SNV (2007) Non-timber forest products in the Lao PDR. *A manual of 100 commercial and traditional products*. The National Agriculture and Forestry Research Institute, Vientiane, Lao PDR. Quoting Mollot et al (2004)

under oak trees (Fagaceae), *Termitomyces* spp. grow near termite mounds, and *Lentinus* spp. are associated with dipterocarp trees) are difficult to replicate for cultivation.

Because of their market value, some species of mushrooms are declining due to increased numbers of collectors and over-harvesting. Deforestation, land use change, and habitat loss are also significant factors leading to decline in species that are dependent on specific host plants.

3.1.1 VULNERABILITY ASSESSMENT FOR *RUSSULA VIRESCENS* WILD MUSHROOM

Russula virescens is a wild mushroom of the Russulaceae family and is found in all LMB countries. It has a nine cm cap diameter. Its fruiting period is between June and October.

Growth and availability is associated with vegetation and undergrowth of deciduous dipterocarp, dry dipterocarp, and mixed forests, especially trees of the family Dipterocarpaceae, e.g., *Shorea obtusa, Shorea roxburghii,* and undergrowth, e.g., *Diospyros filipendula* and *Ixora lobbii*. Fruits can be found on forest soils or on the lower parts of forest trees near the ground, forming ectomycorrhizal symbiotic relationships with the trees, and also in the vicinity of marshes, swamps, and bush and shrub forests. Fruiting bodies may appear singly or in groups, but reappear in the same spots year after year, and are not common.

Russula virescens prefers moist forest, lateritic soil, and termite mounds. This wild mushroom prefers high temperature (30 - 38˚C), high rainfall (1,350 mm/yr on average), and relatively high air humidity (80-90%). Availability is during June through October. Abundance increases after heavy rain in summer, throughout the rainy season, and peaks at the end of the rainy season.

Russula virescens is one of the most popular edible fungi and is one of the best tasting. This wild mushroom is important for local food and health security, and as a source of supplementary occupation and income. Market price is 5 – 8 USD/kg. It also has medicinal property and is used as medicine.

Because of its high market value, this wild mushroom is declining due to increasing number of collectors and over-harvesting. Deforestation, land use change, forest fire and habitat loss are also significant factors leading to population decline. Specifically if the associated trees species (Dipterocarpaceae) are lost, then *Russula virecens* populations will be reduced. Present wild populations are now not commonly found. The IUCN Red List status is 'Not Evaluated'.

In the provinces under consideration, a number of factors are putting additional non-climate related stress upon *Russula virescens,* which is now considered to have a **high to very high non-climate vulnerability**. These include land concessions within protected areas (e.g., Mondulkiri), government policy on converting degraded forest to rubber tree plantation areas, and illegal logging to clear out healthy forest, which happens frequently in Gia Lai for example. In Khammouan, threats to habitats include increase in infrastructures & economic development (e.g., hydropower, roads, and settlements). In Chiang Rai, the future development of transportation routes and tourism under GMS economic development cooperation schemes also threatens habitat through land use conversion. There is currently no conservation status for *Russula virescens* and the conservation status of its habitats (as Forest Parks, Non-Hunting Areas, and even National Parks) is very weak and inadequate for safeguarding this species and the environment it depends upon.

Future average temperature ranges in all four of the hotspots evaluated (Mondulkiri, Chiang Rai, Gia Lai, and Khammouan) will still be within the optimal range for this wild mushroom. Higher rainfall during the wet season in all four hotspots may enhance availability and abundance of this wild mushroom. Although Mondulkiri will have higher risk of drought, this will be followed by higher rainfall in the wet season increasing the abundance of this wild mushroom. Future less risk of drought in Chiang Rai and little change in drought patterns in Gia Lai and Khammouan will be beneficial to this wild mushroom.

Key threats from future climate change that may decrease the availability of appropriate habitats of this wild mushroom include drier dry seasons, decrease in soil moisture availability, higher risk of wild fire due to increase in temperature especially during dry season months, and bigger and more frequent storms. **In all four hotspots, *Russula virescens* will have moderate vulnerability to the projected future climate change.**

Recommended adaptation measures
Short term

- Encourage and support the attempt and effort of local communities to achieve 'sustainable harvest', to develop 'sustainable harvesting systems' of the wild mushroom *Russula virescens*, and to avoid over-exploitation
- Promote and support the cultivation projects/programs for *Russula virescens* in order to reduce pressure on the wild population

Medium term

- Identify and protect 'specific habitats' of *Russula virescens*
- Build 'check dams' to maintain and increase soil moisture availability within the forests, especially during dry season months, and to reduce wild fire risk
- Restore and rehabilitate deteriorated forests. Increase forest canopies, crown covers, and shady areas
- Increase 'Protected Forests' in order to maintain the habitats and to safeguard the existing wild population
- Increase the effectiveness of 'Protected Area Systems' and the management of existing protected areas in order to reduce deforestation, commercial and illegal logging, encroachment, forest fires, land use change, and habitat deterioration and loss
- Establish the 'buffer zone' for existing forest areas in order to allow natural shift of forest distribution under future climate change

Long term

- Research on ecological characteristics of *Russula virescens* and of its specific habitats. Enhance and increase habitats appropriate for *Russula virescens*

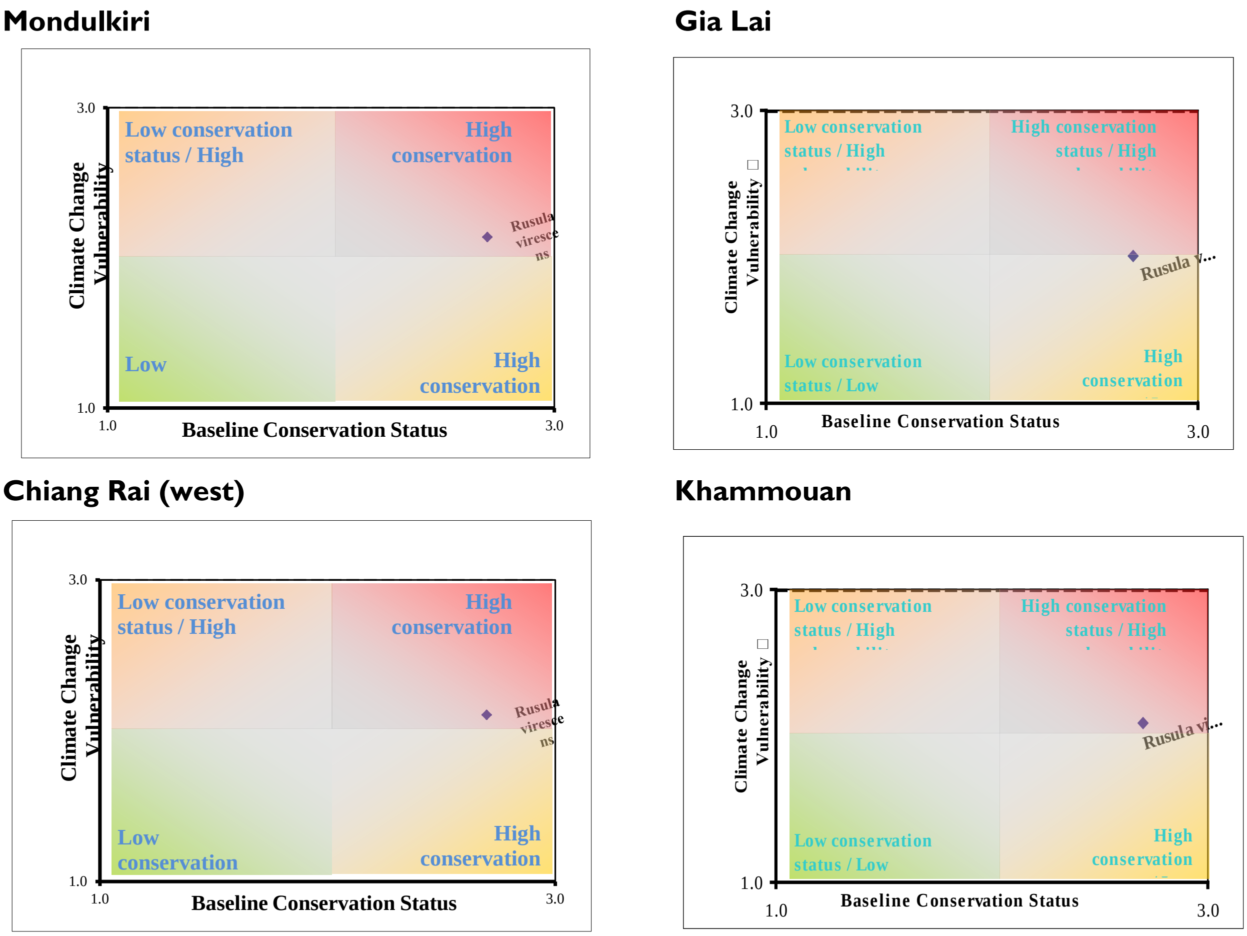


Figure 3: Baseline conservation status for *Russula virescens* in four hotspot provinces in the Lower Mekong Basin

3.2 GRASSES AND HERBS

Grasses are herbaceous plants with narrow leaves growing from the base. They are a wide group of plants that include the "true grasses", of the Poaceae (or Gramineae) family, as well as the sedges (Cyperaceae) and the rushes (Juncaceae). These latter are described under aquatic plants. The true grasses include cereals, bamboo, and the grasses of lawns (turf) and grassland. Sedges include many wild marsh and grassland plants, and some cultivated ones such as water chestnut (*Eleocharis dulcis*) and papyrus sedge (*Cyperus papyrus*). The term "herbs" is used to describe any non-woody flowering plant, regardless of its flavor, scent or other properties. They include grass-like plants and forbs, which are broad-leaved herbs other than grasses.

Grasses and herbs are widely distributed in various natural and man-made habitats of tropical zones including grasslands and pastures, forests, swampy areas, rice fields, and home gardens. They increase in availability and abundance in the rainy season.

Uses for grasses and herbs include food (as grain, sprouted grain, shoots, or rhizomes), brewing of alcohol, pasture for livestock, thatch, paper, fuel, clothing, insulation, construction, basket weaving, and many others. Culturally important wild herbs such as *Curcuma singularis, C. sessilis, C. aeruginosa,* and *C. alismatifolia* are used as food, vegetable, medicine, and ornament. Small herbaceous perennial herbs such as *Centella asiatica* are also used as vegetables for consumption. Extracts of some grasses and herbs are used for beverage and cosmetics. The whole plants are of high conservation value for soil coverage and soil erosion prevention. Grasses and herbs may be gathered during the rainy season for domestic consumption and for sale, or as in the case of broom grass in the middle of the dry season, after the seeds have set.

Grasses and herbs are under threats due to wild plant trade, increasing export of rhizomes, and land use changes. The species that have been considered for this study include:

- *Apium graveolens* – wild celery
- *Amomum microcarpum* – false cardamom
- *Centella asiatica*
- *Curcuma singularis*
- *Thysanolaena latifolia* – broom grass

A vulnerability assessment on *Amomum* spp has been carried out. Also note that wild rice species are grasses and these have been considered under the section on Crop Wild Relatives.

3.2.1 VULNERABILITY ASSESSMENT FOR FALSE CARDAMOM, *AMOMUM* SPP.

There are several species of *Amomum* widely spread throughout the LMB such as *A. microcarpum*. Other species of *Amomum* inhabit more localized areas such as *A. villosum* (red cardamom) and *A. ovoideum* (green cardamom), which grow in the north of the basin in Thailand, Lao PDR, and Vietnam; *A. uliginosum* is found in southern Lao PDR and Vietnam; and *A. kravanh* is found in Cambodia. A member of the Zingeriberaceae or ginger family, false cardamom is a valuable medicinal spice exported from Lao PDR and Cambodia, especially to Thailand and China. It is a perennial understory herb with thick rootstocks growing up to 2 – 3.5 m high. Essentially a forest species, requiring at least 50% canopy cover, it grows in lowland evergreen and deciduous forests on a variety of soil types. It is a creeping species with long rhizomes, so it spreads to make extensive colonies. Inflorescences grow from the root stock and produce pairs of white flowers. The oval fruit is a spiny red capsule 2 cm long with brown seeds with a camphor-like odor.

Fruit is picked from the rootstock for a period of 15 – 25 days in July/August. The unpeeled fruit is dried in sun or over wood fires/ovens. In China, the fruit is processed into essential oils. In Thailand, seed oil is obtained by water distillation. Although extensively collected from the wild, domestication and cultivation under shade trees or enrichment planting in the forest is increasing. The quality of seeds tends to be higher from plantations.

As a medicine it is used for stomach aches, constipation and other digestive problems. It is an appetite promoter and the seeds and fruit are used in a variety of sweet and spicy dishes, especially in curries. As indication of its value, it is an important export crop from Lao PDR – export estimates for 2007 were between 1,000 – 1,800 tonnes per year[12]. In 1998, *Amomum* was Lao PDR's second most important agricultural export after coffee. In Vietnam, between 1999 to 2000, about 8 tonnes were exported to China and 18 tonnes to Japan. It is also an important export crop from Thailand and Cambodia, with

[12] NAFRI, NuOL, SNV (2007) NTFP Manual.

dried fruit selling at up to 5 USD/kg, and *Amomum* fruit extract selling at 25 – 34 USD/kg on the internet. One hectare of wild cardamom can yield about 50 kg of whole dried fruits, and under plantation conditions this may rise to 200 kg/ha/yr.[13]

Amomum species are widely distributed throughout the region, but in the Climate Study's hotspot areas they are found in Mondulkiri (Cambodia), Gia Lai (Vietnam), Chiang Rai (west) (Thailand), and Khammouan (Lao PDR), as well as in Stung Treng Province in Cambodia, and Sekong and Champasak Provinces in Lao PDR. In terms of its ecological requirements, it grows best in moist riverine places within mixed secondary deciduous and evergreen forest and requires 50% shade. It has soil preferences for medium organic soils with high fertility, low salinity, and an optimal pH of 6-7 (with 4.3-7.5 representing its absolute threshold range for pH). Its temperature tolerances (c.f. *Zingeriber officinale)*[14] may lie between 19 – 29°C (optimal), 13 – 35°C (absolute), and it has wide rainfall tolerances of 1400 – 3000 mm/yr (optimal), 700 – 4000 mm/yr (absolute). It requires at least 100 days of rainfall per year. It is not known to what extent these conditions vary between the different *Amomum* species.

Within the hotspot areas it is generally considered to be quite a hardy and adaptive species, propagating both vegetatively from the rootstock and also from the seeds, which may be distributed by birds or by water flow in streams. Pollination may occur via honeybees, which may also be negatively affected by climate change. It is not a protected species in any of the countries and the IUCN Red List considers all the species in the LMB as of Least Concern. However, since it thrives in shady conditions, loss of forest habitat generally throughout the region, is tending to reduce its distribution. Harvesting of the seeds is generally at a sustainable level, and the tendency towards cultivation or enhancement planting tends to reduce the pressure on wild stock.

However, local pressures upon the habitats in the provinces under consideration are putting additional non-climate related stress on *Amomum,* which is now considered to have **high non-climate vulnerability**. These pressures include land concessions within protected areas (e.g., Mondulkiri), government policy on converting degraded forest to rubber tree plantation areas, and illegal logging to clear out healthy forest, which happens frequently in Gia Lai for example. In Khammouan, threats to habitats include increase in infrastructures & economic development (e.g., hydropower, roads, and settlements). In Chiang Rai, the future development of transportation routes and tourism under GMS economic development cooperation schemes also threatens habitat through land use conversion. There is currently no conservation status for *Amomom* spp. and the conservation status of their habitats (as Forest Parks, Non-Hunting Areas, and even National Parks) is very weak and inadequate for safeguarding these plants and the environment they depend upon.

The key climate change threat is the increase in temperature. This is especially acute in Mondulkiri, where the increases in maximum daily temperature could push above the threshold tolerance of 36°C

[13] Aubertin, C. (2004). Cardamom in Lao PDR: the hazardous future of an agroforest system product in Forest Products, Livelihoods and Conservation, ed. Kusters, K. and Belcher, B.

[14] FAO Ecocrop database for *Zingeriber officinale*

and make *Amomum krevanh* highly vulnerable, though the high temperatures may be mitigated to some extent by the shade cover in the forest. The increased temperature in April and May (mean maximum over 36°C) is especially concerning since this is the key flowering period. In Mondulkiri, this is also combined with decreases in the amount of monthly precipitation in the dry season months, leading to significantly lower soil moisture content at this critical time of year. In the fruiting season (June –August) the temperature falls and the rainfall increases, and is considered to be less critical.

In the other hotspot areas, Chiang Mai, Khammouan, and Gia Lai, the temperature thresholds at the critical flowering period are not likely to be reached, and rainfall and soil moisture changes are not likely to be critical. Rainfall generally throughout the hotspot areas shows an increase over the whole year with some decreases in the dry season, but not as marked as in Mondulkiri. It is considered that in its preferred habitat as a forest understory herb living in moist riverine areas, it is relatively protected from high daily temperatures, from drying out and from extreme events. With its vegetative rootstock, it has a relatively high adaptive capacity after adverse conditions, including after fire.

In Mondulkiri, *Amomum* is considered to be highly vulnerable, while in the other hotspot areas it is considered to be moderately vulnerable, although even in these, it may be pushed against its temperature thresholds. In Mondulkiri, it could be expected to die out gradually in the lower elevations (which are hotter) and to maintain itself or shift upwards to higher elevations where temperatures may be less extreme. In shifting to higher elevations it would have to rely upon birds for distributing the seed, rather than the streams which only carry the seeds downhill. In the other hotspot areas, *Amomum* may be expected to survive, though productivity and quality of fruit and seeds may be lower, perhaps because of higher humidity in the fruiting season.

Recommended adaptation measures

The key province for adaptation measures for *Amomum* is Mondulkiri. This should be the province to watch to see if the critical climate change threat of increased temperatures is having an impact upon both productivity and fertility. The predicted availability of water at the end of the dry season is most acute in Mondulkiri as well, although overall annual rainfall would increase within the optimum range for *Amomum*. The following adaptation measures are suggested:

Short term

- Ensure protection of forest from logging and other destructive practices
- Protect water courses near stands of *Amomum*
- Build check dams to maintain ground water level near areas that may tend to dry out
- Ensure harvesting practices are sustainable
- Ensure that cultural practices do not threaten wild stock

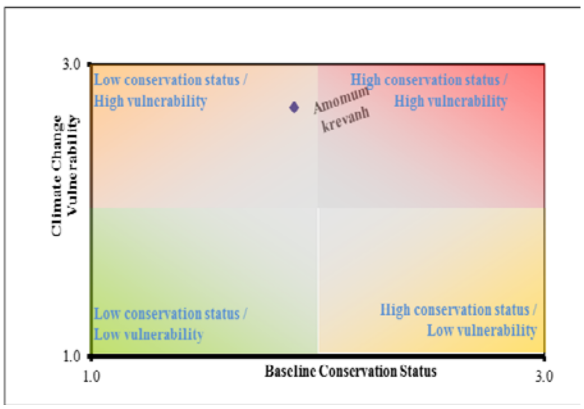
Medium term

- Monitor stands of *Amomum* to observe changes in productivity and prevalence of disease or insect infestation at higher temperatures
- Monitor forest around stands of *Amomum* to observe reproduction, dispersal of seed, and success of young plants at higher temperatures
- In Mondulkiri, conduct monitoring research to identify stands of *Amomum* that appear to be more resilient to temperature for possible transplanting

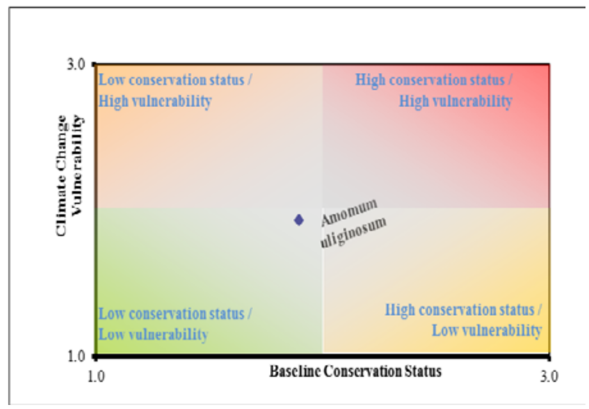
Long term

- If there are signs of morbidity, lowered productivity, or reduced fertility:
  - o Actively transplant some rootstock to higher elevations in forest
  - o Consider bringing in stock from plants in Mondulkiri, or other provinces already exposed to higher temperatures
  - o Consider replacement of different *Amomum* species that thrive at the predicted temperature and water availability ranges

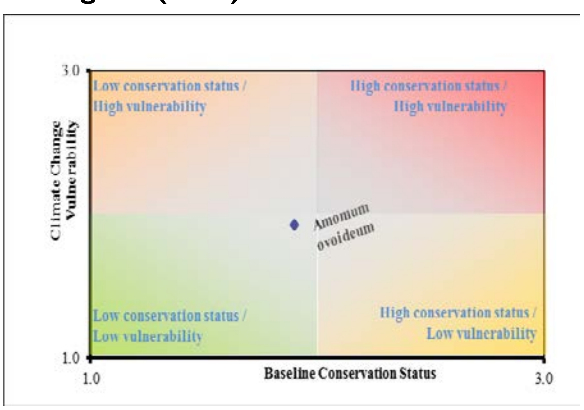
Mondulkiri



Gia Lai



Chiang Rai (west)



Khammouan

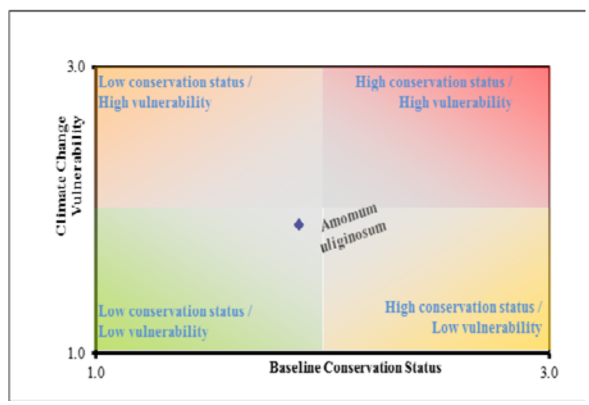


Figure 4: Baseline conservation status for *Amomum* spp. in four hotspot provinces in the Lower Mekong Basin

3.3 AQUATIC PLANTS

Aquatic plants, referred to as hydrophytes, are plants that have adapted to living in aquatic environments. In the LMB, these plants are found in freshwater, brackish, and saline wetlands including shallow areas near the banks of water courses and water bodies. Some species are also found at the edges of cultivated lands.

These species are classified according to their growing characteristics - emergent, submerged, or floating plants – and have adapted to the seasonal fluctuation of water levels in the LMB. They are found in wetlands and water edges throughout the basin, especially in the Mekong Delta in Vietnam.

Parts of the aquatic plants found in the LMB are mainly used for food, fiber, and medicinal purposes. Many of the aquatic plants are commonly used as vegetables throughout the LMB. The aquatic plants are harvested year round, but the main harvest season is during the high water season in the basin as the aquatic plants are most productive during this time of the year. The stems of water lilies, for example, grow longest and more rapidly during the flooding season from July to December annually in the LMB. Sesban flower also blooms during the flood season.

Harvesting is mainly done annually for home consumption and for sale. Some species such as *Typha angustifolia, Eleocharis* spp., lotus, and water lilies have been planted by local farmers for income

Most of the aquatic species can still be found in the wild but are on a declining trend mainly due to conversion to agriculture and aquaculture land uses as well as a wide range of development projects such as dams, flood control structures, waterway modifications, irrigation structures, mining, and pollution.

Vulnerability assessments have been carried out on the following aquatic plants:

- *Sesbania sesban*
- *Lepironia articulata*
- *Typha angustifolia*

3.3.1 VULNERABILITY ASSESSMENT FOR *SESBANIA SESBAN* – SESBAN FLOWER

Sesbania is a shrub belonging to the Fabaceae family. It is a short-lived shrub or small tree up to 8 m tall. Its leaves are pinnately compound, 2-18 cm long with 6-27 pairs of linear oblong leaflets (26 x 5 mm). The raceme has 2-20 flowers which are yellow with purple or brown streaks on the corolla. Pods are sub-cylindrical, straight, or slightly curved up to 30 cm long and 5 mm wide containing 10-50 seeds. Five varieties of *S. sesban* are recognized botanically but their differences do not correlate strongly with their agricultural value (J.M. Suttie, FAO website 2012).

The flower of *Sesbania* is a popular vegetable in the LMB. It can be eaten raw, added to soups, pickled, or used to make salads. In Vietnam, it is considered a specialty of the deeply flooded areas such as Long Xuyen Quadrangle and the Plain of Reeds. The flower is found at local markets during the flood season in the fresh water provinces in the Mekong Delta such as An Giang, Hau Giang, Can Tho, Dong Thap, Tien Giang, and Vinh Long Provinces during the flood season at a price around 2.5 USD/kg.

The stem of the plant is also used as green manure and a source of forage for animals. The roots of the plant also help improve soils because they contain nodules that help fix nitrogen. The plant also produces high woody biomass, popularly used as fuel wood in the rural areas in the Mekong Delta, though the wood is soft and quick burning. The flower is picked manually for home consumption and small trading in local markets. In the LMB, *Sesbania* is seen flowering during the early flood season from July to October.

SESBANIA ÆGYPTIACA:—PERS.—DC.—Miq.
—VAR.—BICOLOR:—Miq.

The species is widespread throughout South and Southeast Asia, most abundant in deeply seasonally inundated wetlands. Habitat of *Sesbania sesban* is being lost due to conversion of wetlands to agriculture. The distribution range probably remains the same though habitats may be declining.

S. sesban is assumed to be largely out-crossing, and interspecific hybridization is reported with *S. goetzei*; the carpenter bee is its main pollinator. Flowering starts shortly after the onset of the rains (in areas where there are two rainy seasons, it flowers and sets fruit twice). Pods are indehiscent and do not shed their seeds until well after pod maturity

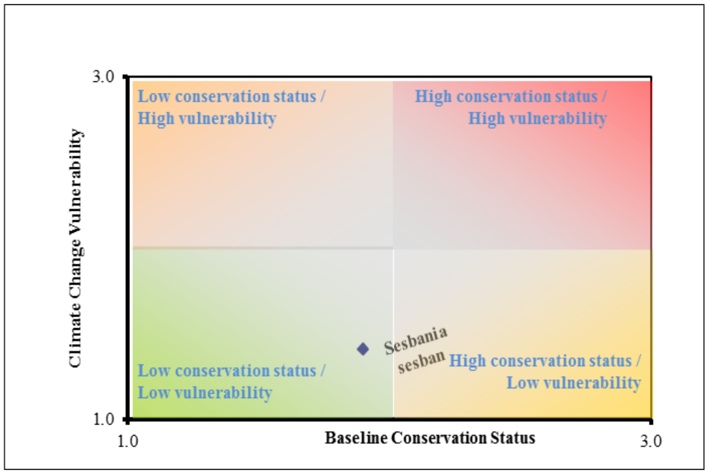
The plant grows in a wide range of soils from loose sand to heavy clay. It is native to monsoonal, semi-arid to sub-humid regions with annual rainfall ranging from 500-2000 mm. It grows best where periodic waterlogging or flooding is followed by progressively drier conditions. The plant does not require a large habitat: small clumps of Sesban occur in the wild in moist riverine areas and can be domesticated at edges of ponds and canals. The plant can disperse long distances by water: the ripe fruits and seeds are buoyant.

In terms of tolerance, it has outstanding ability to withstand waterlogging and is ideally suited to seasonally flooded environments. When flooded, it initiates floating adventitious roots and protects its stems, roots, and nodules with spongy aerenchyma tissue. It is common along streams, swamp banks, and moist and inundated bottomlands.

S. sesban shows some tolerance to moisture stress and tolerates soil alkalinity and salinity to a considerable degree. The plant is resilient to drought. Resprouting from the rootstocks can occur easily when moist conditions return.

S. sesban is not threatened by human use: flowers are harvested for food and stems are harvested for fuel wood of low value. *S. sesban* is attacked by nematodes, insects, fungi, and viruses. The leaf-eating beetle *Mesoplatys ochroptera* can completely defoliate *S. sesban*, leading to mortality. Caterpillars, Hymenoptera, and stem borers are normally associated with *S. sesban*. Some potentially destructive root-knot nematodes have been recorded in India as associated with *S. sesban.*

S. sesban is not protected and has not been assessed by IUCN Red List but is in the Catalogue of Life. It is considered to have a low conservation status.



Climate change

Exposure to temperature is not an issue for *S. sesban*. The plant temperature comfort zone is between 18°C to 23°C (min 10°C, max 45°C). For rainfall exposure, as a tree legume, the plant is found growing in a very wide range of rainfall environments. Sesban is less tolerant to drier environments. When soil moisture drops below 12.5%, 55% of leaves will fall. As the plant shows excellent tolerance for inundation conditions, exposure to flooding is not an issue. The change of timing of the onset of the rainy season is likely to affect the flowering of the plants as it flowers at the onset of the rainy season in June-July.

For extreme events, strong winds and storms will cause the stands to collapse but are unlikely to kill the plant. In terms of fire risk, in dry conditions the above-ground stems can be burnt but stands quickly recover when moist conditions return from seeds in the soils.

S. sesban has some good traits for adapting to adverse conditions:

- Water-impermeable seed coat enabling seed dormancy can help seed to wait out adverse conditions
- Provided there is flooded and moist areas, the plant will survive
- Populations are widespread; excellent tolerance of waterlogging conditions
- Individual plants live for 1.5 years with rapid establishment and early growth
- Seeds are carried long distances by water

It is considered that *Sesbania sesban* generally has a very low vulnerability to climate change because the species has wide ranges of tolerance for heat, inundation, and drought. However, under new climate conditions in the LMB, baseline stresses may increase for *S. sesban*. If other plants become stressed by temperature and decline, the additional pressure from human collection will increase. If climate change affects the Sesban pollinators, then pollination and fruit/seed setting may be reduced. In coastal areas, e.g., in Kien Giang, increases in soil salinity are likely to change the wetland habitats so that they are less suitable for *Sesbania*. In this province the climate change vulnerability is considered moderate.

Recommended adaptation

This species does not need any special adaptation measures. The only threat is the increasing conversion of wetland habitats to agriculture in the LMB.

3.3.2 ORIENTAL CATTAIL - *TYPHA ORIENTALIS*

Typha orientalis (synonym: *T. muelleri*; previous name: *T. augustifolia)* is a perennial aquatic plant found in marshes and on the edges of lakes with a rhizome that produces long strap-shaped basal leaves. It is widespread in Asia, found distributed in coastal to lowland habitats in fertile wetlands, on the margins of ponds, lakes, slow-flowing streams, and rivers. Less frequently, it is found on the margins of low moor bogs. Occasionally, it is found in muddy ground within industrial areas. In the Mekong Delta, *Typha* is found in freshwater and brackish-water wetlands in the coastal provinces of Soc Trang, Bac Lieu, and Ca Mau Provinces. Soil preferences are wide-ranging including sandy, loamy, and clay soils with acid, neutral, or alkaline soil pH.

Typha is a popular vegetable in the Mekong Delta. The tender base of the stem is used for making salad, adding to soup, or making pickles. *Typha orientalis* is an important chemical-free vegetable crop of economic value in the Mekong Delta. While it can still be found in the wild, it has been planted for commercial purposes. Harvested *Typha* can be sold as fresh or pickled. Farmers in Soc Trang, Bac Lieu, and Ca Mau Provinces raise fish in their *Typha* fields fetching an income of up to 2,500 USD/hectare/year. Pickled and fresh *Typh*a can be ordered from almost any restaurant in the Mekong Delta. In low-lying areas, *Typha* has proven to be a more economically competitive crop than rice. Fresh young *Typha* shoot is sold at around 1.5 USD/kg and pickled *Typha* fetches 2.0 USD/kg. *Typha* can be harvested every other month. Young shoots and tender bases of stems are harvested manually.

Typha also has important environmental values. It is part of the native wetland vegetation that provides habitat for fish, birds, and other aquatic animals. It also filters water and protects land from erosion. *Typha* is known as being able to remove arsenic in water and could be used to form inexpensive Arsenic filtration systems to clean up drinking water (Michael Graham Richard 2009). *Typha* provides important habitat for water birds.

T. orientalis flowers during the dry season from December to May. *Typha* requires wet and warm conditions to grow. The best growth occurs at 25°C. The plant is highly productive through sexual reproduction and rhizome propagation. Seedlings can flower after 6 months. Flowers of *Typha* are monoecious (individual flowers are either male or female; both sexes can be found on the same plant) and are wind-pollinated. Maximum above-ground growth occurs during the higher temperatures and long photoperiods whereas productivity of roots and rhizomes is highest during low temperatures and short photoperiods.

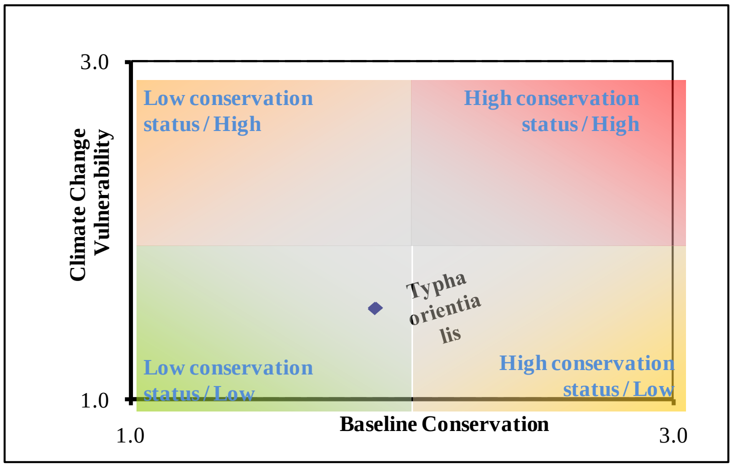
The plant does not require a lot of habitat as it can occur in small stands. It is highly tolerant to deep flooding and can tolerate drought in a single year

The plant in the wild is declining rapidly as habitat is becoming less available. However, as it has become a commercially important crop, it can be being planted by farmers. IUCN Red List rating is Least Concerned. Non-climate vulnerability is considered to be Low. The only current significant threat to *Typha* in the wild is loss of habitat due to conversion of land to agriculture and aquaculture. However, the plant is being domesticated due to high commercial demand.

Climate Change

Typha is among the first wetland plants to colonize areas newly exposed as wet mud, with its abundant wind-dispersed seeds. It can also survive in the soil for long periods with buried seeds. It geminates best with sunlight and fluctuating temperatures. It also spreads by rhizomes, forming large interconnected stands. Hence, it has three interlocking reproductive strategies: dominance in local habitats by clonal growth, survival of long adverse periods with buried seeds, and dispersal to new sites with win-dispersed seeds.

As noted above, *Typha* colonizes new areas by seeds. Many thousands of seeds are contained in a *Typha* inflorescence and can remain viable in the soil for several decades. *Typha* can also reproduce asexually via rhizomes that form new shoots. Rhizomatous growth is the primary form of reproduction used by *Typha* to overtake and dominate already vegetated areas.



In terms of genetic diversity, asexual rhizome reproduction results in low diversity within a stand but genetic diversity exists among stands due to sexual reproduction. After early settlement of *Typha* population, genetic diversity within the species decreases over time.

Owing to the well-developed aerenchyma, it is quite resistant to flooding. Even the dead stalks are capable of transmitting oxygen to the rooting zone.

Typha orientalis is considered to have a low vulnerability to climate change. However in coastal areas where soil salinity may increase with sea level rise, *Typha* is expected to have a moderate vulnerability.

Recommended adaptation

The analysis shows that *Typha* has a strong inherent adaptive capacity to climate changes. At present, the only threat to the plant is the loss of habitat due to land conversion to agriculture and aquaculture. The plant is also being planted by farmers (in the Mekong Delta in Vietnam).

Given the value and the multiple uses of the plant and even though it is being domesticated, it is suggested that populations of this plant should be conserved in the wild as a genetic source because genetic diversity of domesticated plants will be eroded over time through human selection.

Short term:

- Conduct inventories and map existing populations of *Typha*

Long-term

- Include *Typha* in new protected areas and/or reintroduce *Typha* to existing protected areas. However, as it is a strong wetland plant competitor that can out compete other native species, its expansion should be monitored and kept in check

3.3.3 GREY SEDGE (TUBE SEDGE) - *LEPIRONIA ARTICULATA*

Lepironia articulata, grey sedge, is a slender perennial rush belonging to the *Lepironia* genus under the sedge family (Cyperaceae). It is the only species worldwide in the genus *Lepironia.* The plant is a rhizomatous macrophyte that forms large dense swards of foliage with hollow cylindrical stems of 2-3cm in diameter with basal sheathing scales.

Lepironia propagates with seeds and rhizomes. *Lepironia* seeds germinate well although the germination rate is slow initially. It grows in open wet areas, from littoral areas to deep water, in swamps, ex-mining ponds, lakes, and ditches. It is typically grown in swamps with low pH (down to pH 3).

The culms can grow up to 3 m tall. A small seed head is borne at the top of the culms. The culms are used for weaving into a variety of handicrafts such as hats, bags, mats, hammocks, and decorative objects. The culms are cut manually and dried under the sun before weaving. The plant is also used extensively for planting in wetlands constructed for urban run-off management and for decorative ponds and lakes.

Handicraft making from *Lepironia* can be an important income-generating activity for local communities. A project in Phu My grassland area in Kien Giang Province, implemented by the International Crane Foundation, has proven that income from *Lepironia* is higher than rice cultivation per unit of land area.

Lepironia as a type of wetland vegetation also provides good habitat for fish, water birds, and other wetland fauna species. The natural wetlands in Phu My hold freshwater, especially during dry seasons, providing an important source of drinking water for the local community.

L. articulata is distributed in subtropical and tropical areas in Asia to the Pacific and seems to be restricted to coastal acid sulphate soil areas. It can grow from wetland margin and in water up to 5.5 meters deep.

It grows in full sun and partially shaded waterlogged marshes and swamps. It often occurs in non-saline acid sulphate soils. In the Mekong Delta, *Lepironia* is found in the seasonally inundated areas including Ha Tien grassland in Kien Giang Province, An Giang Province in the Long Xuyen Quadrangle, and Long An Province in the Plain of Reeds.

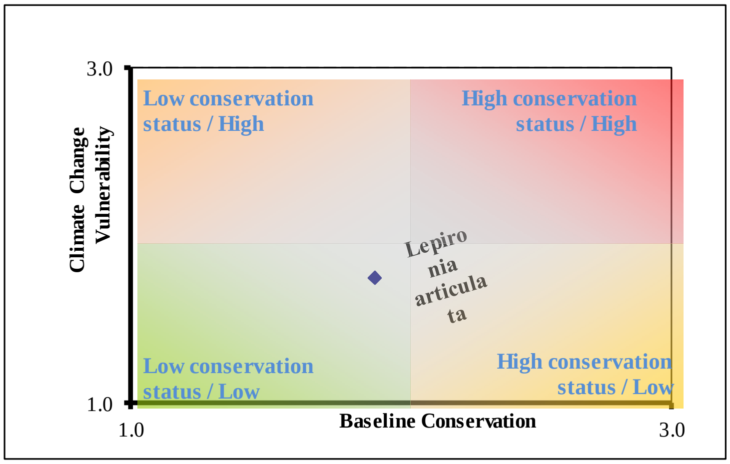
The distribution range remains the same but populations have declined rapidly due to conversion of natural wetlands to aquaculture and agriculture. *Lepironia* used to be distributed widely in the Plain of Reeds and Long Xuyen Quadrangle; at present about 1,000 hectares of *Lepironia* remains in Phu My grassland in Kien Luong District of Kien Giang Province and is the largest remaining area of *Lepironia*.

The IUCN Red List status is "Not Assessed" but *Lepironia* is in the Catalogue of Life. Its conservation status is considered to be moderate.

Climate change

Increase in temperature will cause water surface temperature to increase but this will likely not affect *L. articulata* as it grows in deep water. As a sedge, *L.articulata* is also tolerant to drought. Increase in projected depth and frequency of flooding is certainly not an issue for *L. articulata* as it is known to grow in depths up to 5.5 meters.

The drier dry season might lead to higher frequency of grassland wildfires. The above-ground stems might be burnt off but will regenerate quickly from rootstocks once moisture conditions return. The vegetative reproduction mode allows the plant to wait out adverse conditions.



In terms of habitat requirements, *L. articulata* has fairly specific requirements for habitat. It can grow well in acidic and nutrient poor soils but is unlikely to be able to compete with other species in non-acidic soils. The plant has low genetic diversity due to vegetative reproduction.

Although the rainfall and temperature climate changes will not likely affect *L.articulata*, in coastal areas where soil salinity may increase due to sea level rise in the future, *Lepironia* may have moderate vulnerability to climate change. It is expected that in the future the non-climate stresses will increase for *L.articulata* from (a) land use pressure for conversion to aquaculture and agriculture (b) invasion of alien species, *Mimosa pigra* in particular, and (c) increase in demand for handicraft making that might lead to overexploitation.

Recommended adaptation

L. articulata is a plant that can grow in harsh environments and is very resilient to climate changes. It has the potential to contribute to livelihood adaptation for local communities in coastal acidic areas. However, its continued existence is being threatened by baseline stresses that will increase in the future. Besides, the plant should also be conserved for its habitat and ecosystem services values (in providing freshwater to local communities in the dry season).

The plant does not need any specific measures to adapt to the new climate, but measures are needed to address current stresses that could be exacerbated under climate change. A successful project conducted by the International Crane Foundation is on the right track to tackle the current issues. The measures undertaken include:

- Advocacy to establish and strengthen the management of the Phu My Nature Reserve
- Organize sustainable use of the plant by local community members
- Improve marketing to increase profit margin of handicraft making
- Apply handicraft making and *Lepironia* harvesting techniques that use less raw materials and avoid damages to the plant to reduce pressure on resource harvest
- Environmental education

The measures together increase competitiveness of the option to maintain the natural grassland over other options such as conversion to aquaculture and agriculture. By providing viable alternative income from the wild plant and increasing value assigned to the biodiversity of the wetland ecosystem, conservation of species such as *L. articulata* is more feasible.

3.4 CLIMBERS

Both creepers and climbers are weak-stemmed plants and, hence, cannot grow erect without support. The difference is that creepers spread horizontally along the soil. At the nodal regions - where leaves grow - they produce fiber-like roots arising from the base of the stem, which get fixed and grow further. Climbers take the support of an object for climbing. Some climbers simply twine around certain supporting plants in a spiral manner; some of them produce hooks to climb, and some others produce special roots serving as holdfasts to climb. Climbers are a widespread plant type, associated with bush and shrub trees of various forest types, and grow well on various soil types.

Parts and extracts are used as food, dessert and beverage, medicine for the treatment of a wide range of diseases and symptoms, and fiber. Some climbers have high nutritive and medicinal values.

The climbing plants used for NTFPs that have been considered for this study include:

- *Cissampelos pareira*, which has great potential as a commercial hydrocolloid for the food industry. It is widely used and traded locally. It is harvestable in the wet season. It is widespread and associated with bush and shrub trees of various forest types. However, it is becoming rare and near extinct due to deforestation and habitat loss. There is no breeding or replanting of this species.
- *Coscinium fenestratum*
- *Fibraurea recisa*
- *Dioscorea hispida*

A vulnerability assessment has been carried out for *Dioscorea hispida.*

3.4.1 VULNERABILITY ASSESSMENT FOR ASIATIC BITTER YAM, *DIOSCOREA HISPIDA*

The bitter yam, *Dioscorea hispida,* is a perennial climber up to 2 m long with stems twining to the left, and with a system for fibrous roots, some of which develop into small round tubers. As these mature they stretch and can reach 30 cm in diameter and up to 35 kg in weight. It is widely distributed throughout the region with several varieties found in all four countries of the LMB. There are 12 – 15 other species of yam found in Indochina, of which *D. alata* and *D. bulbifera* are often cultivated.

Dioscorea hispida

D. hispida grows well on all soil types, but especially on moist clay loam, under shade and along the banks of streams in lowland evergreen and secondary forests up to 1,000 meters elevation, often in association with bamboo. It flowers in April/May and forms winged seeds, i.e., dispersed by wind, between June to December. When flowering and during seed formation, the plant is without leaves in the dry season. The wet season is the time of active growth when the leaves grow and the root tubers form. Root tubers are used to perennialize the plant, storing nutrients over periods when the plant cannot actively grow, e.g., in the dry season, thus permitting survival from one year to the next. It can be easily propagated from portions of tubers, planted at the beginning of the rainy season and harvested after 12 – 18 months.

The bitter yam is used almost exclusively as subsistence food, and will not be marketed outside of the locality, or exported. It is often harvested and eaten in times of rice deficit, i.e., it is an important food source for the poorest communities. The starch is used to make sweets that are eaten with sticky rice. However, in its raw form it is poisonous – an apple sized piece of raw tuber can paralyze the central nervous system and kill a man in six hours. It is also used as a medicine for skin diseases, irritations, and aching joints, and the extracted poison is used on arrowheads and for fishing.

The tubers are dug up easily when the long vines begin to shrivel. They are not deep and can be manually harvested with a fork. They may yield up to 20 tonnes per hectare. They are peeled and sliced and the slices soaked in salt water for 24 hours, during which time the water is changed several times. They are then placed under pressure, still in water for another 24 hours. This process is repeated eight times until the poison is removed.

Being widely distributed throughout the region and a hardy, generalist plant, and well adapted to over-year survival through tuber formation, it is not at risk. Its sustainability in Lao PDR, for example, is not considered a problem. The IUCN Red List has not assessed its conservation status. However, it is a forest species, and with the degradation and loss of habitat, its range may be becoming more restricted.

D. hispida grows well even under difficult conditions. In comparison to *D. esculenta*[15] it thrives at temperatures between 28 and 32°C but can survive in temperature ranges of between 17 – 45°C. It has a rainfall range of 800 – 2,000 mm per year, but can survive in an even wider range between 600 – 8,000 mm per year. Critical times of year are the flowering and fruiting period between March to May, and to a lesser extent during seed setting between June to December.

In terms of the Climate Study's hotspots, it is considered to occur in the lowland evergreen and secondary forests of Chiang Rai, Khammouan, Gia Lai and Mondulkiri. The most extreme climate change patterns are exhibited in Mondulkiri, but even here the predicted maximum daily temperature ranges (increasing by 3 – 5°C above current) still lie within the absolute range for *Dioscorea*. At the critical times of flowering the mean maximum temperatures may be as high as 37/38°C, but being a shade-loving, low-lying climber it is likely to be protected to some extent from extremes of temperature. The other hotspots do not exhibit these extremes and so temperature change is not considered critical.

In general, the precipitation patterns follow an increase in monthly rainfall during the wet season, and decreases in monthly rainfall during the dry season. Dioscorea is adapted to grow well in moist conditions by streams, putting on growth during the wet season. The additional rainfall and soil moisture in the wet season months should encourage growth and the development of tubers. During the dry season, the plant is more or less dormant, and relies upon its tubers to survive to the next wet season. Lower levels of rainfall and somewhat decreased soil moisture during the dry season are unlikely to threaten the survival of these plants.

As an understory, climbing plant in the forests, it is unlikely to be affected by storm events and strong winds, and the growth of tubers will enable it to survive forest fire. Though in these hotspot areas, there is often an increase in rainfall in April and May, which can counteract the risk of fire. It is a plant that likes high soil moisture, and growing along stream banks it can withstand a certain amount of flooding.

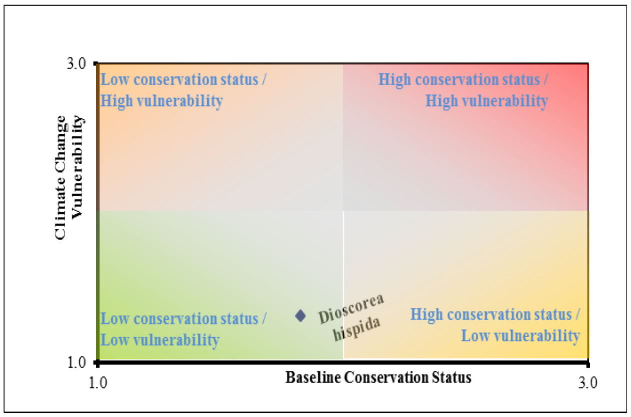
[15] FAO Ecocrop – www.ecocrop.fao.org

In all of the hotspot areas, it is considered that *Dioscorea hispida* has a very low vulnerability to the predicted climate changes. With increased temperatures and higher rainfall in its growing season it is likely to be more productive than currently. The main non-climate vulnerability is loss of forest habitat to all pressures listed for other species – illegal logging, deforestation, land conversion, etc. These may increase the non-climate vulnerability from low to moderate in specific areas.

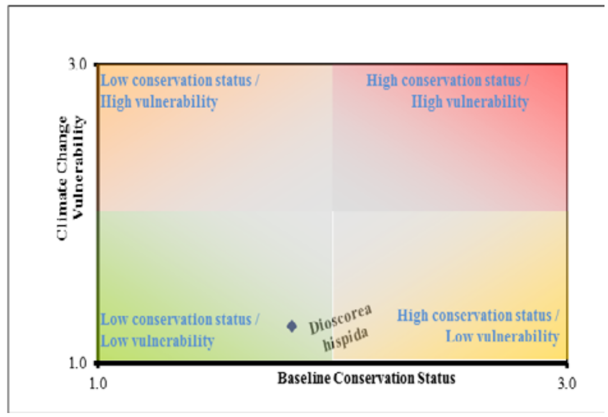
Recommended adaptation measures

Because of its low vulnerability to climate change, there are no particular adaptation recommendations for this species. However, general threats to forest habitat will require continued and improved protection and management to reduce the non-climate vulnerability related to habitat loss.

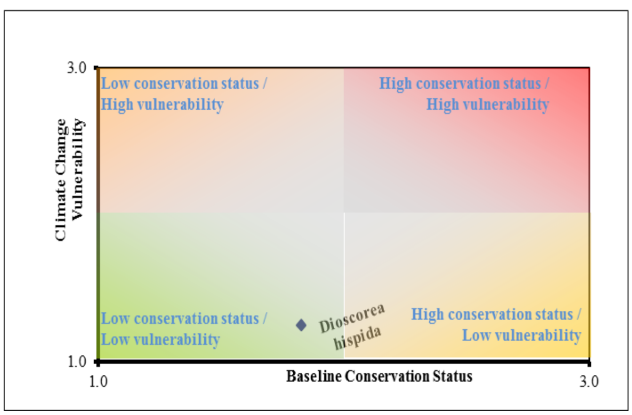
Mondulkiri



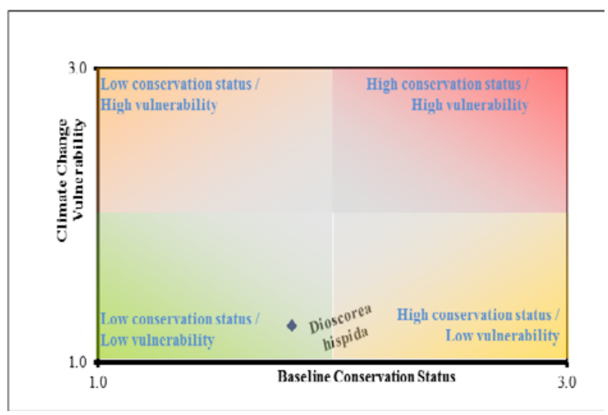
Gia Lai



Chiang Rai (west)



Khammouan



3.5 ORCHIDS

There is a wide range of wild orchids of this region, widely distributed in various forest types.

In the genus *Paphiopedilum* alone, there are about 70 species and more than 1,000 hybrids exist. These orchids are popularly known as Lady's Slippers. They are mostly terrestrial, moderately sized, and originate in the wild from the jungles of countries in Southeast Asia, e.g., Thailand, Cambodia, Vietnam, Myanmar, China, Malaysia, Indonesia, Philippines, as well as India, Bangladesh, and Nepal. These orchids are among the popular orchids in wild plant and cross-boundary trades with high market price.

Dendrobium is one of the biggest orchid genera, widely distributed in Asia and the Pacific, and has over 1,000 species. In Thailand, wild *Dendrobium* exists and is distributed across all regions. These orchids are very popular for home gardens and commercial cross-boundary trades.

Different orchid genera grow in different forest types. *Paphiopedilum* inhabits hill evergreen forest with slight shade and naturally grows on humus layers on forest floor or between rocks with dead leaf, grass, and organic matter deposits, or on tree trunks. It grows well in open forests with cool climate and light penetration. *Dendrobium* grows in dry evergreen, mixed deciduous, open forest and prefers sunlight during the cool season.

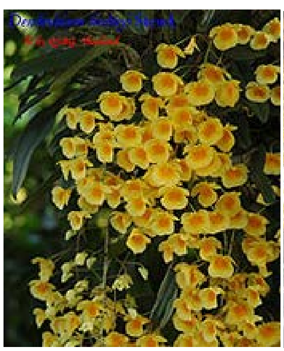
Many wild orchids are endemic, rare, and endangered. Some are symbolic flowers of specific provinces and localities. They are gathered throughout the year and popularly used as ornamental plants having high market values. *Paphiopedilum hirsutissimum* is sold in the market at 10 USD/bunch or 20 USD/kg. *Dendrobium aggregatum* or *Dendrobium lindleyi* is sold in the market at 0.5 – 2 USD/plant without flower and 5 – 15 USD/plant with flowers.

Wild orchids are under threats including deforestation, habitat loss, over-harvesting, wild orchid trading, and cross-boundary trades. Wild populations still remain, but are becoming rare. Cultivation at the commercial scale is currently possible and wild orchids are highly demanded for cross-breeding. The orchid species considered for this study are:

- *Dendrobium* spp.
- *Dendrobium aggregatum or D.lindleyi*
- *Paphiopedilum hirsutissimum or P.esquirolei*

A vulnerability assessment has been carried out on *Dendrobium lindleyi* as an example.

3.5.1 VULNERABILITY ASSESSMENT FOR *DENDROBIUM LINDLEYI* - WILD ORCHID



Dendrobium lindleyi is a native wild orchid of Indochina, found in all LMB countries. It is semi-epiphytic with a stem height between 3 and 10 cm. It has small yellow flowers of 3 cm diameter and is capable of producing relatively large sprays of up to 20 flowers. Its flowering period is very short, only 4 – 5 days to a week in summer or during February – May. If flowers are covered with water, they will last only 2 – 3 days. Full sunlight plus cool climate produces more flowers, which are more beautiful.

Dendrobium lindleyi grows in an elevation range between 300 – 1,500 m asl, attaching to big trees or on high branches in dry evergreen, mixed deciduous, and open forests. It can live in temperatures ranging from 7 – 32˚C and rainfall ranging from 965 – 1,550 mm/yr. It prefers large amounts of water in summer along with warm temperatures and moderately bright light. During the cool season, it prefers sunlight and just enough water.

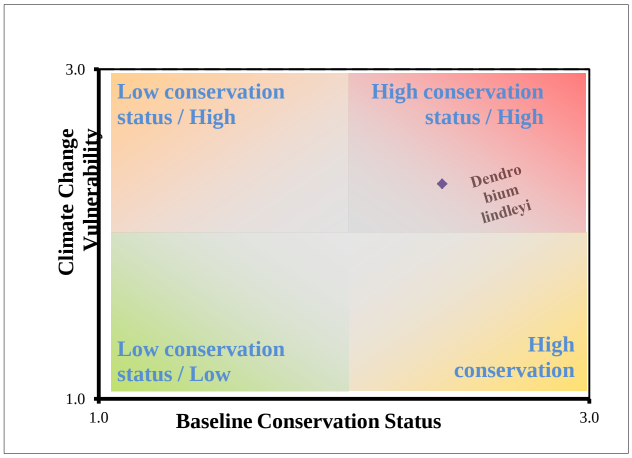
It can be cultivated from seeds with better growth rates than in the wild. *Dendrobium lindleyi* is gathered throughout the year and is very popularly used as high value ornamental plants, for home gardens and commercial cross-boundary trades. It has high market value, sold in the market at 0.5 – 2 USD/plant without flower, 8 – 10 USD/hanging pot, and 5 – 15 USD/plant with flowers. Cultivation at commercial scale is currently possible. Wild populations are highly demanded for cross-breeding and have high potential in the perfume industry.

Threats facing *Dendrobium lindleyi* include deforestation, habitat loss, over-harvesting, wild orchid trading, and cross-boundary trades. The increasing demand and high market prices will add to the pressure. The wild population still remains, but is decreasing and becoming rare. IUCN Red List status is 'Not Evaluated'. In the provinces under consideration, the **non-climate vulnerability is expected to be increased from High to Very High** due to pressures and losses of habitat from land concessions and changes of land use in Protected Areas and forest areas; as well as from the conversion of degraded forest to rubber plantations (Gia Lai) and from infrastructure and other economic developments and tourism (Chiang Mai and Khammouan).

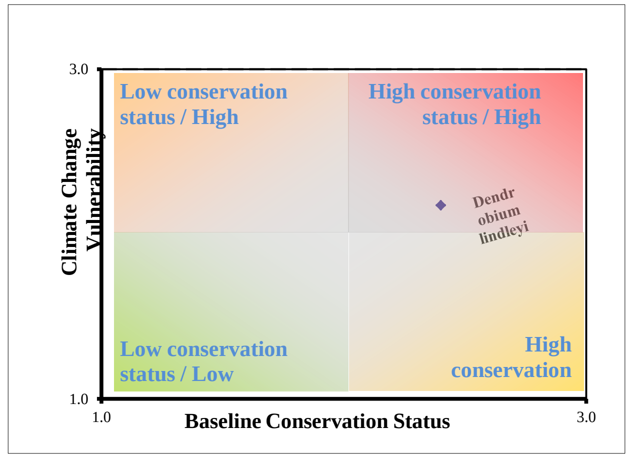
In Mondulkiri and Khammouan, future increase in temperature and decrease in dry season rainfall will affect the growth of *Dendrobium lindleyi* and will increase wild fire risk. Chiang Rai and Gia Lai will have less risk of wild fire and increase in dry season rainfall may enhance its growth. In all four evaluated hotspots, bigger and more frequent storms, and increase in rainfall and high winds will directly affect this wild orchid as it grows on high canopy. In addition, future increase in temperature during the early flowering period will reduce the number of flowers produced; and increase in rainfall, storms, and high winds during the flowering period will make flowers last for a shorter period. Wild orchids have specialized insect pollination systems. Shifts of their pollinators due to future increase in temperature will also affect their populations.

Growth and reproduction will be stressed by the future new climate, which will shift beyond the comfort zone of *Dendrobium lindleyi*. As a semi-epiphyte attached to big trees on high canopy, it has no higher places to which it is able to migrate. *Dendrobium lindleyi* in Mondulkiri and Khammouan will have high vulnerability to future climate change. *Dendrobium lindleyi* in Chiang Rai and Gia Lai will have moderate vulnerability.

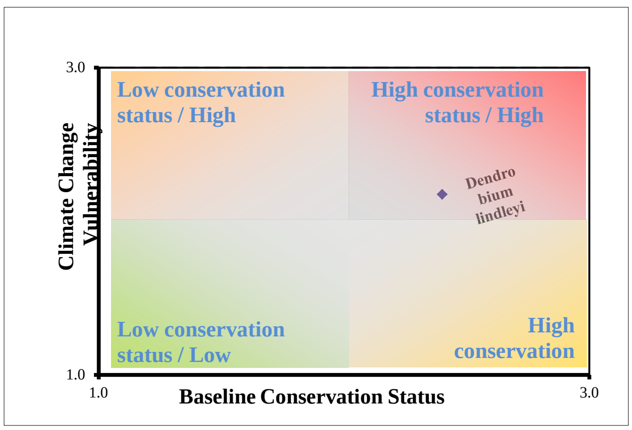
Mondulkiri



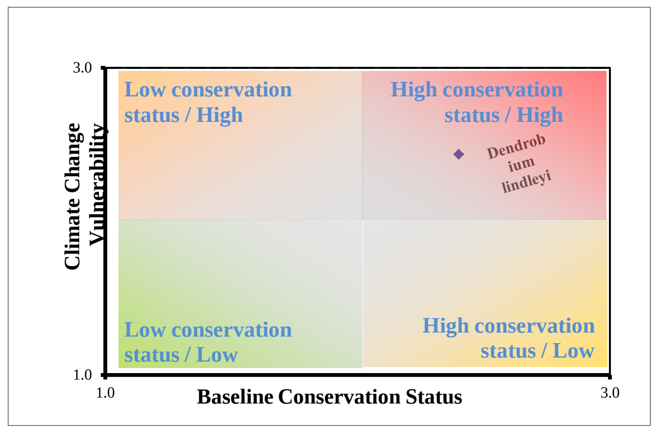
Gia Lai



Chiang Rai (west)



Khammouan



Recommended adaptation measures

Short term

- Better conserve and safeguard the existing wild population in protected areas, promote and enhance in-situ conservation
- Increase the effectiveness of 'Protected Area Systems' and the management of existing protected areas in order to reduce deforestation, commercial and illegal logging, encroachment, forest fires, land use change, and habitat deterioration and loss
- Encourage and support the attempt and effort of local communities to achieve 'sustainable conservation' of *Dendrobium lindleyi*
- Strictly control and properly manage wild orchid trading and cross-boundary trading

Medium term

- Increase 'Protected Forests' in order to maintain the habitats and to safeguard the existing wild population
- Increase and support reforestation and afforestation programs/projects/activities
- Restore and rehabilitate deteriorated forests. Increase forest canopies and crown covers in order to provide more habitats for *Dendrobium lindleyi* (as well as other wild orchids)
- Build 'check dams' to maintain and increase soil moisture availability within the forests, especially during dry season months, and to reduce wild fire risk
- Consider and take actions to put wild *Dendrobium lindleyi* on the protected plant list

Long-term

- Support efforts for ex-situ cultivation and trading in order to reduce pressure and demand on wild populations

3.6 BAMBOOS AND RATTANS

In the LMB countries, there is a wide range of bamboo and rattan varieties. In Lao PDR there are over 32 species of rattan identified. Cane production is entirely taken from wild stocks. Commercial species include large diameter species, e.g., *Calamus poilanei*; medium-large species, e.g., *C. platyacanthus*; and small diameter species, e.g., *C. palustris, C. gracilis*, and *C. tetradactylus*. Two broad forest types encompass the main commercial production for *Calamus* spp., which are evergreen or semi-evergreen lowland forests dominated by dipterocarps and evergreen forests dominated by Fagaceae and Lauraceae. Total forest area suitable for rattans estimated of well-stocked closed canopy forest at about 22,000 sq km in 1999 within the LMB.

Bamboos and rattans prefer high humidity, but they are also drought-tolerant, and have very few pests. New shoots germinate all year round. Young seedlings cannot withstand severe floods.

Bamboos and rattans are available and harvestable all year round. Parts such as young shoots, young leaves, barks, fruits, bulbs, stems, canes, and fibers, as well as the whole plants and clumps are widely used. They offer a wide range of uses including food, medicine, firewood, household utensils, handicrafts-making, fine weaving, rope, furniture, fences, construction, toys, musical instruments, paper, fibers, sources of wood products of economic value, popular ornamental plants, and sources of supplementary occupation and income for local households. At least 60 – 100 USD/month can be earned from bamboo/rattan-based handicrafts-making. The entire plants and clumps are of high conservation value for agroforestry, stabilization of eroding banks, erosion control, and windbreaks.

Bamboos and rattans are threatened by deforestation, habitat loss, over-harvesting, forest fires, and severe floods. The large, single-stemmed species such as *C. poilanei* is very heavily harvested and declining throughout Lao PDR.

The bamboos and rattans considered for this study include:

- *Bambusa arundinacea*
- *Bambusa tulda*
- *Calamus caesius*

- *Dendrocalamus latifolius*
- *Dendrocalamus lonofimbriatus*
- *Indosasa sinica*

Calamus caesius is used for the vulnerability assessment.

3.6.1 VULNERABILITY ASSESSMENT FOR *CALAMUS CAESIUS* - RATTAN

Calamus caesius is a perennial, evergreen, multi-stem or clustering, moderate-size, high-climbing rattan of the Palmae family with canes reaching a length of 100 m. The clump is often close and dense. It has a long life > 10 years, is drought-tolerant, and has very few pests. New shoots germinate all year round. Stems are strong, durable, and flexible. It has lots of roots and is able to find water and food. Its fruiting period is November – March.

Calamus caesius is found between 20˚N – 20˚S latitude range and up to 800 m elevation range and can be found in all LMB countries. Habitats include natural dense and moist forests, moist evergreen and dry evergreen forests, and lowlands on alluvial flats, riverbanks, freshwater swamp forests, or at the margins of peat swamp forests, but also drier sites.

It prefers organic soils of medium depth (50 – 150 cm) with poor drainage (saturated > 50% of year) and high humidity. It is also drought-tolerant and has very few pests. Young seedlings cannot withstand severe floods. Absolute temperature range is 16 - 34°C, while optimal range is 23 - 30°C. Absolute rainfall range is 1,700 – 4,200 mm/yr, while optimal range is 2,500 – 3,200 mm/yr.

Calamus caesius is a high quality rattan, and a new promising economic crop of interest. It is harvestable all year round at the age of 10 – 14 months. New young shoots are cut for foods. At the age of 6 – 7 years, the first harvest can be used for handicrafts making until 15 years when it reaches its full production. As described above for bamboos and rattans in general, multiple parts of the plant as well as the whole plant can be used for a variety of uses. These uses include food, medicine, firewood, household utensils, handicrafts-making, fine weaving, rope, cordage, construction, furniture, fences, toys, musical instruments, paper, fiber, a source of wood products of economic value, and supplementary occupation and income for local households. It also has become popular as an ornamental plant. The entire plant and clumps are of high conservation value for agroforestry, stabilization of eroding banks, erosion control, and windbreaks.

Calamus caesius is threatened by deforestation, habitat loss, over-harvesting, forest fires, and severe floods. Increasing demand and high market prices add to the pressure from overharvesting. It is near extinction, but IUCN Red List status is 'Not Evaluated'. Protection and conservation is needed. Pressure on wild populations may be reduced, for example, by successful cultivation for canned rattan shoots for exports. In the hotspot provinces, the existing pressures on the habitats of *Calamus caesius* from illegal logging, land conversion to rubber and other crops, and development of infrastructure such as roads and hydropower result in **a non-climate vulnerability of high or very high**. It has no protection status and the habitats in the Protected Areas generally have weak management.

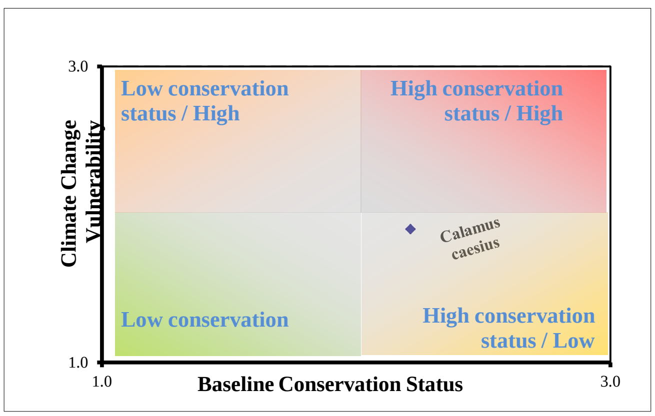
In all four of the evaluated hotspots (Mondulkiri, Chiang Rai, Gia Lai, and Khammouan), future increase in temperature slightly beyond the comfort zone for this species, as well as decrease in dry season rainfall especially during the fruiting period, and increase in wild fire risk will be key climate change threats to *Calamus caesius*. Increase in wet season rainfall, bigger storms, and high winds will affect its young seedlings, which cannot withstand severe floods. In all four hotspots, *Calamus caesius* will be moderately vulnerable to future climate change.

Recommended adaptation measures

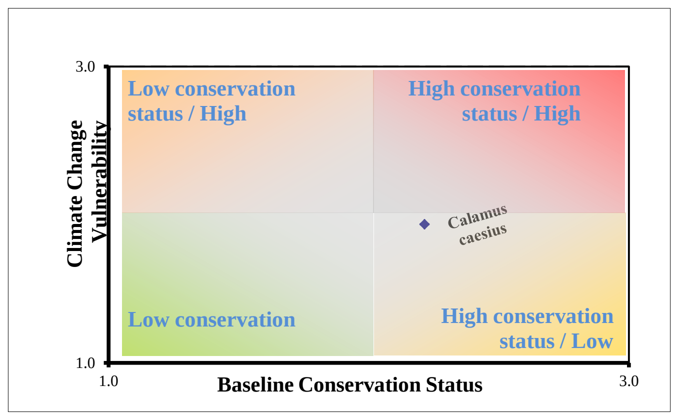
Short term

- Build 'check dams' to maintain and increase soil moisture availability within the forests, especially during dry season months, and to reduce severe floods
- Encourage and support the attempt and effort of local communities to achieve 'sustainable harvest' and to develop 'sustainable harvesting systems' of rattan and avoid over-exploitation

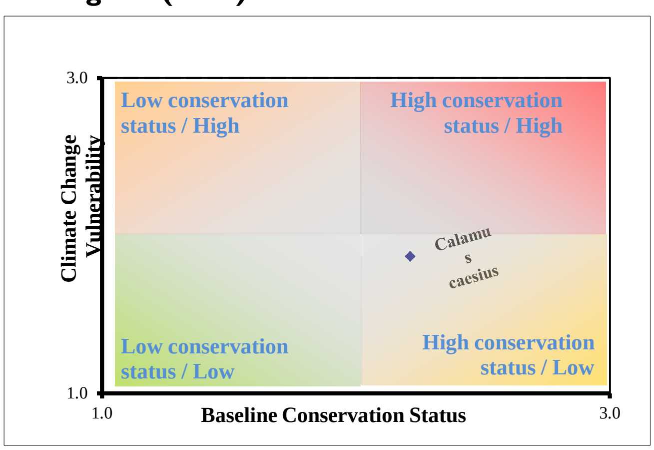
Mondulkiri



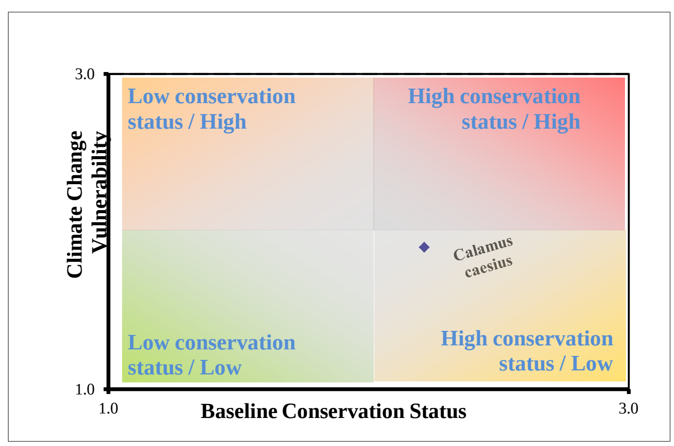
Gia Lai



Chiang Rai (west)



Khammouan



Medium term

- Better conserve and safeguard the existing stands in protected areas, promote and enhance in-situ conservation
- Increase the effectiveness of 'Protected Area Systems' and the management of existing protected areas in order to reduce deforestation, commercial and illegal logging, encroachment, forest fires, land use change, habitat deterioration and loss

Long term

- Establish the 'buffer zone' in order to allow natural shift of forest distribution under future climate change
- Support rattan cultivation/plantations for ex-situ conservation and commercial uses in order to reduce demand and pressure on wild populations

3.7 SHRUBS

The term shrub is used to describe the particular physical structural or plant life-form of woody plants that are less than 8 meters high and usually have many stems arising at or near the base. They are found on many soil types and habitats of primary /secondary forests, ricefields, and home gardens. Alternate wet and dry weather enhances the flowering period. They generally do not prefer waterlogged areas, but are adaptable to drought.

Various parts and extracts including stems, barks, young leaves, shoots, flower buds, nectar, and gum are widely used for many purposes such as food, vegetable, beverage, forage for animals, medicine, dyes, firewood, and construction. Some have high market price compared to other vegetables due to their specific seasonal availability. Products are seasonally gathered for domestic consumption and for sale. Availability and abundance of harvestable products is highest during the rainy season or after heavy rain.

Threats include deforestation and over-harvesting. Some shrubs are difficult to cultivate, others have been cultivated with success such as paper mulberry.

The shrubs used to illustrate this study are:

- *Broussonetia papyrifera*
- *Cratoxylum formosum*
- *Meliantha suavis*

The vulnerability assessment has been carried out for paper mulberry, *Broussonetia papyrifera*.

3.7.1 VULNERABILITY ASSESSMENT FOR PAPER MULBERRY, *BROUSSONETIA PAPYRIFERA*

Broussonetia papyrifera

Paper mulberry is a shrub/small tree which is widely distributed throughout Southeast Asia from Indonesia through to China and India. It is common in all four countries of the LMB. It is a deciduous shrub, 3 – 9 m tall with a broad spreading crown. Its leaves vary in shape from being deeply lobed in younger trees to egg-shaped with jagged edges in older trees. The young green branches are covered with hair, but the bark on older branches is brown and fibrous. The older branches are weak and vulnerable to wind damage. *B. papyrifera* is dioecious, i.e., male and female flowers are carried on different trees; the male flowers are yellow-white catkins, while the female flowers are ball-shaped heads about 1.2 – 1.8 diameter in size. Flowering occurs in May/June. The flowers are pollinated by wind and insects. The fruits, which ripen in October to December, are juicy, round and orange with purple hair, 1-3 cm in diameter and contain many dark red seeds. The seeds are dispersed by fruit-eating birds, bats, and other animals.

B. papyrifera is a plant that grows naturally in thickets, mountain ravines, and especially on sunny edges of woodland and forests. It is both water and light demanding and is a good pioneer species, spreading rapidly after clearance of both evergreen and deciduous forests, mixing naturally with bamboo, e.g., after slash and burn cultivation.

The principal use for paper mulberry is the production of paper from the bark. Branches are harvested after the leaves have fallen during the dry season, they are steamed, and the fibers stripped off. The color of the paper varies depending on whether outer and inner barks are used together or separately. In Lao PDR, for example, stems 6 – 24 months old are cut at about 10 – 40 cm above the ground to ensure resprouting, and they may be stripped of bark before cutting. The black outer bark is removed and yellow-white bark is cleaned and dried in the sun, and then boiled in water. The boiled bark is pounded into pulp by hand and cleaned in water, spread on mosquito wire sheets, framed, and dried in the sun. The sheets of paper are removed when dry and polished with a stone.

Other parts of the plant are also used. The fruit, leaves, and roots are used medicinally (as a laxative and diuretic, and in the treatment of dysentery) and the leaves also provide fodder for pigs and cattle. The fruit can be consumed but is said to weaken the bones if eaten over a long period. As a medicinal herb, a 100g pack of extract fetched 7.3 USD on the Chinese market in 2005.

The importance and value of paper mulberry is as an export both as the raw bark to Thailand and as finished product to Thailand, China, Japan, and Korea. The exports of bark to Thailand and China reached 2,000 tonnes from Lao PDR in 2005, and one factory in northern Lao PDR produced 400 tonnes of paper product for export (80% to Thailand, 10% to China, and 10% to South Korea). The export price of grade A bark was 0.92 USD/kg and grade B 0.80 USD/kg at a factory in Thailand. The economic yield of paper mulberry per hectare is higher than rice, but lower than maize.

Most commonly, paper mulberry is planted along edges of fields and has been used as a regeneration species after slash and burn cultivation on flat or sloping land. It has also been cultivated as a flood crop along the Mekong River banks, e.g., in Xayaboury Province in Lao PDR. Cultivation is easy both from the seeds, but most usually from resprouting of the rootstock and coppicing. It is adapted to grow in most soils, but grows particularly well in moist alluvial soils. It is often intercropped with fruit trees and other tree species such as teak and kapok. Wild plants tend to give poorer quality bark, but are becoming rare due to loss of habitat. It is not a protected species and has not been assessed on the IUCN Red List.

According to the FAO Ecocrop database, its optimal temperature range lies between 15 – 28°C, and its absolute range lies between 12 – 38°C. Its optimal rainfall range lies between 800 – 2,500 mm per year and absolute range between 500 – 3,000 mm per year. It is reported to be tolerant to drought and atmospheric pollution. It grows up to 2,000 m above sea level, though most commonly between 500 – 800 masl.

As with other species in the hotspot provinces, the natural habitats for *Broussonetia papyrifera* are under threat from a variety of different pressures such as illegal logging, land conversion to rubber plantations and other crops, land concessions in protected areas, and infrastructure development. **The non-climate vulnerability is expected to be increased from Low to Moderate** in these areas.

The key climate change threat is increase in temperature. This is especially acute in Mondulkiri, where the increases in maximum daily temperature could push above the threshold tolerance of 38°C and make *B. papyrifera* highly vulnerable. The increased temperature during the flowering period of May/June (mean maximum over 36°C) is especially concerning. In Mondulkiri, the higher temperatures are combined with decreases in the amount of monthly precipitation in the dry season months, leading to significantly lower soil moisture content at this critical time of year. In the fruiting season (October-December), the temperature falls and rainfall increases, and is considered to be less critical.

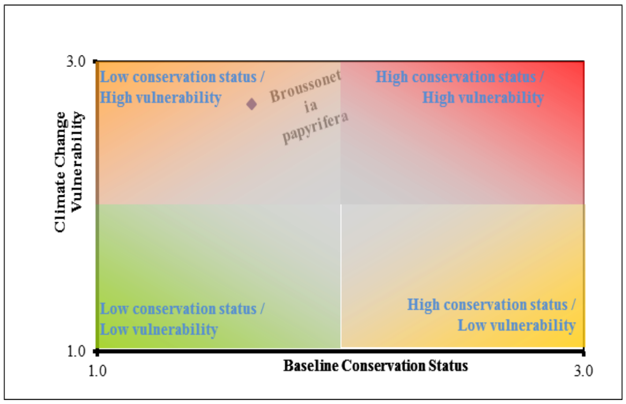
In the other hotspot areas of Chiang Mai and Khammouan, the temperature thresholds at the critical flowering period are not likely to be reached, and rainfall and soil moisture changes are not likely to be critical. However, in Gia Lai, the temperatures may reach the threshold and while not necessarily critical, there may be shifts towards earlier flowering and fruiting (with higher temperatures and rainfall) and there may be gradual movement of plants up the slope of hills to cooler areas.

Rainfall generally throughout the hotspot areas shows an increase over the whole year, with some decreases in the dry season, but not as marked as in Mondulkiri. In Khammouan, annual rainfall increases to just under the absolute maximum annual rainfall (3,000 mm/yr) that is suitable for *B.papyrifera* so it is possible that in this hotspot area the plants would be more vulnerable. Generally as a species that can tolerate drought, and also thrives in wet alluvial soils that may be subject to flooding, *B.papyrifera* may be considered as a relatively hardy species. However, its branches tend to be susceptible to wind damage and the increase in the number of storms especially in Mondulkiri, Khammouan, and Gia Lai may be a further limitation on exposed plants.

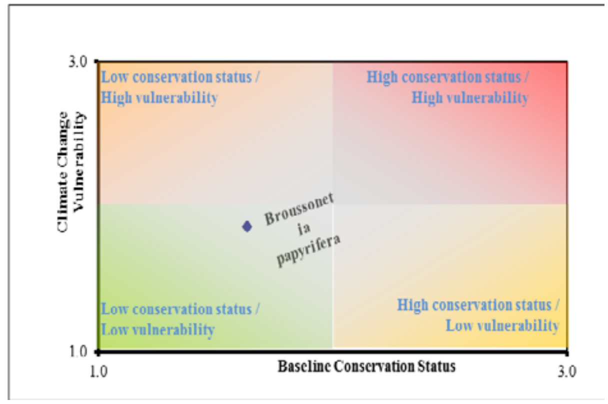
B.papyrifera is not dependent upon the forest cover for survival nor does it require an association with other plant species that might be more affected by climate change. Pollination is by insects and wind and dispersal of seeds by fruit-eating birds and bats. It is susceptible to attack by some insects notably the cotton bollworm, but the effect of climate change on these other factors is uncertain.

In Mondulkiri, *B.papyrifera* is considered to be highly vulnerable, while in Gia Lai it may be considered to be moderately vulnerable, and in Khammouan and Chiang Rai it has low vulnerability. In Mondulkiri, it could be expected to die out gradually in the lower elevations (which are hotter) and to maintain itself or shift upwards to higher elevations where temperatures may be less extreme. In the other hotspot areas, *B. papyrifera* may be expected to survive, though flowering and fruiting may occur earlier in the season due to increases in temperature and higher rainfall at these times of year.

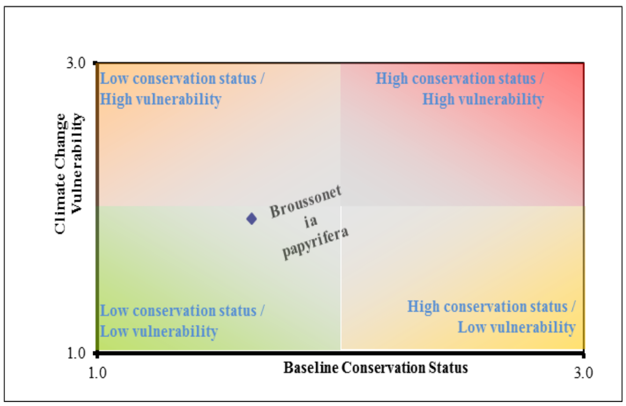
Mondulkiri



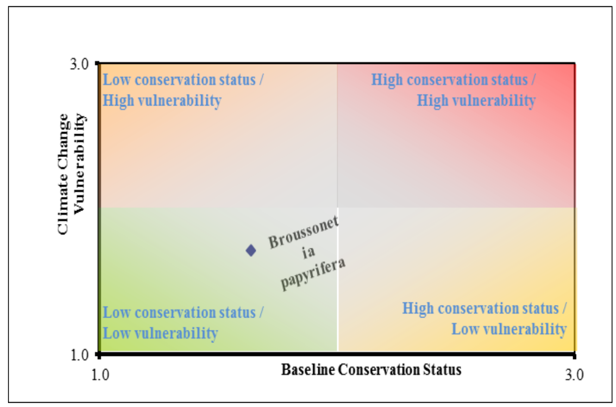
Gia Lai



Chiang Rai



Khammouan



Recommended adaptation measures

Short term

- In Mondulkiri and Gia Lai, where there appears to be increased vulnerability, monitor individuals for signs of increased heat stress and lack of water during flowering
- Protect exposed plants from strong winds where possible
- In Khammouan and Chiang Rai, where *B. papyrifera* appears to be less vulnerable, no specific actions

Medium Term

- Generally protect forest habitat to ensure survival of wild plants
- Identify individual plants in Mondulkiri that appear to have resilient traits against increased temperatures and water stress, and take root stocks/seeds to develop in nurseries
- Select favorable locations, e.g., where ground water is likely to remain available and use these areas for cultivation

Long Term

- In Mondulkiri where the threat to *B. papyrifera* is highest, consider replanting at higher elevations, with more resilient stock, or accept that this plant may disappear.

- In other locations, monitor the effects of increasing temperature on the productivity and survival of the plants

3.8 TREES

Trees are the climax vegetation of the forest, and in the forests of the LMB are the defining characteristic of the different types of forest. The main forest types found in the basin include evergreen, mixed deciduous, and dry dipterocarp. These different forest types have developed depending on ecological factors such as elevation, rainfall, soil type, and soil moisture. Some, especially at young stages, are sensitive to fires and high winds.

Quite apart from the timber which can be extremely valuable, various parts of the trees and extracts including stems, barks, branches, leaves, oil, latex, and resin are widely used for such purposes as construction, housing materials, furniture, firewood, paper pulp, and extracts, e.g., resin, latex, gum, oil, medicine, and aromatic materials.

The forest trees have high conservation value, and the mix of forest species defines the forest structure, and the understory vegetation that develops underneath it. This structure and particular mix of vegetation provides the basis for the variety of habitats and food required by wildlife species.

The availability of NTFPs from trees is variable throughout the year. Flowering often occurs late in the dry season just before the start of the wet season with fruiting occurring later on in the year. Sometimes fruiting and collection of seeds is variable depending upon the year, with large crops one year followed by lower crops in subsequent years, e.g., the Malva nuts "mast" years from *Scaphium macropodum.*

The threats faced by forest trees include over-harvesting, deforestation, forest fires, illegal logging, and land use changes for agriculture and plantations leading to overall habitat losses.

The following NTFP trees have considered for this study including:

- *Aquilaria crasna*
- *Arenga westerhouttii*
- *Baccaurea ramiflora*
- *Dipterocarpus alatus*
- *Markhamia stipulata*
- *Scaphium macropodum*
- *Shorea obtuse*
- *Sonneratia* spp.
- *Styrax tonkinensis and S. benzoides*

Two tree species have been considered for Vulnerability assessment – *Dipterocarpus alatus* and the mangrove species, *Sonneratia* spp.

3.8.1 VULNERABILITY ASSESSMENT FOR *DIPTEROCARPUS ALATUS*

Dipterocarpus alatus (Lao PDR: mai yang, Thailand: yang-na, Vietnam: dau nooc) of Dipterocarpaceae family, is a large perennial single tree up to 55 m and diameter up to 5 m.

Dipterocarpus alatus is indigenous to all the LMB countries and is widely distributed throughout the region at elevation range up to 800 m asl in dry evergreen, dry dipterocarp, lower moist evergreen, and evergreen or semi-evergreen forests. Its habitats are along the banks of large rivers and streams, the bottom of ridges, in valleys, moist and swampy areas, and floodplains.

Temperature, rainfall, and soil moisture have effects on its growth. It does not withstand very low temperatures but can grow in areas with as high a temperature as 45˚C. It can grow in a wide rainfall range, from 1,500 to 5,200 mm/yr. Its germination rate is low if moisture in the seeds is < 30%. It is found on alluvial soils with high-moderate fertility. It prefers good drainage and does not grow in water-logged areas. Seeds are distributed by water flow and wind. At its young stage, seedlings are sensitive to fires and high winds. Its flowering period is between January – May and its fruiting period is between April – June. Its bark is thin and does not withstand fire and once burnt, seedlings and saplings hardly recover.

Various parts and extracts of *Dipterocarpus alatus* including stems, barks, branches, leaves, oil, latex, gum, and resin are available and abundant all year round, and widely used by local households and for sale. They provide a wide range of uses includes construction, housing materials, furniture, paper pulp, boat caulking, boat varnishing, waterproofing paper and bamboo basket coating, torch making, charcoal, firewood, medicine, and aromatic materials. Fallen twigs and branches are used for stimulating appetite of livestock. *Dipterocarpus alatus* is a valuable source of timber of commerce and wood products with high market price. The species has high potential in agroforestry and soil improvement, and provides habitat and food for wildlife.

Dipterocarpus alatus is facing threats including over-harvesting, deforestation, improper tapping techniques and hole maintenance during and after oil and resin extract, forest fires, illegal and commercial logging, and habitat loss due to encroachment and land use change. Natural enemies are longhorn beetles that attack living trees under extreme drought conditions and insect pests which destroy the seeds and reduce seedlings and growth.

In the hotspot provinces under consideration, loss of habitat due to various factors represents one of the main threats to *Dipterocarpus alatus,* so that its **non-climate vulnerability ranges from High to Very High in these areas**. Pressures include loss of habitat due to illegal logging, conversion of forest habitats to rubber and other crops, and infrastructure development. Protected areas are under threat from concessions, e.g., in Mondulkiri, and protection and management of habitats in protected areas is often weak.

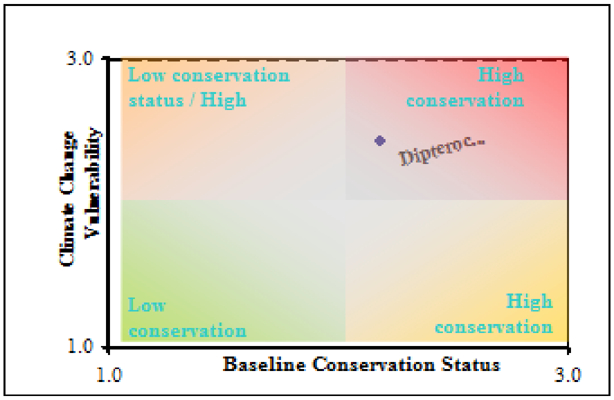
Dipterocarpus alatus has very high conservation values. Its IUCN Red List status is 'Endangered'. In Thailand, most stands are limited to protected areas and in-situ conservation programs were initiated in 1999. Future increase of temperature range from the baseline will occur in all hotspots. Although the projected temperatures will still fall within the absolute range for this species to survive, they will be higher than what is optimal. For example, despite its ability to grow in areas with high temperatures up to 45°C, the increase in future temperature during the flowering and fruiting periods will have negative effects on *Dipterocarpus alatus*. Seedlings and seeds will also be more vulnerable to higher temperatures and droughts. Especially, Mondulkiri will have higher risk of drought, and as a result the growth and germination rate of *Dipterocarpus alatus* will be lower. Full growth trees will be attacked more by longhorn beetles during extreme droughts. Future increase in temperature and drought in Mondulkiri as well as Khammouan will increase risk of forest fires, which kill seedlings, saplings, and seeds. Once burnt, they can hardly recover. Less rainfall during the dry season months in Khammouan will also affect flowering. Chiang Rai will have less future risk of drought and growth and germination rate of *Dipterocarpus alatus* may be enhanced. Gia Lai will have no change in drought patterns. However, slight shift upwards of rainfall above the comfort zone for this species in Gia Lai and Chiang Rai will affect seedlings, which cannot grow in water-logged areas.

Heavy rains and high winds will be major issues in all hotspots, because seedlings of *Dipterocarpus alatus* are sensitive to high winds. With higher demand for oleo-resin, which results in improper tapping techniques and lack of hole maintenance, full growth trees will be more vulnerable to bigger and more frequent storms. Trees, saplings, and seedlings can be knocked down.

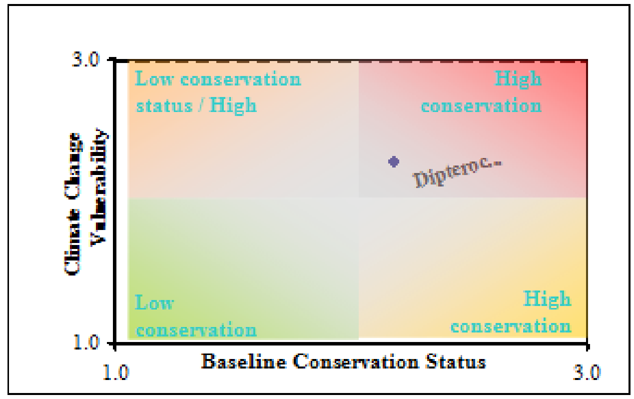
Although *Dipterocarpus alatus* flowers and fruits every year and has seed dispersal mechanisms, the full growth trees prefer alluvial soils and their distribution is limited to 800 m asl. They may not be able to move up to higher elevation to take advantage of more suitable climatic conditions.

In three of the hotspots evaluated, Mondulkiri, Chiang Rai and Khammoun, *Dipterocarpus alatus* will be highly vulnerable to future climate change. *Dipterocarpus alatus* in Gia Lai will be moderately vulnerable.

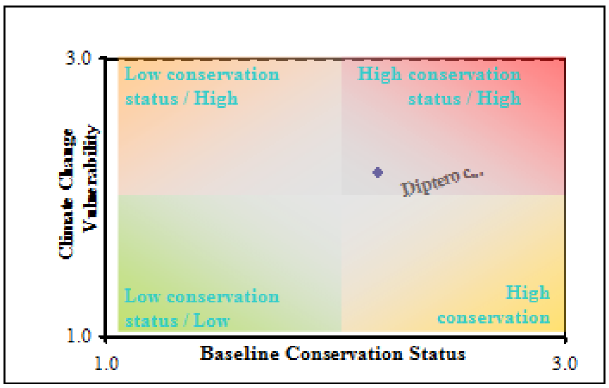
Mondulkiri



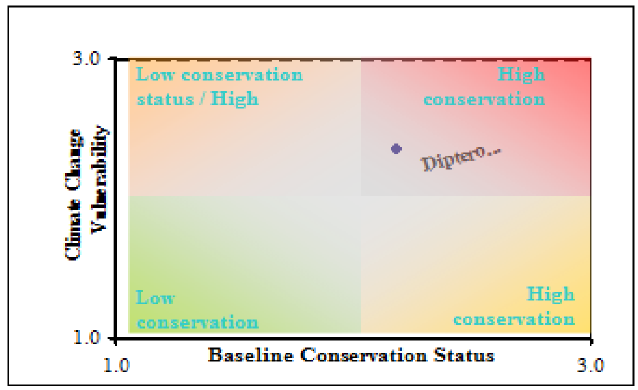
Gia Lai



Chiang Rai (west)



Khammouan



Recommended adaptation measures

Short term

- Better conserve and safeguard the existing stands of *Dipterocarpus alatus* in protected areas, promote and enhance in-situ conservation
- Encourage and promote the planting of *Dipterocarpus alatus* in reforestation and afforestation programs/projects at community, national, and regional levels
- Encourage and support the attempt and effort of local communities to achieve 'sustainable harvest' and avoid over-exploitation

Medium term

- Increase 'Protected Forests' in order to maintain the habitats and to save existing wild populations
- Increase the effectiveness of 'Protected Area Systems' and the management of existing protected areas in order to reduce deforestation, commercial and illegal logging, encroachment, forest fires, land use change, and habitat deterioration and loss
- Establish the 'buffer zone' for existing forest areas in order to allow natural shift of forest distribution under future climate change
- Improve oleo-resin harvesting techniques, develop proper tapping and hole maintenance methods in order to reduce vulnerability to extreme events

Long term

- Strengthen and systemize the overall watershed management for forest and water resources conservation
- Build 'check dams' to maintain and increase soil moisture availability within the forests, especially during dry season months
- Collect seeds, establish seedbanks, and produce seedlings and saplings for ex-situ conservation and re-introduction to deteriorated forest areas

3.8.2 VULNERABILITY ASSESSMENT FOR *SONNERATIA* SPP. (MANGROVE APPLE)

Sonneratia is a genus of plants in the family Lythraceae. Formerly the *Sonneratia* were placed in a family called Sonneratiaceae, which included both the *Sonneratia* and the *Duabanga*, but these two are now placed in their own monotypic subfamilies of the family Lythraceae. The genus was also named "Blatti" by James Edward Smith, but *Sonneratia* had botanical nomenclature priority. The three species found in the Mekong Delta are S. *alba, S. lanceolata, S. ovata*

Tree: 3-30 meters tall; bark ream to light grey, finely fissured; thick underground cable roots spread out from the trunk. These bear sturdy conical pneumatophores (25cm to 1 meter tall). The tree might lack pneumatophores if it grows on a solid substrate.

The fruits of the trees are picked for making sour soup or eaten raw; young tender leaves are also eaten raw or cooked. Timber is used for firewood but it is not a preferred tree for this use; timber can be used for building boats and houses as well as bridge and wharf construction (low value) and also for interior work including furniture and musical instruments but requires bronze nails. The buoyant pneumatophores can be used to make corks and floats.

Sonneratia spp. grow mostly along banks of tidal rivers, creeks, and within sheltered bays of offshore islands and reef cays. In estuaries, they occupy distinct upriver ranges where *S. caseolaris* and *S. lanceolata* occur in upstream reaches of river-dominated estuaries; *S. alba* occurs in downstream stands and offshore island embayments; and *S. X gulngai* and *S. X urama* hybrids occur in small intermediate stands between the respective parents. Another species, *S. ovata,* prefers a different habitat occurring at the high tide margin.

These trees are found in all tropical shores of the Eastern hemisphere from East Africa to the Pacific, though habitats might be declining.

Sonneratia spp. produce large numbers of fruits that may contain a thousand seeds per fruit of which around 90% are viable. *Sonneratia* sets fruits for only 3 months of the year however and seed germination seems the only way of propagation of this plant.

It is shade intolerant with a maximum salinity of 35 ppt. It is found in lower saline areas on deep muddy soil along tidal creeks with slow moving freshwater. It is fast growing with low seed viability (sets fruit only three months of the year). Laboratory studies showed that high salinity inhibited the germination of seeds of *S. caseolaris*. The inhibition was proportional with the salinity.

The tree does not require much habitat as it can occur in small stands. Fruits containing seeds can disperse a long distance by water. Seeds are buoyant. The tree provides habitat for dawn bat. These are the same bats that pollinate commercially important crops such as durians, bananas, and papayas. Thus, without *Sonneratia*, there would be less of these favorite fruits.

The tree is not protected in Vietnam but occurs in Kien Giang coastal protected forest. It is listed as Least Concerned in the IUCN Red List. In Kien Giang, *Sonneratia* occurs in the biosphere reserve but management is probably not very effective.

Its baseline conservation status is considered moderately vulnerable.

Climate change

Temperature preferences of *Sonneratia* spp. are not known but mangrove communities in general occur in areas where the average temperatures of the coldest month are higher than 20°C and where the seasonal range does not exceed 10°C. Temperatures of around 50°C and frosts also limit mangrove distribution.

For drought exposure, as the tree grows in saturated coastal environments, drought doesn't seem to be an issue. Flood doesn't seem to be an issue either as the species is adapted to waterlogged conditions. Strong winds, however, can destroy mature trees. Growing in waterlogged environments, fire is not an issue for the plant.

Mangrove species in general have high tolerance to fluctuations. Plants growing in the intertidal zone are subjected to large fluctuations in salinity - they are inundated by seawater (high salinity) during high tides, while at low tide, or during heavy rains or floods, they can be exposed to fresh water (low salinity). The plant is adapted to daily fluctuation of tidal water, but sea level rise will still be a problem as large areas of mangroves will become permanently inundated, which they cannot withstand.

Sonneratia spp. will also have little option for survival in case of strong winds/storms. Sea level rise, strong waves, and coastal erosion will be a major problem in the future. If there is a coastal dyke in the back, the dyke will prevent the tree from migrating inland and it will have little option for survival. For example, in Kien Giang, the planned coastal dyke will prevent mangroves from expanding inland as sea level rises.

The baseline stresses for *Sonneratia* spp. will probably increase as other plants become stressed by climate changes and decline; the additional pressure from human collection will increase.

Sonneratia spp are considered to be very highly vulnerable to climate change because sea level rise, strong waves, and coastal erosion will be major problems affecting them. Also, it is likely that coastal dykes will be built behind the mangroves, which as noted above will prevent migration inland as a response to sea level rise. The species will suffer mortality in their present tidal zones and will attempt to reestablish at higher elevations in areas that were previously landward zones. If a coastal dyke is built behind the mangroves, their movement inland will be blocked.

Adaptation recommendations

Short-term:

- Reestablish mangroves along the coast through planting and natural regeneration
- At areas with strong waves, wave breaking structures are needed to protect the young trees from being destroyed by waves
- Promote establishment of multi-species mangrove forests to better cope with storm damage

Long-term

- Through land use planning, leave enough space for establishment of mangroves along the coast, including relocation of the planned coastal dyke further inland
- Plan sluice gates together with the coastal dyke to allow saline water to move in and out of the coastal dyke to provide habitat for mangroves and *Sonneratia* to migrate inland

3.9 INSECTS

There are over 500 insects recognized and used as food worldwide. Throughout the region, insects are valued as food. For example in Thailand, there are over 50 edible insects, including cicadas, scarab beetles, grasshoppers, crickets and dung beetles. Insects are popular food for the locals of Northeast Thailand and Lao PDR and have become part of food culture. The local wisdom has been appreciated in finding wild food of such highly nutritional value amidst poverty and economic crisis.

Wild honeybees are valued sources of honey, but also perform the essential ecosystem service of pollination for many plants, both wild and cultivated.

Some detail is provided on cicada and scarab beetle as examples of insects as NTFPs and vulnerability assessments have been carried out on the giant honeybee, *Apis dorsata,* and red ants.

3.9.1 CICADA

The major part of the cicada's life cycle is in soil. Larvae hide and feed on water in tree roots in the soil for 4-6 years. Adults live only 2-4 months and feed on water on trees.

Cicadas provide a good source of protein and vitamins and are collected for food and for sale, fetching a high market price (1 – 2 USD/10 insects). This provides a supplementary occupation and income for local people during the dry season.

Adult cicadas are available and gathered during the dry season by at least three traditional collecting methods. With high skills, 800 – 1,000 insects/day can be collected.

There is a trend towards decreasing abundance due to deforestation, encroachment, forest fires, over-harvesting, and cross-boundary trade.

3.9.2 SCARAB BEETLE

The scarab beetle is associated with a wide range of bush trees and big trees in dry dipterocarp and mixed deciduous forests. Scarab beetles feed on young leaves and leaf litter of a wide range of trees during the night time and hide in holes, soils, and leaf litter during the day-time. For the major part of life they live in the soil and tree roots.

Scarab beetles become available and abundant in summer and peak in early rainy season. They are collected for food and for sale with a local market price as high as 15-27 USD/kg.

The threats to scarab beetles include deforestation, forest fires, and land use change.

3.9.3 VULNERABILITY ASSESSMENT FOR *APIS DORSATA* (GIANT HONEYBEE)

The giant honeybee (*Apis dorsata*) is a honeybee of South and Southeast Asia. They are aggressive and have not been domesticated. The bees build their nests on tree branches. Honey is used as ingredients for food, drink, and medicinal purposes and the wax is used for making candles and cosmetic products. The bees are also an important pollinating agent for plants. Pure bee honey harvested from U Minh region in Kien Giang and Ca Mau Provinces in Vietnam is sold from 10 to 20 USD per liter. Potentially, bee keeping can be an important income generating activity for rural villagers. In Cambodia, honey is one of the important forest-based livelihoods that communities living in and around the protected areas of Mondulkiri are dependent upon.[16] Honey is a very important emergency and supplementary source of income.

To harvest honey in the wild, people apply a traditional method known as "rafter beekeeping" for collecting honey and wax from honeybee colonies. Simply, a rafter is the trunk of a tree, 2 m in length and 15 cm in diameter supported by two vertical poles. One vertical pole is about 2 m high and the second 1.2 m high. The rafter therefore slopes at an angle of about 15-35Â° to the horizontal. It appears like the branch of a tree and *Apis dorsata* can build its nest beneath it. It is named rafter because it looks like the rafter of a house (Phung Huu Chinh et al. 1995).

Robinson WS (2012), citing various sources, states that pollinators are in decline worldwide. Giant honeybees are not only a splendid spectacle but are indispensable pollinators of cultivated crops and wild flowering plants. They manufacture honey and other hive products, and are culturally revered in Asia. Their current population decline and vulnerability to human impacts and "local extinctions across extensive areas" make them deserving of "the sort of conservation attention that is normally reserved for charismatic vertebrates". Gallai et al. (2009) estimated that the total economic value of crop pollination worldwide is 153 billion pounds annually. Y. Le Conte & M. Navajas (2008) citing various sources stated that the long-term survival of farming worldwide relies in part on insect pollinators. In monetary terms, they contribute an estimated 117 billion USD per year; around 35% of agricultural crops depend directly on pollinators; and 84% of cultivated plant species are involved with the activity of these insects.

Apis dorsata is distributed in forest areas throughout the LMB. The range of the species probably has not been changed, however its population has been on a declining trend due to declining extent of forest cover in the basin, increasing human modifications of landscapes, and the increasing use of pesticides and

[16] Mondulkiri Wild Honey symbolises the community's commitment to sustainable use and management of forest resources. http://wwf.panda.org/?161621/Mondulkiri-Wild-Honey-symbolises-the-communitys-commitment-to-sustainable-use-and-management-of-forest-resources

agrochemicals in the region. I.F. Ibrahim, S.K. Balasundram, N.A.P. Abdullah, M.S. Alias and M. Mardan (2012) (citing Kiew 1997) wrote that *Apis dorsata* has a surprising degree of diet specialization because they tend to forage on trees rather than herbaceous species.

In the Mekong Delta in Vietnam, for example, the honeybee in the wild remains mainly in the protected melaleuca forests of U Minh Thuong National Park in Kien Giang, U Minh Ha National Park in Ca Mau, and Lang Sen Wetland Reserve in Long An Province.

The bees can reproduce fast as they mate annually and produce many offspring. Mating success depends on the weather and availability of favorable environmental conditions, especially pollen and nectar. Mating season depends on seasonal blooming cycles and this can be affected by climate change.

In terms of habitat requirements, although the bee is restricted to forest, any type of forest with sufficient supply of pollen and nectar can provide habitat for the bee. Within the hotspot provinces under consideration, Gia Lai and Chiang Rai were identified as having high non-climate vulnerability compared to Kien Giang, Mondulkiri and Khammouan. This is largely because the pressures on suitable forest habitat may be greater in these provinces.

For dispersal ability, according to Robinson WS (2012), the giant honeybee can fly and migrate annually up to 200 km and it has been assumed that their migrations occur stepwise, with stops for rest and foraging. Robinson WS (2012) reported discovery of a site in northern Thailand where bivouacs appeared in large congregations during the wet seasons of 2009 and 2010. The bivouac congregation stopover site is a small mango orchard along the Pai River.

F.C. Dyer and Th.D. Seeley (1994) monitored the arrival and departure of colonies in a rain forest habitat in northeastern Thailand and reported that colonies arrived in the area during the end of the dry season, reproduced, and then departed early in the rainy season. During the immigration phase, early-arriving colonies stayed only temporarily, as if assessing habitat quality. Colonies departing after a long stay always left barren combs behind, suggesting that they had left in response to deteriorating resource quality. These observations support the idea that migration allows colonies to track seasonally varying resources in different regions.

In the Mekong Delta*, Melaleuca* is the main freshwater forest plant. *Melaleuca* blooms mostly from January to April and June to August. The bees come to the area in December and stay until May. The first honey harvest is between February and April. In May the colonies fly away and return in June. The second honey harvest season is in July and August after which the bees depart. At other times of the year, some *Apis dorsata* colonies can be found in the *Melaleuca* forests, but honey is stored only in small amounts (Phung Huu Chinh et al. 1995).

Robinsin WS (2012), reporting on the migration of the giant honeybee in Thailand, wrote that as forage decreases toward the end of the season, colonies abandon their combs and migrate to lower elevations, establishing new nests there for the mass flowering of the monsoon season.

Floods do not affect bees, but the trees that they depend on. Trees are not currently affected by floods. Forests, however, are subject to fires and severe forest fires can kill the bees.

As demand for bee honey increases, especially high quality honey harvested from the wild, honeybees are increasingly disturbed and overexploited. Strong winds, storms, and cyclones can destroy forests and bee hives.

The giant honeybee is currently not a priority for national protection and not on the IUCN Red List. The conservation status of *A. dorsata* is considered to be moderately vulnerable, with juveniles being more sensitive. The conservation and management of forest habitats in various forms of Protected Areas used by *Apis dorsata* is generally weak.

Climate change

Y. Le Conte & M. Navajas (2008) wrote that climate change can impact honeybees at different levels. It can have a direct influence on honeybee behavior and physiology. It can also alter the quality of the floral environment and increase or reduce colony harvesting capacity and development. It can define new honeybee distribution ranges and give rise to new competitive relationships among species and races, as well as among parasites and pathogens. Beekeepers will also be obliged to change their apiculture methods. They will favor moving their hives to new foraging areas and importing foreign races to test their value in the new environments.

Apis dorsata honeybees migrate seasonally in response to seasonal flowering patterns. They can fly up to 200 kilometers to escape starvation or predators. After leaving their nests unoccupied for several months or even one or two years, the same honeybee colony returns to colonize the same nest in the same tree every year. With this great dispersal ability, the bees have a good chance of ensuring their survival by seeking more favorable habitats and abandoning regions that have become too hostile. A plausible scenario is that the bees will have to abandon some areas that have become no longer suitable for them and colonize areas previously not suitable but have become more suitable for them under the changing climate conditions. As a result, they will tend to concentrate more at the fringes or the interface of the old and new areas.

A well-studied example is that of the Africanized honeybee. The Africanized honeybee's geographical distribution has now extended as far as Argentina and the USA, where it has come to a halt. According to researchers, this is because the climatic conditions beyond that are too cold for the Africanized honeybee. Global warming is therefore conducive to the bee's expansion outside its current distribution range.

Rattanawannee, A., Chanchao, C., Lim, J., Wongsiri, S., and Oldroyd, B. P. (2012) conducting research in Thailand found that *A. dorsata* is currently able to tolerate habitat fragmentation and annual harvesting. The authors speculated that the population is sustained by immigration from forested regions to the northwest of their study sites in Burma.

In terms of heat tolerance, the optimal temperature range for foraging for *Apis dorsata* is 22-25^{0}C. However, they are still able to forage at temperatures > 30^{0}C. The bee also has a mechanism to adapt to increasing temperature up to 50^{0}C for short periods, but above 38^{0}C their activities are slow and below 7-10^{0}C they become immobile. The bee can use evaporative cooling to release heat from its mouth - under hot conditions, heat from the thorax is dissipated through the head and the bee regurgitates a droplet of hot internal fluid – honey crop droplet.

An advantage of the bee is its ability to fly and use cultivated trees with flowers to find alternative microrefugia to avoid particularly high incidents of temperature, drought, and flood. In terms of hydrologic impacts, flooding itself does not affect the bee but rather the trees that the bee depends on. Prolonged and heavy rainfalls affect flowers and the ability of the bee to fly out and forage. Bees can adjust their behavior, however, to weather conditions. When it rains the bees do not go out and when it is hot, bees gather water to keep the colony cool.

In terms of risks from other associated species, honey can be robbed by other bee colonies when foods become scarce. Birds are common predators of the honeybee; but the large size of workers protect themselves well from ant invasions.

In Kien Giang, the projected future means of daily temperature in the dry season of 34^{0}C will be outside of the existing temperature comfort zone for *A. dorsata* (30^{0}C to 33^{0}C). The probability of drought also increases significantly in April toward the end of the dry season, from 60% to 80%. Meanwhile in the wet season there will be more water availability, deeper inundation, and hotter water surfaces. The predicted increase in precipitation in the wet season will not affect the bees as they are not present at the site after August. However, the reduction of rainfall in the dry season will make the peat areas in U Minh Thuong, the key site in Kien Giang where the giant honeybees are found, drier and this may affect the flowering of *Melaleuca* trees.

For Mondulkiri, similar changes are expected: increased rainfall in the wet season and reduced rainfall in the dry season. The mean maximum temperature change will be shifted upwards by 2 - 3 degrees Celsius and exceptionally upwards by 4°C in May. In April and May, the mean maximum temperature may be between 34 and 36^{o}C. This will likely cause the bees to leave earlier from the site toward the end of the dry season to lower areas with more moisture and more supply of pollen and nectar.

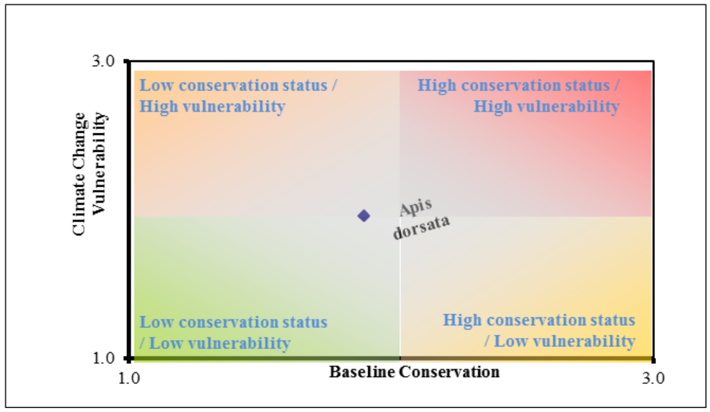
For Gia Lai, besides similar changes in rainfall as in the other sites, the key concern is that mean maximum temperature change will also be shifted upwards by 2 - 3 degrees Celsius and exceptionally upwards by 4°C in May. In April and May, mean maximum temperature may be between 34 and 36^{o}C. The mean of dry season temperature will be outside of the bees existing comfort zone. This will likely cause the bees to leave the site earlier toward the end of the dry season to lowland areas in search of nectars and pollens in more moist areas.

For Chiang Rai, the dry season will be drier by a few mm in monthly rainfall and the wet season rainfall will be higher by 5%. Daily maximum temperature for both the dry season and wet season will stay within the bees existing comfort zone, so temperature increase is not as much of a concern. The key concern for Chiang Rai is increased frequency of storms. The biggest storms may reach 161 mm rainfall in a day compared to 141 mm under baseline conditions. There will be 10 storms of more than 100 mm in a day, compared to 7 storms for the baseline. These bigger, more frequent storms are more likely to destroy bee combs.

In terms of biodiversity, according to Engel (1999) there are 4 recognized subspecies including *Apis dorsata dorsata* primarily from India; *Apis dorsta binghami* Cockerell (Indonesian honeybee) from Malaysia and Indonesia; *Apis dorsata breviligula* Maa from the Phillipines; and *Apis dorsata laboriosa* Fabricius (Himalayan honeybee), which is also found in Myanmar, Lao PDR, and southern China. It is not clear how much gene flow occurs among the sub-species.

Another advantage of the bee is that their colonies can grow quickly and reproduce by fission (swarming). Although the bees can fly great distances to escape starvation and stresses, the increasing loss of stopover sites may be bottlenecks for populations of migrating species such as *Apis dorsata*. To cope with the changes, adaptive capacity may be developed at the population level, but individuals will remain pressured as loss of habitat increases.

In the future, current baseline stresses will increase. Hunting pressure will increase as demand for bee honey increases, especially honey harvested from the wild, which is of higher quality. Habitat loss will also increase as more land will be converted to agriculture to feed growing populations. According to Y.



Le Conte & M. Navajas (2008), pesticides kill many colonies every year. New pathogens have been added to the already long list of honeybee diseases. However, researchers agree that the bees' environment and stress, both of which are influenced by climate change, have been decisive factors in this heavy mortality. There appear to be strong interactions between diseases, pesticides, environment, and climate. Climate change has an action on each of these factors. To understand the effect of climate change on the evolution of honeybee populations, each of these factors will need to be taken into account.

Y. Le Conte & M. Navajas (2008) also wrote that in the context of climate change, plant phenology will be modified, especially the flowering period. A new bioclimatic and economic balance will shape the types and distribution of agricultural crops, as well as those of spontaneous vegetation. Climate change could destabilize relationships between flowers and pollinators, and pollinators will need to be protected to ensure that they continue their pollination function.

***Apis dorsata* is considered to be moderately vulnerable to climate change.** Because of its life history traits, its great ability to disperse, its special mechanism to tolerate heat, and its genetic variability, the bee possesses a high resilience and capacity to adapt to new environmental conditions.

Recommended adaptation

Although the giant honeybee will be fairly tolerant to future climate changes, the increasing baseline stresses will probably be the determining factor to affect the survival of the species.

Because of its critical role as a keystone pollinator that wild flora and farming systems depend on, the honeybee should receive more conservation attention and a higher priority in national conservation status. Environmental Impact Assessments for development activities that modify the landscape in a large scale should take impacts on honeybee and associated secondary impacts on agriculture and the wild flora into account.

Populations of many migratory animals, and the migrations themselves, have been damaged or destroyed by loss of specific habitat crucial to vulnerable stages of the animals' life histories. Insects are not immune to such loss (Robinson, WS 2012). Therefore, research efforts should be directed at discovering and documenting migrating routes and stopover sites of the honeybee in the LMB. Legal and technical protection measures should be undertaken to protect critical stopover sites of the bees including establishing a legal protection status, regulating the use of agrochemicals, and conducting enrichment planting of flowering plants at the critical stopover sites.

For the particular case of the peat areas of U Minh Thuong National Park in Kien Giang Province and U Minh Ha National Park in Ca Mau Province, the current existence of the canal systems inside these areas have led to rapid loss of water in the dry season. In the future, dry season rainfall is expected to reduce rendering the dry season drier and more subject to droughts. This will affect the physiology and the flowering of *Melaleuca* trees, the main flowering plant the giant honeybee depends on at the site. It is recommended that the hydrology of the site be managed appropriately to retain moisture to compensate for the rapid loss of water through increased evaporation and reduced dry season rainfall. Simple techniques can be applied such as construction of low check-dams on key canals to keep water from being drained freely at the end of the dry season.

3.9.4 VULNERABILITY ASSESSMENT FOR *OECOPHYLLA SMARAGDINA* RED ANT, WEAVER ANT


Oecophylla smaragdina is an insect in the Formicidae family. It is arboreal, living and nesting on trees, especially leaves. Nests are formed of living leaves and stems bound together with larval silk. This ant is medium to large in size, a carnivore and/or scavenger, and normally feeds on small creatures, e.g., small insects and insect larvae, as well as nectar. It is commonly found on tree trunks. Red ants live in big colonies comprising a queen who is responsible for commanding and egg laying, as well as males, females, and workers responsible for feeding, nesting, and guarding. The stronger the colony, the more eggs are produced. They have four stages of life cycle – eggs, larvae, pupae, and adults. They will bite aggressively when disturbed and release formic acid from the end of the gaster and hurt intruders.

Oecophylla smaragdina distributes in elevations < 1,000 m asl. They are very commonly found in all LMB countries. They live and nest on almost all kinds of trees in a wide range of localities, but prefer perennial big trees, bushes, and shrubs. They have delimited territories with distribution in a wide range of habitats, both natural and plantation areas. Favorite habitats include secondary deciduous dipterocarp forests with scattering grassland, and fruit plantations such as mango, rose-apple, and tamarind plantations.

Oecophylla smaragdina do not prefer shady areas or dense canopies, grounds without reach of sunlight, high humidity, and low temperature. Soil temperature and humidity, amount of rainfall, litter humidity, and biomass of litter are all factors related with their existence, population, abundance, and movement. They prefer dry soils with access to sunlight. They live and feed in open areas with sunlight penetration and good ventilation. They live in a temperature range of 10 - 40°C. The best and optimal temperature for feeding is 30°C. Temperature affects the occurrence of weaver ants and their feeding habits. They live in areas having average annual rainfall of 1,350 mm/yr. Humidity affects ant activities and feeding habits. Seasonal changes cause habitat changes.

Oecophylla smaragdina is abundant during the dry season, from November –June, peaking in May. Abundance in deciduous dipterocarp forest is higher than in disturbed land uses. Under normal conditions, they have quick population recovery. Regeneration takes 17 – 24 days. According to collectors, it takes 5 days before new nests appear and around 20 days for ants to produce new larvae. Ants, their colonies, eggs, and larvae are used as food. Parts, especially the abdomen, or the entire insects contain formic acid and are used as medicine for various trauma and treatments. They have very high nutritive value (very high protein) and probably are the most favorite and popular food insect and favorite food for local consumption. They are an important source of occupation and income and important for local food and health security. Eggs are harvestable in only one season per year (during December – May) and gathered after rice harvesting during the dry season for consumption and for sale, with a very high market price of 7 – 15 USD/kg. They are also processed and canned for exports. Red ants are an important emergency and supplementary source of income. Ecologically, red ants are controllers or predators of >50 species of insect pests on many tropical tree crops and forest trees.

Threats include forest fires, deforestation, habitat loss, and over-harvesting. Forest fires and deforestation directly lead to habitat loss. Fire incidents reduce the abundance of ants. Over-harvesting of ant eggs is destructive, and they become scarce in several exploited areas. The IUCN Red List status is 'Not Evaluated'. In the hotspot provinces considered, the pressure on habitats from land use change, illegal logging, and deforestation will increase their **non-climate vulnerability from Low to Moderate.**

In all four hotspots, future increase in temperature will still fall within the comfort zone and will favor *Oecophylla smaragdina*. The increase in maximum temperature up to 44°C in Mondulkiri will be beyond the best optimal temperature for feeding and will slightly affect *Oecophylla smaragdina*. Drier dry seasons and decrease in soil water availability will enhance the red ant population. Increase in temperature and less dry season rainfall, however, will lead to more risk of wild fires, which can decrease the abundance of ants. Increase in wet season rainfall slightly beyond the ants comfort zone, bigger and more frequent storms, and high winds will affect their habitats, nests, population, movement, and feeding habits. If the nests are wet or moist, disease will occur. Future less risk of drought Chiang Rai and Khammouan will slightly affect their population and abundance.

Oecophylla smaragdina has good adaptability to the environment. They are arboreal, have delimited territories, prefer dry substrates, and their abundance is highest during the dry season. Eusociality, or their high level of social organization, greatly increases the efficiency with which ants can defend themselves and forage for resources, but may also make ants more sensitive to climate change. *Oecophylla smaragdina* have quick population recovery and produce new larvae in short time. They are specialized nest builders and able to avoid nest damage from rain and wind in the rainy season. In three hotspots (Mondulkiri, Chiang Rai, and Gia Lai), *Oecophylla smaragdina* will have low vulnerability to future climate change. *Oecophylla smaragdina* in Khammouan will be moderately vulnerable.

Recommended adaptation measures

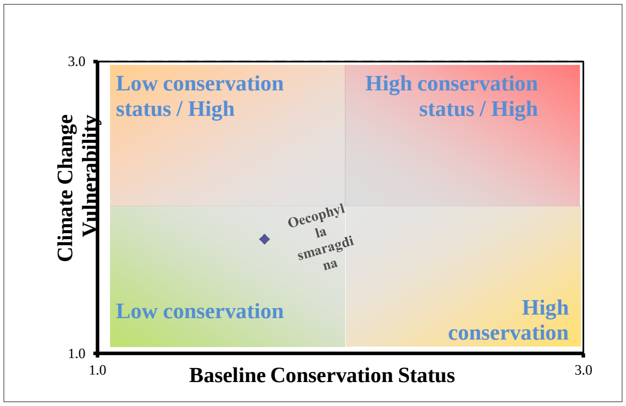
Short term

- Encourage and support the attempt and effort of local communities to achieve 'sustainable harvest' of red ants and their eggs by establishing and managing sustainable harvesting systems
- Ensure that the harvesting techniques are proper and avoid over-exploitation

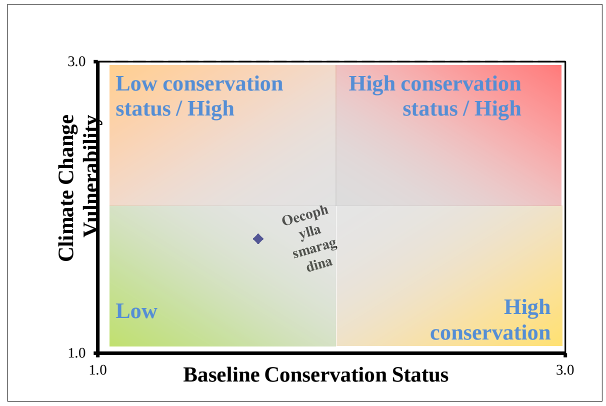
Long term

- Increase the effectiveness of 'Protected Area Systems' and the management of existing protected areas in order to reduce deforestation, commercial and illegal logging, encroachment, forest fires, land use change, and habitat deterioration and loss.

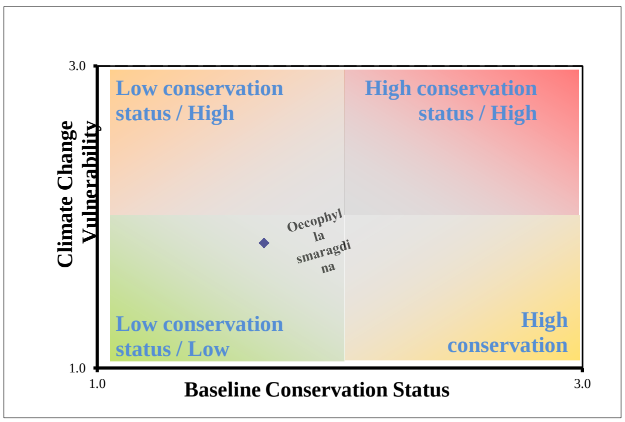
Mondulkiri



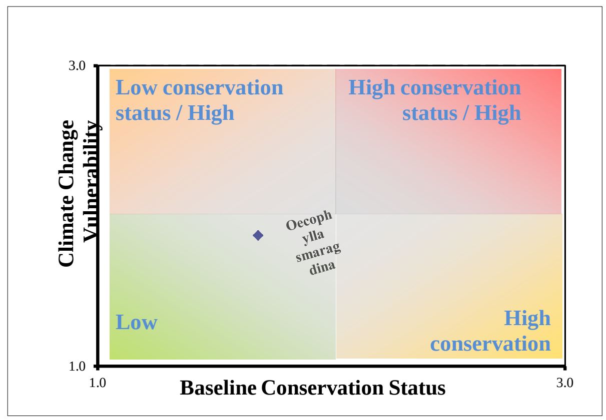
Gia Lai



Chiang Rai (west)



Khammouan



3.10 EARTHWORMS

The earthworm is an invertebrate of the phylum Annelida. There are > 4,400 species of earthworms. In the LMB countries, earthworms are commonly found throughout the region. Species commonly found include *Pheretima posthuma* or *Metaphire posthuma, Pheretima peguana, Amynthas alexandri, Pontoscolex corethrurus,* and *Lumbricus terrestris*.

Earthworms have tube-shaped, thin-skinned, segmented bodies. They live for 6.5 years on average and have various different sizes and colors. Earthworms lack a skeleton, maintain their structure with fluid-filled chambers functioning like a hydro-skeleton, have simple closed blood circulatory systems, conduct respiration through the cuticle covering their skin, and have digestive systems running straight through their body. Earthworms are hermaphrodites – each individual carries both male and female sex organs. They can fertilize themselves, but most earthworms require mates of the same species to reproduce. They can produce 3 – 80 cocoons per year depending on species. Young earthworms hatch from their cocoons in 3 weeks to 5 months and mature in 10 – 55 weeks, depending on the species. Earthworms feed while they are moving and eat decaying plant and animal matters. Earthworms live and travel around in the soil and form burrows as they move. Some species make deep vertical burrows, some make shallow ones, and some form a network of vertical and horizontal channels.

Earthworms live in wide latitude and elevation ranges, and live in various forest types and habitats, e.g., dry evergreen and dry dipterocarp forests, forest plantations, grasslands, agricultural lands, cattle manure, backyard gardens, and building areas.

Various species of earthworms have different ecological requirements. Earthworm density varies according to soil type and texture, soil moisture, rainfall, temperature, total nitrogen, and organic matter. Light loam, light sandy soil, medium loam, alluvium, and clay soils have higher density of earthworm populations. Moisture is the most important requirement of earthworm life. Although they are capable of acclimatizing to different temperatures and soil moisture content, they prefer moist slightly warm soil to grow and reproduce. Optimal soil moisture content is 60 – 80%. Since earthworms breathe through their skin, it is important that their environment is moist to allow for respiration. Most earthworms are more active in moist soils than dry soils. In the wet season with higher soil moisture content, earthworms produce more cocoons than in summer or winter.

Earthworms have high economic and ecological values. They are used as fishing baits, high-protein feeds for ornamental fish, chicken, and frogs, and traditional medicine for inner trauma treatments. Vermiculture and vermicomposting now have become popular occupations with high income. Their excreta (vermicast) are excellent organic fertilizer and have high price. Earthworms have important ecological roles in improving soil physical, chemical, and biological properties.

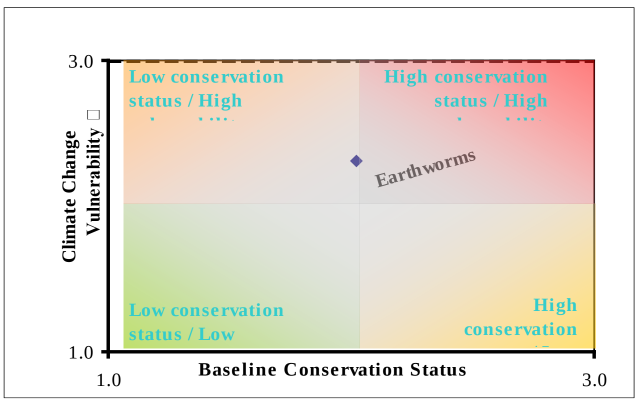
Natural predators include ducks, chicken, birds, frogs, toads, rats, snakes, leeches, beetles, and fish. Moisture is the most important requirement for earthworm life. If moisture content is too low or under prolonged due to extreme drought, they begin to lose internal water content, try to adapt, and finally die. Too much moisture, heavy rainfall, and floods can be more serious, depleting oxygen in the soil and causing them to crawl up to the soil surface to be exposed to sunlight, which can be lethal to them. Lower temperatures negatively affect food availability, growth rates, and reproduction rates of earthworms. Human threats include land use change and intensive cultivation. The IUCN Red List status is 'Not Evaluated'.

Future increase in temperature up to 44°C during the dry season in Mondulkiri will significantly exceed the comfort zone for earthworms. Compounded by less rainfall and less soil moisture availability, temperature change will be a major issue for earthworms in Mondulkiri. If soil moisture content is too low or droughts are prolonged, earthworms will begin to lose their internal water content and may finally die. Higher percentage of drought years and increase in forest fires will significantly decrease earthworm populations. Future increase in temperature in Chiang Rai, Gia Lai, and Khammouan will be within or slightly beyond the comfort zone, but still lower than the upper lethal temperature for earthworms. Chiang Rai, Gia Lai, and Khammouan will have less risk of drought, no change, and little change in drought patterns, respectively, which will have minimal effects on earthworms. During the wet season, higher rainfall beyond the comfort zone, along with bigger and more frequent storms in all four hotspots will affect life, growth, living, and feeding activities and force earthworms to crawl up to the soil surface increasing vulnerability.

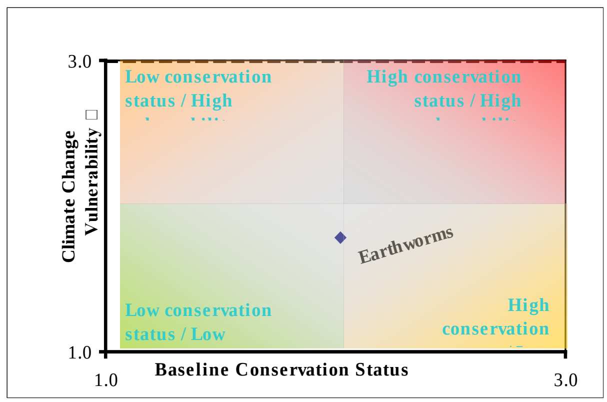
Earthworms have quite high adaptive capacity; they can live in diverse habitats and different layers of soils. They are specialized burrowers. During drought periods, they recede deeply into their burrows, which can be as deep as 6 feet. They have developed certain survival strategies which help them cope with nasty environmental conditions. Earthworms can move deeper than 20 m into the soil and aestivate when conditions are hot and dry.

Increase in temperature, less rainfall, less soil moisture availability, especially during the dry season will harden life, growth, movement, and activities of earthworms. Higher rainfall during the wet season months will make earthworms more vulnerable. In Mondulkiri, the hotspot with the most extreme climate change patterns, earthworms will be highly vulnerable to future climate change. In other hotspots – Chiang Rai, Gia Lai, and Khammouan, earthworms will have low to moderate vulnerability to future climate change.

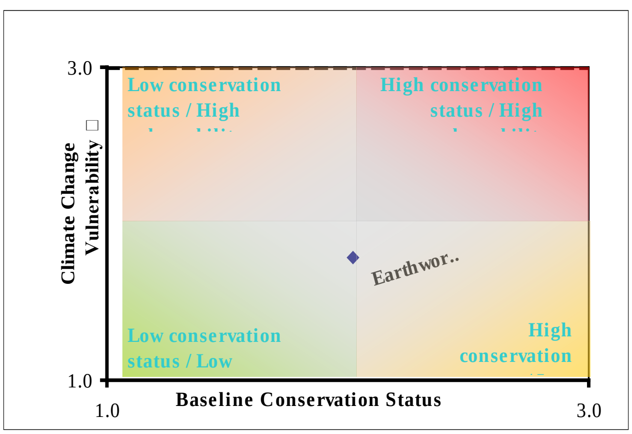
Mondulkiri



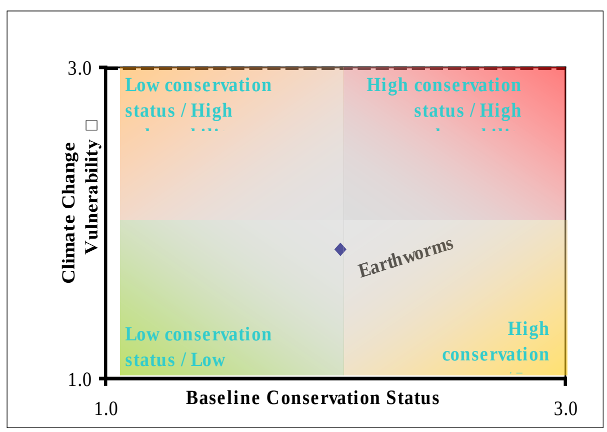
Gia Lai



Chiang Rai (west)



Khammouan



Recommended adaptation measures

Short term

- Promote and support organic farming, integrated farming systems, and environmentally friendly agricultural systems
- Encourage and support local communities to achieve 'sustainable harvest' of earthworms

Medium term

- Build 'check dams' to maintain and increase soil moisture availability within the forests, especially during dry season months and prolonged droughts
- Develop 'wet season refuge' for earthworms in order to reduce their vulnerability to heavy rainfall, flooding, natural predators, and human threats

Long term

- Increase 'Protected Forests' in order to maintain the habitats and to safeguard the wild populations
- Increase the effectiveness of 'Protected Area Systems' in order to reduce deforestation, land use change, intensive mono-cultivation, habitat deterioration and loss
- Restore and rehabilitate deteriorated forests. Increase forest canopies, crown covers, and shade areas
- Strengthen and systemize the overall watershed management for forest, land, and water resources conservation

4 CROP WILD RELATIVES

4.1 WHAT ARE CROP WILD RELATIVES?

A crop wild relative (CWR) is a wild plant closely related to a domesticated plant, whose geographic origins can be traced to regions known as Vavilov Centers.[17] It may be a wild ancestor of the domesticated plant, or another closely related taxon. The wild relatives of crop plants are an increasingly important resource for improving agricultural production and for maintaining sustainable agro-ecosystems. Southeast Asia includes and lies between the Indo-Burma and Siam-Malaya-Java subcenters and the Chinese center. These centers are considered to be the areas of origin for the plants indicated in Table 9.

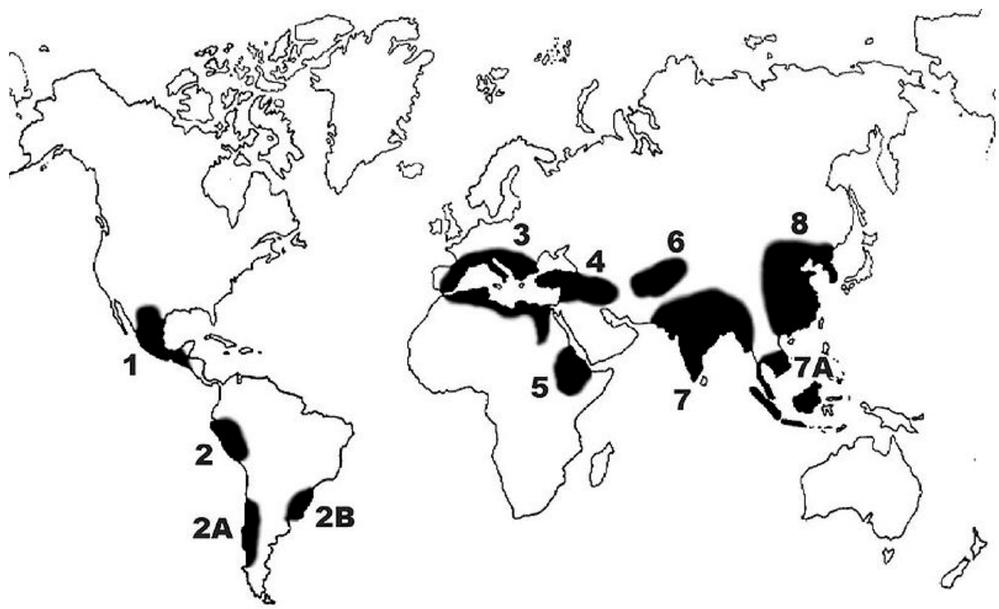


Figure 4-1: Vavilov Centers

1) South Mexican and Central American Center
2) South American Center
3) Mediterranean Center
4) Middle East
5) Ethiopia
6) Central Asiatic Center
7) Indian Center – Indo-Burma and Siam-Malaya-Java subcenters
8) Chinese Center

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[17] Vavilov Centers are named after Dr. Nikolai Ivanovich Vavilov who first developed the theory of centers of origin of domesticated plants. A Vavilov Center is a region of the world considered to be an original center for the domestication of different plant crops

Table 9: Plants whose origin lies in the Indian and Chinese Vavilov Centers[18]

Center	Plants
7) Indian Center - two subcenters	***7) Indo-Burma***: Main Center (Hindustan): Includes Assam and Burma, but not Northwest India, Punjab, nor Northwest Frontier Provinces, 117 plants • **Cereals and Legumes**: rice, chickpea, pigeon pea, urd bean, mung bean, rice bean, cowpea • **Vegetables and Tubers**: eggplant, cucumber, radish, taro, yam • **Fruits:** mango, orange, tangerine, citron, tamarind • **Sugar, Oil, and Fiber Plants**: sugar cane, coconut palm, sesame, safflower, tree cotton, oriental cotton, jute, crotalaria, kenaf • **Spices, Stimulants, Dyes, and Miscellaneous**: hemp, black pepper, gum arabic, sandalwood, indigo, cinnamon tree, croton,bamboo ***7A) Siam-Malaya-Java***: Indo-Malayan Center: Includes Indo-China and the Malay Archipelago, 55 plants • **Cereals and Legumes**: Job's tears, velvet bean • **Fruits**: pummelo, banana, breadfruit, mangosteen • **Oil, Sugar, Spice, and Fiber Plants**: candlenut, coconut palm, sugarcane, clove, nutmeg, black pepper, manila hemp
8) Chinese Center	A total of 136 endemic plants are listed in the largest independent center • **Cereals and Legumes**: e.g., broomcorn millet, Italian millet, Japanese barnyard millet, Koaliang, buckwheat, hull-less barley, soybean, Adzuki bean, velvet bean • **Roots, Tubers, and Vegetables**: e.g., Chinese yam, radish, Chinese cabbage, onion, cucumber • **Fruits and Nuts**: e.g., pear, Chinese apple, peach, apricot, cherry, walnut, litchi • **Sugar, Drugs, and Fiber Plants**: e.g., sugar cane, opium poppy, ginseng, camphor, hemp.

In its database on crop wild relatives and climate change, the Global Crop Diversity Trust at FAO states that their website is dedicated to compiling and providing information on the taxonomy, distribution, conservation status, and breeding potential of the wild relatives of major crops. They note that:

"Adapting agriculture to climate change is one of the most urgent challenges of our time. There is, quite simply, no more important step we can take to prepare for climate change than to ensure that the crops that feed humanity are able to thrive in the new climates that are developing all over the world. The need for new crop varieties that can be productive in the new climates of the future is increasingly widely recognized. But our ability to breed these new varieties should not be taken for granted, as it so often is."[19]

[18] http://en.wikipedia.org/wiki/Center_of_origin
[19] Crop Wild Relatives and Climate Change (2012). Online resource. Accessed on 23-08-2012. www.cwrdiversity.org

4.2 IMPORTANCE OF CROP WILD RELATIVES AS GENETIC RESOURCES

CWRs differ from NTFPs in that their products are not necessarily collected by local people as part of their livelihoods. However, there is evidence that wild rice has been used in Lao PDR as a famine food in the past, even as recently as 20 years ago.[20] The importance of CWRs is in the traits that may be found in the gene pools that may be used to strengthen the domesticated varieties.

CWR species may be prioritized on the basis of the relative economic importance of the associated crop, the level of threat to the populations, and the availability of eco-geographic data. Perhaps the potential ease of CWR utilization would be the most important feature. The potential CWR utilization is assessed by the ease of crossability and trait transfer between the CWR and the crop. Taxa are placed in different gene pools depending on these characteristics.

The CWR database (www.cwrdiversity.org) lists a large number of uses and traits that may be found in CWRs. The following traits may be useful in the context of climate change and the impacts occurring in the LMB:

- Adaptation to high altitude and cold
- Adaptation to xerophytic conditions
- Resistance to fungal, bacterial, and virus diseases
- Resistance to insect pests
- Improved agronomic traits
- Drought and salinity tolerance
- Drought and temperature tolerance
- Earliness and early maturity
- Flooding tolerance
- Grain quality improvement
- Salt tolerance
- Tolerance to acid soils
- Tolerance to heavy rainfall

Using the example of wild rice species, Table 3 shows the genome groups of the *Oryza* species in Lao PDR. *Oryza nivara* and *O. rufipogon* are AA genome and part of the primary gene pool of domesticated rice. *O. officinalis* has CC genome. *O. granulata* has GG genome. *O. ridelyi* is tetraploid with HHJJ genomes.

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[20]Y. Kuroda, S. Appa Rao, C. Bounphanousay, K. Koongphanh, A. Iwata, K. Tanaka and Y.I. Sato (2006) *Diversity of wild and weedy rice in Laos.* In *Rice in Laos* (2006). IRRI.

Table 10: Genome groups of the species of the genus *Oryza* in Lao PDR[21]

Species	Eco-type[a]	Chromosome no. (2n)	Genome group	Geographical distribution in Laos	Geographical distribution in World
O. sativa L.	A/P	24	AA	Throughout Laos	Worldwide
O. rufipogon Griff.	P	24	AA	Throughout Laos (mainly in central and southern regions)	Asia, Oceania
O. nivara Sharma et Shastry	A	24	AA	Throughout Laos (mainly in central and southern regions)	Asia
O. officinalis Wall ex Watt	P	24	CC	Khammouane and Savannakhet provinces	Asia
O. ridleyi Hook. f.	P	48	HHJJ	Champassak Province	Asia
O. granulata Nees et Arn. ex Watt	P	24	GG	Luang Prabang, Oudomxay, and Saravane provinces	Asia
Weedy rice	A	24	AA	Central and southern regions	Worldwide

In Thailand some varieties of *Oryza rufipogon* have high resistance to tungro viruses. *O. nivara* contains a gene for resistance to grassy stunt virus that has been transferred to cultivated rice. *O. officinalis* has a high resistance to several pests and diseases. Brown planthopper resistance from a strain in Thailand has been transferred to rice and also released as varieties in Vietnam. *O. ridleyi* is reported to be resistant to stem borers. *O. granulata* is difficult to cross with rice, but hybrids have been reported using embryo rescue techniques.

4.3 OVERVIEW OF CWRS FOUND IN THE MEKONG BASIN

Drawing upon the CWR database, Table 11 shows an analysis of the distribution of different CWR species in the four countries of the LMB. There are a total of 154 species listed with 102 from Thailand, 99 from Vietnam, 52 from Lao PDR and 35 from Cambodia from 33 different genera. The difference in the numbers of species in each country is indicative of the diversity of different ecological conditions within each country as well as the numbers of studies that have been undertaken. Also the whole of Thailand and Vietnam is considered, not just the LMB.

Table 11: Numbers of CWR species found in the four countries of the Lower Mekong Basin

Name	Genus	Cambodia	Lao PDR	Thailand	Vietnam	Total
		Number of CWR species				
Plum	Armeniaca		1		1	1
Jackfruit	Arctocarpus	3	3	8	5	9
Asparagus	Asparagus		1	1	1	2
Bean	Cajanus		2	2	4	4
Camellia	Camellia		1	2		2
Cherry	Cerrasus		1	1	2	2
Lime	Citrus			2	1	3

[21]Y. Kuroda, S. Appa Rao, C. Bounphanousay, K. Koongphanh, A. Iwata, K. Tanaka and Y.I. Sato (2006). *Diversity of wild and weedy rice in Laos.* In *Rice in Laos* (2006). IRRI.

Name	Genus	Cambodia	Lao PDR	Thailand	Vietnam	Total
			Number of CWR species			
Taro	Colocasia	1	1	2	1	2
Cucumber	Cucumis			2		2
Crab or Finger Grass	Digitaria	8	6	12	11	16
Yam	Dioscorea	3	3	8	4	8
Cockspur grass	Echinochloa	1	1	2	1	2
Snow banana	Ensete			1		1
Figs	Ficus	1	5	9	17	19
Strawberry	Fragaria		1		2	2
Bloodgrass	Imperata	1	1	1	1	1
Convolvulus	Ipomea			1		1
Hyacinth bean	Lablab		1		1	1
Apple	Malus		1		1	1
Mango	Mangifera	2		10	5	13
Banana	Musa	1	2	5	4	7
Olive	Olea			1		1
Wild rice	Oryza	6	5	7	3	8
Palm	Phoenix	2	1	3	4	4
Plum	Prunus		1	1	3	3
Pear	Pyrus		3	1	6	7
Brassica	Rorippa	1	2	2	4	4
Grass	Saccharum	2	2	6	5	7
Grass	Sclerostycha			1	1	1
Tomatoes/Eggplants	Solanum			3	1	3
Sorghum	Sorghum			2		2
Peas/beans	Vigna	3	4	5	6	10
Grape	Vitis		3	1	4	5
TOTAL		35	52	102	99	154

Three CWRs are described in further detail below, with a vulnerability assessment carried out on wild rice species.

4.3.1 KENAF - SIAMESE OR THAI JUTE *HIBISCUS SABDARIFFA*

Kenaf, a member of the *Hibiscus* in the Malvaceae family, is one of the world's most economically important crops for soft fiber production, particularly in Asia and the Pacific. The dissemination of kenaf was from Africa through Asia to Central and North America. Kenaf has been a traditional source of fiber for making ropes, sacks, canvas, and carpets as well as recent applications for pulping, papermaking, oil absorption and bioremediation, board and filtration media making, and animal feed. In Asia, kenaf *Hibiscus cannabinus* was first cultivated and commercially used in India around 1900 and is now commercially cultivated in many countries, particularly India, Bangladesh, China, Iran, Indonesia, Myanmar, Vietnam, Cambodia, and Thailand. It grows under a wide variation of climate conditions and stresses.

In Thailand, kenaf was firstly cultivated in 1932 using varieties from China/Taiwan and becoming Siamese or Thai Jute *Hibiscus sabdariffa*. It is mostly grown in the northeastern region of Thailand. The country's kenaf productivity was not enough as demand was increasing. Each year, Thailand needs 220,000-250,000 tons of kenaf for kenaf bag factories, and kenaf has been imported every year since 1927.

A large number of kenaf varieties have been developed to meet the demands for high fiber yielding, for high quality fiber, and for pest and disease resistant varieties. In Thailand, accessions and landraces of kenaf include a wide range of cultivars, e.g., Ton Khiew, Khiew Yai, None Soong 2, and Khon Kaen 60, which give a range of productivity from 312 – 557 kg/rai, have rapid growth, tolerate drought, and can grow in low fertile soils. Most kenaf landraces are sensitive to insect pests and plant diseases. These varieties have played an important role in the further improvement of kenaf as genetic resources.

The maturity of *Hibiscus sabdariffa* is much later than that of other kenaf accessions and normally does not flower in nature at latitudes higher than 30°N. In Thailand, *Hibiscus sabdariffa* is considered a neglected and underutilized species (Cheng et al. 2004).[22]

Hibiscus sabdariffa var. altissima is light sensitive and requires 12 – 12.5 hours daylength for flowering and fruit production. It cannot tolerate strong winds. Although it is well tolerant to drought and water shortage, it requires water throughout 4 – 5 months of its growing period. Water inadequacy will limit its growth and lowers its fiber quality. Too much water will cause diseases such as collar rot. Rainfall availability, distribution, and amount are thus important during the growth period.

Hibiscus sabdariffa is produced in abundance from large-scale commercial production systems, but also from local-scale farming systems. Stems and barks are mainly used for fiber. Leaves are used for animal feed. It is considered an economic plant with high market demand, both in country and for export. Market price is 60 – 70 USD/ton. The present demand in Thailand is as high as 200,000 tons/year.

Hibiscus sabdariffa is harvestable after 140 – 160 days of cultivation. After harvest, retting under water is a very important process. Appropriate water depth, water flow, and water temperature determine the microbial activities and thus determine the length of retting time. Good water quality is also required for retting. *Hibiscus sabdariffa* is threatened by plant diseases and insect pests.

4.3.2 MANGOS

There has been growing interest in the conservation of wild relatives and landraces of fruit trees. In most tropical regions, the rich diversity of native fruit species is an important and valuable resource enhancing nutritional security, reducing poverty, and protecting the environment. Many species are currently underutilized. Many are also threatened and vulnerable due to habitat loss. Wild mangos are among significant fractions that are on the verge of disappearance. Some wild fruit tree species are related to economic fruit tree species. In Thailand, for example, the existence of 18 species of the genus *Mangifera* is recorded. The commercial fruit industries rely on improved varieties supplemented with these local varieties.

The genus *Mangifera* is indigenous to Southeast Asia and mango (*Mangifera indica)* is the most important species in this genus. Currently, mango is grown commonly throughout tropical areas. At least 69 species in this genus have been described based on morphological characteristics (Eiadthong et.al. 2000). Thailand possesses at least three species in the subgenus *Euantherae,* i.e., *M. caloneura, M. cochinchinensis,* and *M. pentandra,* and four species in the subgenus *Limus,* i.e., *M. lagenifera, M. foetida, M. macrocarpa,* and

[22] http://kanchanapisek.or.th/kp6/BOOK17/chapter7/t17-7-11.htm; http://it.doa.go.th/vichakan/print.php?newsid=29

M. odorata, which are considered the most primitive and possibly ancestral species of mango. The existence of so many primitive species indicates that Thailand has a long history of evolution and diversification of the genus *Mangifera* and of *M. indica* since the Oligocene or Miocene.

Of the 70 species in the genus *Mangifera*, a total of 20 species were reported to exist in Thailand. Among them, *M. caloneura, M.foetida, M. laurina, M. odorata, M. pentandra,* and *M. sylvatica* were cultivated or semi-cultivated for their edible fruits, while *M. indica, M. collina,* and *M. linearifolia* are endemic species. The other 11 species are *M. caesia, M. cochinchinensis, M. flava, M. gedebe, M. gracilipes, M. griffithii, M. lagenifera, M. longipetiolata, M. macrocarpa, M. oblongifolia,* and *M. quadrifida.*[23]

Distribution of *Mangifera* spp. in other LMB countries appears to be more restricted as shown in the table below but this is likely due to absence of appropriate research.

Species	Cambodia	Lao PDR	Thailand	Vietnam
Mangifera caloneura			X	
M. cochinensis				X
M. collina			X	
M. dongnaiensis				X
M. flava	X		X	X
M. foetida			X	
M. linearifolia			X	
M. longipetiolata			X	
M. macrocarpa			X	
M. minutifolia				
M. oblongifolia			X	
M. odorata			X	X
M. sylvatica	X		X	

Mangifera foetida occurs wild in dipterocarp and lowland forests where there is abundant rainfall evenly distributed over the year at elevations of above 1,000 m asl. It is native to Thailand and also found in Cambodia, Vietnam, and probably in Lao PDR. Seedlings require much moisture and light shade. They tolerate much shade but later on grow well in full light. It is rarely cultivated, but has proven to be a suitable rootstock for cultivars of *M. indica* in a moist climate.

Mangifera caloneura is native to northern and northeastern Thailand and is a remnant of the old forest. It is considered to be one of the most primitive wild forest mango species in Thailand. This wild mango is found in dipterocarp forests, prefers open areas with strong sunlight, and is widely distributed in the north, northeast, southwest, southeast, and the south of Thailand. The fruits are smaller and more sour than those of cultivated mangos. It is widely and popularly consumed as vegetables and snacks by the locals. It can survive without any particular management.

Wild forest mangos native to Thailand such as *Mangifera foetida* and *Mangifera caloneura* can be found in dipterocarp forests, lowland rainforests, and undisturbed forests. They prefer open areas with strong sunlight. They can adapt to abundant rainfall. Fruits are available and abundant in summer.

[23] Eiadthong, W., Yonemori, K., Sugiura, A., Utsunomiya, N. and Subhadrabandhu, S. (2000). *Records of Mangifera species in Thailand.* Acta Horticulturae No. 509: 213 – 223, 2000.

Various parts including fruits (both raw and ripe), stems, leaves, seeds, flowers, and sap are used for a wide range of purposes including food, fruit, vegetable, beverage, pickles, medicine, tattooing, light constructions, plywood, furniture, and ornament. There is a possibility for use as breeding materials of common or commercial mango. Fruits are threatened by pests and diseases, but trees still remain.

4.3.3 WILD RICE

Because of the standing of rice as the staple food for the region, the following discussion focuses on wild rice – *Oryza* spp. – as a CWR of critical importance. There are 8 species (6 full species with 2 additional varieties) of wild rice found in the Lower Mekong region, 7 in Thailand, 6 in Cambodia, 5 in Lao PDR and 3 in Vietnam. These are described below.[24]

Wild Rice Species diversity

According to Ma Lizbeth Barona (2012), scientists are scouring the deep and "wild" end of the rice gene pool to help find hidden traits and genes that can facilitate breeding new rice varieties better at thriving and producing food in difficult environments. Although the genetic diversity of cultivated rice is already rich, widening its diversity through its wild relatives is important, as they possess high-value traits that can help breeders make new rice varieties that can stand up to climate change and other challenges. Rice has wild or undomesticated relatives, called "wild rice," that are rich repositories of genetic material that can provide tolerance of environmental stresses and help improve yield. Wild rice diversity is considered to be in the periphery of the rice gene pool, with the center being around varieties cultivated from the two main species of rice: *Oryza sativa* and *O. glaberrima*. In total, there are 35 species with 10 sub-species and varieties of rice listed in the CWR database. Wild rice's richness in desirable traits, such as pest and disease resistance, is born out of centuries of surviving in harsh environments—untended and away from human intervention. These important traits have been infused in cultivated varieties to help protect them against pests and diseases that have affected thousands of hectares of rice farms and have caused millions of dollars of damage.

The distribution of the wild rice species in the four LMB countries is as follows:

Species	Cambodia	Lao PDR	Thailand	Vietnam
Oryza granulata		X		
O. meyeriana (only S. Thailand)			X	
O. nivara	X	X	X	X
O. officinalis	X	X	X	X
O. ridleyi	X	X	X	
O. rufipogon	X	X	X	X

Distribution and habitats

Much of the distribution of the different wild rice species has already been included in the narrative above. This distribution can be attributed to the different ecozones that make up the region. Of the various wild rice species found within the LMB, *Oryza rufipogon* and *Oryza nivara* are widely distributed through many of the ecozones.

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[24] These descriptions are largely derived from: Y. Kuroda, S. Appa Rao, C. Bounphanousay, K. Koongphanh, A. Iwata, K. Tanaka and Y.I. Sato (2006). *Diversity of wild and weedy rice in Laos.* In *Rice in Laos* (2006). IRRI.

The other species have a more limited range. *O. granulata* is more of a hill species and restricted to the high-elevation moist broadleaf forests and *O. officianalis* is found in the upper and middle floodplains and low-mid moist broadleaf forest ecozones.

In Lao PDR, *O. ridleyi* has only been found in one location in the mid-elevation dry broadleaf forest ecozone.

Ecological and Climate tolerances

Very little information is available on the ecological and climate tolerance of wild rice species. Table 12 shows the responses of cultivated rice to critical temperatures at different stages of growth. There is no reason to suppose that *O. rufipogon* or *O. nivara* would differ from this, though *O. granulata* may have a lower temperature tolerance.

Table 12: The response of the rice plant to varying daily mean temperature at different growth stages[25]

Growth stages	Critical temperature (°C)		
	Low	High	Optimum
Germination	10	45	20–35
Seedling establishment	12–13	35	25–30
Rooting	16	35	25–28
Leaf elongation	7–12	45	31
Tillering	9–16	33	25–31
Primordia initiation (panicle)	15	–	22–23
Panicle differentiation	15–20	38	–
Anthesis	22	35	30–33
Ripening	12–18	30	20–25

Source: Yoshida (1981).

There are distinct ecological preferences between the wild rice species. *O. rufipogon* is a deep water species that can live in permanently wet soil conditions. It propagates vegetatively through replication at the nodes in the culms and through seeds. In comparison *O. nivara* prefers shallower water and requires a period of drying out. It propagates through its seeds.

O. granulata is a hill species that prefers upland forest areas. *O. officinalis* can withstand a variety of different conditions from dry to permanently wet, and can be found in both grasslands and along forest margins. *O. ridleyi* has a restricted range and can grow in shaded conditions along river banks and canals.

In the past when wild rice was more abundant, the poor people used to harvest it for subsistence consumption. Wild rice is tolerant of deep inundation, drought, and acidity. Productivity of wild rice is low but the rice is of high quality. Wild rice provides very good habitat for fish and wildlife, especially water birds in the flood season.

[25]Quoted from: J. Basenayake, T. Inthavong, S.P.Kam, S. Fukai, J.M. Schiller and M. Chanphengxay (2006). *Climatic diversity within rice environments in Laos*. In *Rice in Laos* (2006). IRRI.

Table 13: Matrix showing the distribution of wild rice species in the different ecozones

Species	Ecozone										
Wild Rice	High Elevation Moist Broadleaf Forest (North Indochina)	High Elevation Moist Broadleaf Forest (Annamites)	Upper Flood Plain	Low/mid Moist Broadleaf Forest	Mid Elevation Dry Broadleaf Forest	Mid Flood Plain	Low Elevation Dry Broadleaf Forest	Lower Flood plain	Tonle Sap Swamp Forest and Floodplain	Low Lying Acidic Delta	Alluvial Fresh water Floodplain	Delta/ Mangrove and Saline Water
O. granulata	X											
O. nivara	X		X	X	X	X	X	X	X		X	
O. officinalis			X	X		X						
O. ridleyi					X							
O. rufipogon	X		X	X	X	X	X	X	X	X	X	

Trends and threats

The distribution of wild rice species is declining largely because of changes in the habitat. These changes are caused by conversion of the habitat into more intensively cultivated paddy lands, with little space for bankside or roadside habitats suitable for these *Oryza* species. Irrigation developments near annual populations of *O. nivara,* which require a definite dry season, may tend to replace these populations with perennial plant species. Rapid economic development also leads to loss of habitat, especially the spread of urban areas. For upland varieties, the intensification of agroforestry crops such as rubber will reduce the habitat available for species such as *O. granulata*.

In Thailand, the rate of loss of biomass (size of population x cover rate) over a 10-year period to 1994 was 21% for *O. rufipogon* and 79% for *O. nivara.*

For the landraces, while most of these are still cultivated, they are principally used for domestic consumption rather than for sale, simply because of taste preferences amongst the local people. However, because yields tend to be lower than the high-yielding varieties, there is an increased tendency for these landraces to fall into disuse. The Lao PDR government has a target of producing 4.2. million tonnes of rice by 2015 on a total area of about 800,000 ha, which would require a yield of about 5 tonnes per ha. In 2011, the annual production was about 3.2 million tonnes. This target is extremely high and could only be reached by progressive intensification of rice cultivation. This would mean that much less of the landraces would be cultivated.

4.4 VULNERABILITY ASSESSMENTS FOR WILD RICE

4.4.1 ORYZA NIVARA


Oryza nivara is considered to be an ancestor of the indica cultivars of rice. It is a wild annual species that propagates by seed and grows in an open air, full sunlight, and shallow water environment. It has short to intermediate height, mostly < 1.5 m, and does not have floating ability. Most (87%) of *Oryza nivara* plants reach maturity during September. It flowers over an extended period between July – November. After flowering, *Oryza nivara* plants wither and die, even in areas with favorable moisture conditions. Seeds have long awns, are easy to fall off, have long duration of dormancy, and become black when mature. Seeds may be distributed by ducks, cattle, and goats. This wild rice is easy to outcross with other cultivars (with 5 – 20% outcrossing rate).

Oryza nivara is widely distributed through many of the ecozones between 35˚N - 35˚S latitude, within an elevation range of 0 – 1,800 m asl. It is found in Bangladesh, Cambodia, China, India, Lao PDR, Malaysia, Myanmar, Nepal, Sri Lanka, Thailand, and Vietnam.

It is found in high-elevation moist broadleaf, low-mid moist broadleaf, mid-elevation dry broadleaf, and low-elevation dry broadleaf forests. Natural habitats are on edges of deep depressions, swampy areas, marshes, swamps, lakes, ponds, lowland areas, banks of canals and streams, farm ditches, ricefields, fish ponds, and roadside ditches.

It prefers shallow water up to 30 cm (and is limited to a water depth of 50 cm) and requires a period of drying out in seasonally dry and open habitats. It is not found in artificial reservoirs or along main rivers due to relatively high water level fluctuations. But an observation in Lao PDR reported that this species was found in permanent water deeper than 1 m. Suitable temperature range varies according to life stages:

- Germination: 10 – 45˚C (optimal 20 - 35˚C)
- Seedling establishment: 12 - 35˚C (optimal 25 - 30˚C)
- Anthesis : 22 - 35˚C (optimal 30 - 33˚C)
- Ripening : 12 - 30˚C (optimal 20 - 25˚C)

Oryza nivara requires a definite dry season. Natural rainfall accounts for most of the water source in its habitats (87%). Seasonal fluctuation in water level affects its distribution.

Oryza nivara is a significantly important genetic resource for conservation and for rice breeding programs to improve some characters of cultivated rice. It is germplasm for pest and disease resistance, for grassy stunt virus/disease resistance, and brown planthopper resistance. It also carries aroma allele.

Threats facing *Oryza nivara* include genetic erosion, and habitat destruction and loss. Natural habitats are threatened by various development projects, irrigation development, land use change, shift to monoculture, human habitation, and urbanization. Natural threats include birds and buffaloes. Its IUCN Red List status is 'Not Evaluated'. In each of the hotspot provinces considered, with habitat loss and the lack of recognition of the species for its conservation value, **the non-climate vulnerability is considered to be High to Very High**.

In Mondulkiri (the hotspot with the most extreme climate change patterns), increase in temperature will exceed optimal temperature ranges for all life stages (germination, seedling establishment, anthesis, and ripening) of *Oryza nivara*. Decrease in soil water availability during the early flowering period, increase in percentage of drought years, decrease in dry season rainfall, and increase in wild fire risk will be future threats.

Chiang Rai and Khammouan will experience increases in temperature slightly beyond the optimal range for *Oryza nivara*, but still within the comfort zone; and have slight decreases in percentage of drought years and less risk of wild fire. Gia Lai will have higher temperatures beyond the comfort zone but will have no change in drought patterns.

In all four hotspots evaluated, consistently higher rainfall in all wet season months beyond the comfort zone plus bigger and more frequent storms will affect growth and seedlings; *Oryza nivara* has short to intermediate height and does not have floating ability.

To some extent, *Oryza nivara* is able to adapt to unstable transient habitats. However, in Mondulkiri *Oryza nivara* will be highly vulnerable to future climate change. In Chiang Rai, Gia Lai, and Khammouan, it will be moderately vulnerable.

Recommended adaptation measures

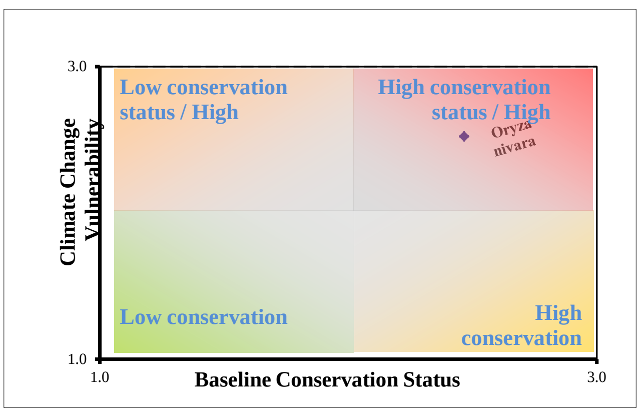
Short term

- Protect and conserve natural habitats and important ecosystems where *Oryza nivara* grows
- Collect seeds and establish seedbank for ex-situ conservation

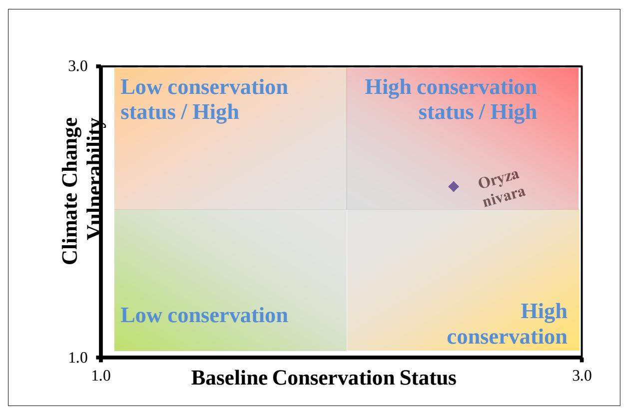
Long term

- Increase 'Protected Areas/Ecosystems' in order to maintain the habitats and to safeguard existing wild populations
- Increase the effectiveness of 'Protected Area Systems' in order to reduce encroachment, land use change, intensive mono-cultivation, fire events, habitat deterioration and loss
- Inventory and research *Oryza nivara* habitats, existence, and its ecological requirements

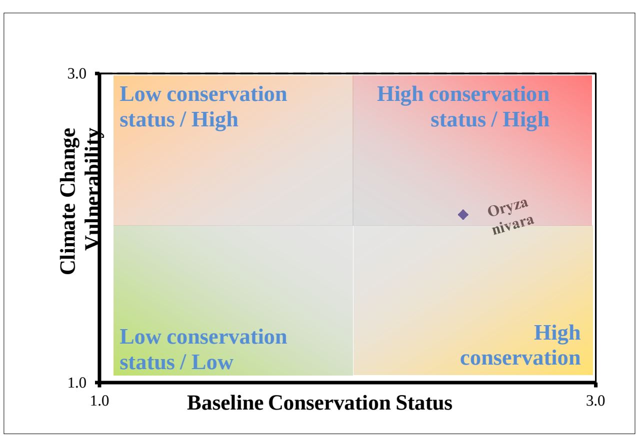
Mondulkiri



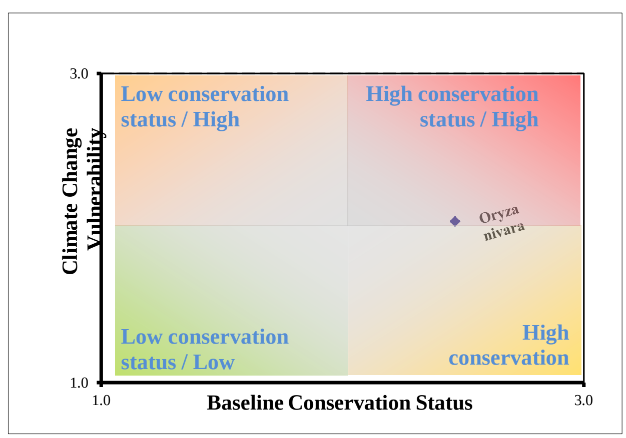
Gia Lai



Chiang Rai (west)



Khammouan



4.4.2 ORYZA OFFICINALIS

Oryza officinalis is a perennial wild rice. It is 30 – 200 cm high. Its habit of herbaceous clumps can produce culms up to 3 m. It has an erect tiller, broad leaf with no hair, and black stigma. It is wind pollinated. Seeds have a round shape, become black when mature, are with awn, and are easy to fall off. Though usually rhizomatous, it has smaller spikelets and more panicle branches of equivalent length from the lower panicle nodes. It flowers in early August.

Oryza officinalis has a wide distribution in tropical Asia between 35˚N - 35˚S latitude and an elevation range of 0 – 1,800 m asl. It is found in all LMB countries, in the upper and middle floodplains and low-mid moist broadleaf, evergreen, and deciduous forests.

Oryza officinalis usually grows in full sunlight and occasionally in partial shaded or half-shaded conditions. It prefers alluvial silt or sandy soils on limestone. It withstands a variety of different conditions, from seasonally dry to permanently wet environments. Habitats include edges of forests, fruit orchards or under shade in citrus plantations, ricefields, open grasslands, moist habitats such as banks of canals, streams, waterways in forests, ditches, seasonally wet areas, low and open vegetation, swamps, marshes, ponds, lakesides, roadside ditches, and shady areas.

Farmers use this species to prevent soil erosion in fruit or citrus orchards. Its Chinese name is 'medicinal rice', so it probably also has medicinal properties. It has a wide range of high resistance to several pests and diseases and is an important source/trait of brown planthopper resistance. Rice flowers show increased sterility at higher temperatures and *Oryza officinalis* has one of the most important early-morning flowering traits to reduce high temperature-induced sterility at anthesis. *Oryza officinalis* also carries aroma allele.

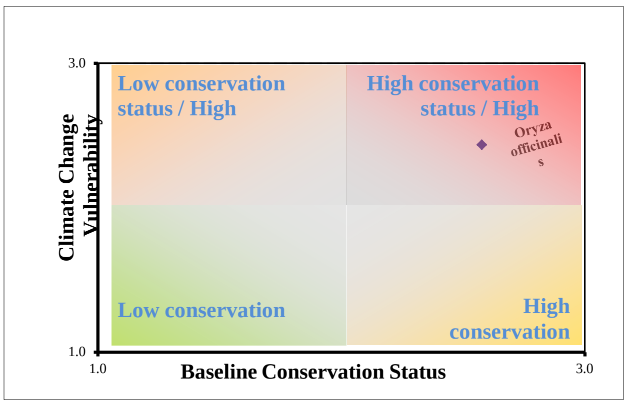
Rapid economic development, urbanization, and intensive monoculture lead to loss of its habitats. Populations of *Oryza officinalis* are in decline, being seriously threatened by habitat changes, fragmentation, and loss. It is very rarely found in natural habitats and may be considered 'endangered' even though its IUCN Red List status is 'Least Concerned (LC)'. In each of the hotspot provinces, with loss or change of suitable habitat and the lack of recognition for its conservation value, ***Oryza officinalis* is considered to have a High non-CC Vulnerability.**

Increase in future temperatures in hotspots such as Mondulkiri (up to 44˚C in Mondulkiri) significantly exceeds the comfort zone and will induce sterility of *Oryza officinalis*. Significant increase in percentage of drought years (up to 80% in Mondulkiri), decrease in dry season rainfall, increase in dry season temperature, decrease in soil water availability especially during its flowering period, and increase in wild fire risk will affect its survival and growth. Higher rainfall in all wet season months beyond the comfort zone and bigger and more frequent storms will also affect its existence.

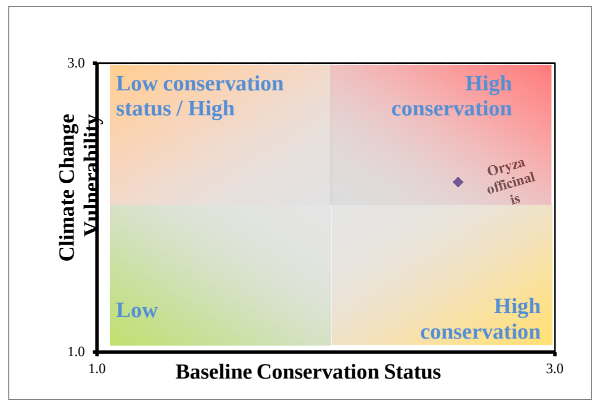
In Chiang Rai, future temperatures will slightly increase beyond the comfort zone for *Oryza officinalis*. Chiang Rai will have a slight increase in rainfall beyond the comfort zone, bigger and more frequent storms, and less risk of drought and wild fire. Gia Lai and Khammouan will have increase in temperatures beyond the comfort zone, drier dry seasons, slight decrease in dry season soil water availability, more exposure to wild fire, increase in rainfall slightly beyond the comfort zone, and bigger and more frequent storms.

Oryza officinalis has intermediate height, usually grows in full sunlight, open areas and, to some extent, withstands a variety of different conditions from seasonally dry to permanent wet. It has an early-morning flowering trait to reduce high temperature-induced sterility at anthesis. Key future climate change threats facing *Oryza officinalis* are increases in temperature and drought, decrease in dry season rainfall and soil water availability, and increase in wet season rainfall and extreme events. *Oryza officinalis* in Mondulkiri (the hotspot with the most extreme climate change patterns) will be highly vulnerable to future climate change. *Oryza officinalis* in Chiang Rai, Gia Lai, and Khammouan will be moderately vulnerable.

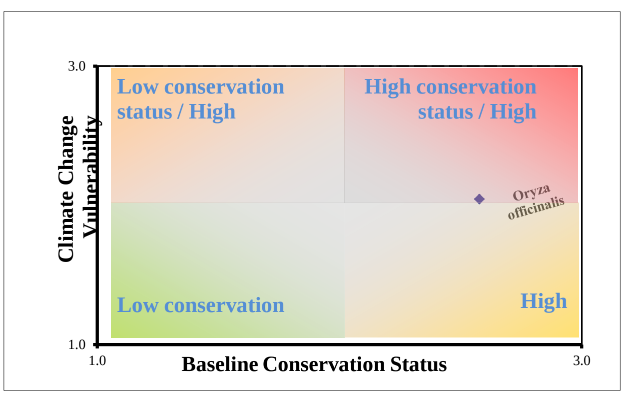
Mondulkiri



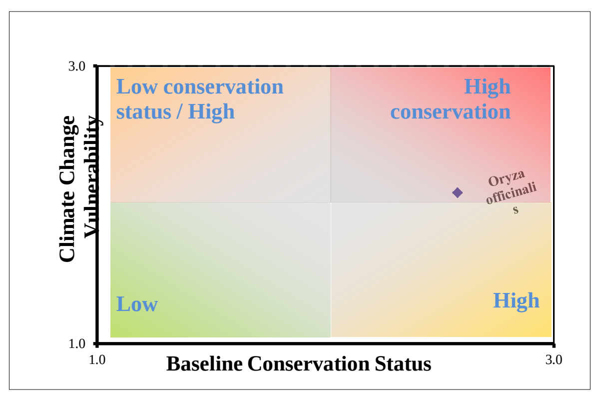
Gia Lai



Chiang Rai (west)



Khammouan



Recommended adaptation measures

Short term

- Protect and conserve natural habitats and important ecosystems where *Oryza officinalis* grows
- Collect seeds and establish seedbank for ex-situ conservation

Long term

- Increase 'Protected Areas/Ecosystems' in order to maintain the habitats and to safeguard existing wild populations

- Increase the effectiveness of 'Protected Area Systems' in order to reduce encroachment, land use change, intensive mono-cultivation, fire events, habitat fragmentation, deterioration and loss
- Inventory and research *Oryza officinalis* habitats, existence, and its ecological requirements

4.4.3 ORYZA GRANULATA

Oryza granulata is widely distributed in Asia, but is mainly found in northern agricultural areas of Lao PDR and Thailand. It is generally found in shaded, upland forested habitats in hilly and mountainous regions. It is photo-period insensitive and flowers all year round. It has a low level of genetic diversity within populations and is difficult to cross with rice, but hybrids have been reported using embryo rescue technique.

It is a perennial, short grass (usually <1 m) with lanceolate and dark green leaves; compact panicles usually without secondary branching; spikelets 5.2-6.4 mm long and 2.4-2.7 mm wide, always awnless, with granulated texture to the lemma and palea; and anthers 2.8-3.6 mm long. It is found in deciduous forests, bamboo thickets, and rarely on grass slopes; on limestone hills or mountains; in damp places beside streams, waterfalls, near water holes, or on seasonally dry, sloping land. It grows in sandy, lateritic soils and organic loamy soils. It is not found in standing water and usually grows in complete shade. A vulnerability assessment has not been completed for *Oryza granulata.*

A close-up of O. granulata panicle

Habitat of O. granulata: forest floor, Thailand[26]

4.4.4 ORYZA RIDLEYI

Oryza ridleyi is fairly narrowly distributed in Southeast Asia, occurring in Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Papua New Guinea, and Thailand. It is a perennial, erect to semi-erect tufted grass, usually 1-2 m tall; panicles open; spikelets 7.6-12.7 mm long and 1.6-2.9 mm wide, with rows of trichomes down the length of the papery lemma and palea; sterile lemmas are narrow and flexuous, and shorter than fertile lemmas; awns are about 1 cm long; and anthers are 2-3.4 mm long.

[26] Photos from: www.knowledgebank.irri.org/extension/oryza-granulata.html

Oryza ridleyi has been found in only one location in Lao PDR in Champasak Province, although it is also reported in Cambodia and Thailand. In Lao PDR it was found growing in shaded conditions under bamboo and trees on the bank of a canal where water was stagnant. It is reported to flower in September. Seed production is low and propagation mainly occurs through rhizomes, which remain dormant during the dry season. It is reported to be resistant to stem borers.

A vulnerability assessment has not been carried out on *Oryza ridleyi.*

Panicles of *Oryza ridleyi*

Oryza ridleyi growing in forest, Malaysia.[27]

4.4.5 ORYZA RUFIPOGON

Asian wild rice (*Oryza rufipogon*) is found in a wide range across the eastern and southern part of Asia and is recognized as the direct ancestor of cultivated Asian rice (*O. sativa*). Very diverse populations of this perennial species (genome AA) have been found from north to south, especially in the Mekong Delta. Widespread and well-established populations of *O. rufipogon*, together with annuals such as *O. nivara* and weedy rice *O. spontanea,* are usually found along borders of rivers and canals of the delta, as well as occasionally in rice fields or marshes. Wild and weedy rice species are most common in abandoned fields and village ponds.

The cultivated rice species (*O. sativa*) hybridizes with *O. rufipogon* or *O. nivara;* then the hybrids backcross in either direction and produce morphological intergrades. These are known as *O. sativa* f. *spontanea* types. They invade cultivated fields and pose as weeds. *Oryza rufipogon* grows in swamps, often suspended in water or procumbent on the ground. The panicles are lax and the spikelets are long (7–10 mm) and slender (2.2–.5 mm wide), well-filled with anthers, and shatter easily. The shattering is also noticed in hybrids (*O. rufipogon*/*O. sativa*) and weedy rice, creating problems in rice fields (B.B. Baki et al, 2000).

Oryza rufipogon is a widely distributed tropical plant growing in shallow water environments. The species is widespread within the LMB and other countries in South, Southeast Asia, and the Pacific including Australia, Bangladesh, China, India, Indonesia, Malaysia, Myanmar, Nepal, Papua New Guinea, the

[27] Photos: http://www.knowledgebank.irri.org/extension/oryza-ridleyi-hook-f.html

Philippines, and Sri Lanka.[28] The distribution range has probably remained the same but populations have declined due to conversion of habitats to agriculture. At present, *O. rufipogon* occurs in about 1,000 hectares of wild rice in Tram Chim National Park in Dong Thap Province and in another 150 hectares in Lang Sen Wetland Reserve in Long An Province. In the news, a farmer in Tan Chau District, An Giang Province has created 19 new strains of rice by cross-pollinating with wild species such as *O. rufipogon*; highly resistant strains to brown plant hopper and rice blast diseases were created from crossing with the wild varieties.

Oryza rufipogon grows in irrigated fields, pools, ditches, and sites with stagnant or slow running water. It is commonly found in areas with water depths from 0.2 to 4 meters. It grows in clay/loam soil and black soil. It reproduces fast both by seeds and rhizome propagation. It occurs at altitudes from 0 m to 1000 m and is suited to sites that support populations of cultivated rice.

The plant does not require a large habitat as it can occur in small clumps. Dispersal is through seeds carried by water, birds, and rats and rhizome propagation. In deeper water areas, *Oryza rufipogon* produces more seeds than in shallower water. The plant is not threatened from human uses except where the meadow is used for buffalo grazing. The plant contains a drought resistant gene.

Studies have found that there is considerable gene flow from cultivated rice to wild rice and this may alter the genetic structure of natural populations of *O. rufipogon* and eventually lead to its genetic erosion. It has been suggested that the existence of "pure" forms of *O. rufipogon* is only conceptual, because of the continual crossing among cultivated and wild rice types, resulting in a conglomerate of hybrids. Thus confusion exists taxonomically about the delineation of species. This may be why some authors consider the name *O. rufipogon* to be that of a perennial grass with rhizomes, while others say it is an annual.

No particular conservation measures have been undertaken for *O. rufipogon* but the plant is included in some wetland protected areas; as noted above, about 1,000 hectares of this species is found in Tram Chim National Park in Dong Thap Province in the Mekong Delta in Vietnam. The plant does not have a national conservation status. It is not assessed by the IUCN Red List and is also not in the Catalogue of Life.

Climate change

Exposure to changes in temperature, flood, drought, and rainfall does not seem an issue to *O.rufipogon*. The wild rice flowers at night. This helps avoid the heat of the day that leads to reduction of yield. When exposed to drought conditions in elevated spots, wild rice stems die off in the dry season and recover quickly when moist conditions return. Wild rice as a semi-aquatic plant tolerates deep inundation and, as noted above, is known to occur in areas with water depths from 0.2 to 4.0 meters. Extreme events such as high winds during the rainy season might cause damages to flowers and formation of milky grains as *O.rufipogon* flowers from September to November during the rainy season.

[28] http://www.knowledgebank.irri.org/extension/oryza-rufipogon-griff.html

Information of heat tolerance of *O.rufipogon* is not available but the cultivated rice *O.sativa* can tolerate up to 48^{0}C. The species possesses traits that can help it bounce back from a new climatic environment: as a semi-aquatic species, increase in precipitation is not a problem and the species grows in a wide diversity of ecosystems from seasonally dry land to permanent water holes like pools and ditches holding stagnant or slow running water.

Occurring in grassland areas, the plant is susceptible to wild fires in the dry season but wild fires do not kill the plant. The above ground stems might be burnt off but recover quickly within days when moist conditions returns.

Wild rice varieties contain many favorable genes that have been removed from cultivated rice through forced selection. These favorable genes enable the wild rice species to resist undesirable environments as well as many diseases and pests. *O.rufipogon* is recognized as the main genetic source for both drought tolerance and pest resistance in rice breeding programs as it can be crossbred with cultivated rice to produce fertile plants.

Studies found that wild rice varieties have much more genetic diversity than cultivated rice. It is suggested that during the course of evolution from wild rice to cultivated rice, many alleles were lost through natural and human selections.

Seeds are typically dormant at maturity. Dormancy is partly due to the presence of inhibitors in the seed coat. Depending on the biotype and environment, seeds may remain dormant and viable for up to three years or more under field conditions. Many seeds decay during long periods of flooded conditions. Germination typically occurs between 15-40^{o}C. Seeds often germinate slightly sooner and at lower temperatures than commercial rice seeds. Some biotypes emerge from soil depths of up to 12 cm.

Habitat loss will increase as pressure on land use for cultivation will increase with climate change and population growth. In Kien Giang loss of habitat due to conversion to agriculture and infrastructure development will **significantly increase the baseline non-CC vulnerability to High** for *O. rufipogon*.

However, *Oryza rufipogon* has **a Low vulnerability to climate change** because it possesses many traits that allow it to adapt to harsh environments. On the contrary, many of the genes for adaptation to changing environments have been lost in cultivated rice during the course of evolution from wild rice to cultivated rice through natural and human selections.

Adaptation Recommendations

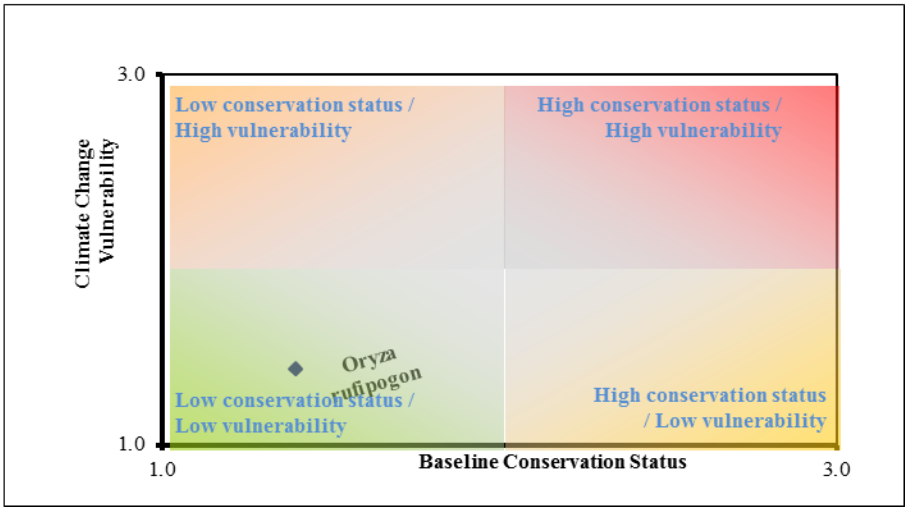
Climate changes do not seem to present any threat to *O.rufipogon*. The threats to the plant are the major baseline ones that will increase in the future:

1. Loss of habitat due to increasing conversion to agriculture
2. Genetic erosion due to genetic flow between cultivated rice and wild rice in proximity

For the importance of wild rice as a germplasm that contains many desirable genes for creating hybrids with cultivated rice that can adapt to changing environments and for the value of habitat for wildlife that *O.rufipogon* provides, the species should be conserved. To address the major threats to the species the following measures are recommended for both short and long term:

1. Protect and reintroduce the species in the wetland protected areas where they naturally occurred in the past

2. Prevent genetic erosion by ensuring that there is no cultivated rice in the proximity of the wild rice



4.4.6 WEEDY RICE

Weedy rice (*O. sativa var. spontanea*) is the result of interspecific hybridization between cultivated rice *O. sativa* and wild rice species. It is common in the central and southern plains of Lao PDR where both *O. rufipogon* and *O. nivara* exist. They have characteristics that resemble both wild and cultivated forms and until the weedy rice flowers it is difficult to distinguish from the cultivated forms. After flowering the panicle and grain characteristics differ. Weedy plants found in paddy conditions have wild-rice specific traits such as small grain size, non-glutinous endosperm, spikelets with long awns, red pericarp and open panicle shape. Weedy rice has been used as a source of cytoplasmic male sterile lines for hybrid rice.

High densities of weedy rice have the effect of reducing the quality and quantity of cultivated rice. It is considered as an aggressive weed by farmers and it is difficult to remove once it contaminates improved rice varieties. In Lao PDR the occurrence of weedy rice has declined in recent years due to the development and distribution of improved rice variety seeds.

Weedy rice occurs throughout South and Southeast Asia: Bangladesh, India, Indonesia, Malaysia, Pakistan, the Philippines, and Vietnam. It is highly variable and thought to originate from outcrosses to wild species (*O. nivara, O. rufipogon*) or as a result of outcrossing within domesticated rice. It is distinguished by the key weedy traits of ready panicle shattering and variable secondary dormancy. It is highly adapted to a wide range of environmental conditions, dryland to deepwater culture. It commonly possesses red pericarp, which requires additional milling, thereby reducing the quality of milled rice.

Weedy rice is a major weed in direct-seeded rice. It reduces rice yields and is an alternate host of rice insects, diseases, and nematodes. It is often spread by contaminated rice seeds. Management may be through cultural control: the use of crop seed free from wild rice, crop rotation, soil puddling, hand weeding of initial infestations, and water management are possible components of an integrated approach to control weedy rice. Established infestations will need to be addressed through the use of stale seedbeds or water seeding or transplanting. And by chemical control: the application of glyphosate before land preparation or seeding is reported to be effective.

In response to climate changes, no assessment of its vulnerability has been carried out, but it is possible that weedy rice will have distinct genetic advantages compared to cultivated varieties, and as such it could become more of a problem in the future as climatic conditions change.

4.4.7 RICE LANDRACES – FLOATING OR DEEPWATER RICE

In addition to the wild rice species, there are a huge number of landraces or local varieties of rice that have been grown traditionally in the region. In Lao PDR alone, a total number of 13,192 samples of traditional varieties of rice have been collected between 1995 and 2000,[29] and a further 2,000 more accessions have been made since then.[30] The germplasm from all of these have been stored in four separate gene banks. Although these have not been DNA fingerprinted, it is probable that at least 5,000 different landraces of rice occur in Lao PDR alone, making it second only to India in the number of accessions and landraces.

Floating rice (alternatively known as deep water rice) is one of the particular landraces found in the Mekong Delta. Farmers in areas prone to deep, prolonged flooding such as Long Xuyen Quadrangle and the Plain of Reeds cultivated floating rice varieties. Kien N.V. et al. (2012) report that floating rice or deep water rice has been planted in the Mekong Delta for 150 years. The stalk of floating rice can grow to as long as 5-6 meters in a short period of time to keep up with the rising flood water level so they can tolerate an inundation of up to 4 meters deep for 3 to 5 months. In Bangladesh, floating rice could elongate by 6-7 cm a day (Catling 1992:11 as cited by Kien N.V. et al. 2012). Yields of floating rice are low at around 1.0-3.0 tons/hectare. Kien N.V et al. (2012) cited Brammer (1990) saying that farmers planting floating rice do not have to use much fertilizer for floating rice relies on blue-green algae species in flood water for nitrogen fixation.

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[29]S. Appa Rao, J.M. Schiller, C. Bounphanousay and M.T. Jackson (2006). *Diversity within the traditional rice varieties of Laos.* In *Rice in Laos* (2006). IRRI

[30] B. Samson (IRRI). Pers comm.

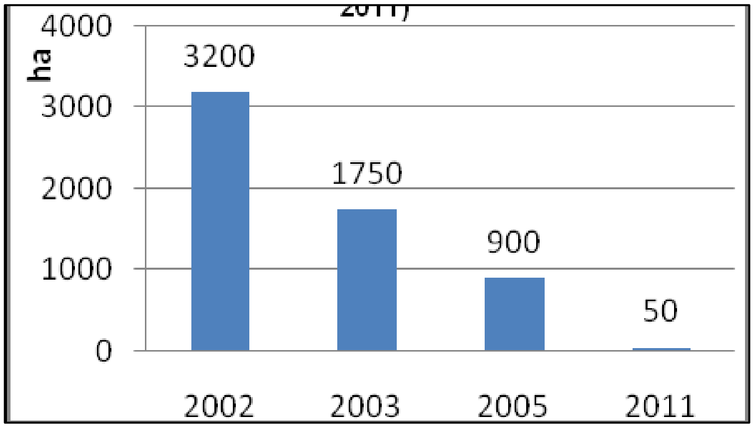


Figure 5: Extent of floating rice from 2002 to 2011

Deepwater rice used to be widely spread. It was grown on the flood plains and deltas of rivers such as the Ganges and Brahmaputra of India and Bangladesh, the Irrawaddy of Myanmar, the Mekong of Vietnam and Cambodia, the Chao Phraya of Thailand, and the Niger of West Africa. In Asia it was grown from latitude 27°N in Assam and Uttar Pradesh, India, to latitude 3°S in Indonesia. In the LMB, floating rice used to be distributed widely in deeply flooded floodplain areas. The potential distribution range has probably remained the same but populations have declined rapidly due to conversion to high-yielding rice.

The Mekong Delta in Vietnam (Vo Tong Xuan and Matsui 1998:41 as cited in Kien et al. 2012) had about 500,000 hectares of floating rice in 1974. The two most common varieties of floating rice in the delta were *Oryza sativa* L and *Oryza prosative*. An Giang Province alone had 250,000 hectares of floating rice before 1975. From 1975 to 1994, about 80% of the area of floating rice disappeared due to changes in land use policy, national food security targets, and the construction of water regulation infrastructures (Karonen 2008:208 as cited in Kien N.V. et al. 2012). At present, only about 50 hectares of floating rice remain in Vinh Phuoc Commune, Tri Ton District and is on a declining trend. Because of this small area remaining in Kien Giang, its **non-climate vulnerability is considered to be Very High**.

The plant does not require much habitat as it can occur in small stands. Seeds can disperse by water flows, birds, and rats. The submergence-induced growth enables the semi-aquatic plants to keep part of their foliage above the rising waters and to avoid drowning. It is also adapted to drought conditions at early stages of growth.

In terms of value, floating rice fetches a little higher price than regular rice, but the yield is much lower and this is the key threat to the plant as not many farmers want to continue to plant this variety of rice. Floating rice tends to share the same pest fauna as regular rice: stem borer, grasshopper, and rats.

The plant does not have national conservation status. An Giang provincial government is interested in conserving the plant but so far no specific actions have been undertaken. It has not been assessed in the IUCN Red List and is not in the Catalogue of Life. Overall it has a low conservation status.

Climate change

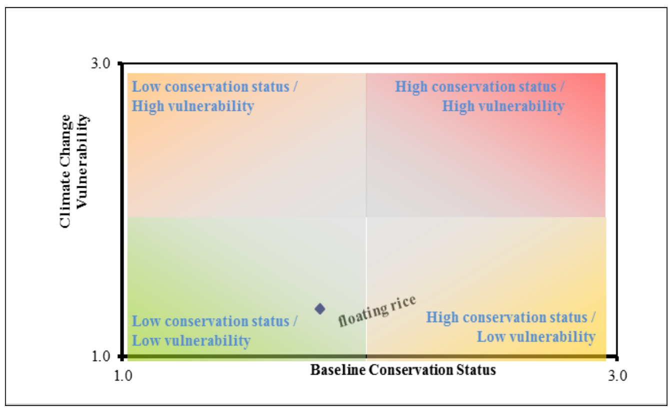
Growing in deep water areas, changes in temperature does not seem to be an issue to floating rice. Drought during seeding, however, may cause poor germination. However, as a cultivated plant, germination depends largely on human intervention. Floating rice can tolerate submergence up to 10 days, so increased flooding associated with climate change in the future is not an issue. Elongation is triggered when the plant is submerged through a mechanism involving ethylene gas. Ethylene is normally produced by plants and diffused into the air but when floating rice is submerged in water this process is disrupted as the gas moves more slowly into water. This leads to a build up of ethylene in the plant. This triggers the production of a hormone called gibberellin which causes the rapid growth in the plant. When the plant reaches the surface the ethylene gas can escape as normal and the rapid growth stops.

Floating rice is sown in April-May. The late onset of rains may delay seeding of floating rice. As all wild and cultivated rices are wind-pollinated, strong winds at flowering time might cause pollination failure.

A vulnerability assessment of floating rice indicates a very low vulnerability in Kien Giang Province. This means that floating rice with its excellent stem elongation ability will be able to cope with climate changes such as increased depth of flooding much better than the other common rice varieties.

Adaptation recommendations

Although floating rice has a strong ability to endure future climate changes, as a cultivated plant its survival depends on human interventions and their willingness to continue to cultivate floating rice. The low yield is a serious threat to the rice as not many farmers want to continue to plant this variety. Given that only 50 hectares of this variety are left in An Giang Province in the Mekong Delta in Vietnam, the variety should be conserved.



In addition to its importance as a food crop, floating rice should be conserved for studying basic aspects of plant growth. Insights into the growth process of this plant, especially the extraordinary elongation ability may help to identify genes that could confer elongation capacity onto modern, high-yielding cultivars. Developing cultivars with high yield and the elongation ability will be of major agronomic importance for the future in the LMB where flooding is expected to increase in the wet season.

As its survival depends largely on human interventions, it is recommended that floating rice should receive a national protection status for conservation both in situ and ex situ.

5 SYNTHESIS OF NTFPS AND CWRS ACROSS THE HOTSPOT AREAS

This brief review of the potential climate change vulnerabilities and impacts upon NTFPs and CWRs highlights the considerable variation that may be expected both between the different types of plant and between the different locations within the LMB. It is important to note that the species that have been described in this report are not necessarily representative of the type of plant – other species of shrub or tree for example will have very different responses to climate change; the species described here are just examples in order to provide a broad range of understanding.

A second point of limitation is that many of these species described have closely associated species or sub-species that are found in different parts of the basin. No attempt has been made to differentiate between these associated species or sub-species, largely because the detailed information required to conduct a full vulnerability assessment based on their innate biological differences just is not available. This means that there may be some species or sub-species out there that have greater resilience than those described and could therefore be used for replacement as conditions in one area become too hostile for survival of the species described.

In general there is a shortage of information on the biological characteristics of most NTFP and CWR species. Often the focus of earlier studies has been upon the use of NTFPs, rather than upon their biology or ecological and climate requirements. For these and for CWRs reference has to be made to other species of the same genus that have been studied because they have been domesticated. This has therefore limited the vulnerability assessment, which in many cases has been based upon a "best guess" approach using whatever information can be gathered together. That being said, due acknowledgement must be made to the incredibly valuable databases, e.g., compiled by FAO, which are available on the internet, and which have provided much of the biological and ecological requirements of the species considered. A list of such useful websites and databases is provided at the end of this report.

Ecologically, the requirements of NTFPs and CWRs are complex. All the species considered grow in forest or wetland assemblages of other species and may depend upon symbioses, synergies, and interactions with the other flora and fauna in these assemblages. As illustrations of this, the following examples can be highlighted:

- Fungi are pervasive throughout forest ecosystems, and the cycle of growth, death, and decay of all species depends upon the functioning of fungi. Many fungi have close associations with specific tree or plant species, e.g., the species considered here, *Russula virescens,* has associations with the trees in the genera of the Fagaceae family. Wild rice species are also associated with certain endophytic fungi, which contribute to their growth and survival.
- Earthworms are also essential for ecosystem functioning, breaking down dead plant materials and releasing nutrients so that they are available for the next generation of plants in the forest. Earthworms have been considered separately here.

- Pollinators such as bees, bats, and birds are also important and many plant species have evolved specific mechanisms to attract pollinators to their flowers. While one of the most important species of bees, *Apis dorsata*, has been considered in its own right, its interactions with related species such as orchids, cardamom, and many tree species have not been considered. The impacts of climate change on pollinators would be cumulative – as pollinators decrease in numbers, so the potential for plants to be pollinated decreases. Eventually a threshold might be reached where the plant is no longer pollinated and dies out. These sorts of interactions are too complex for this study and have not been included.
- Similarly diseases and insect attacks of NTFP plants have not been considered. The plants in their natural habitats are generally tolerant and resilient of such infestations, but if stressed, e.g., by rising temperatures or drought, or by loss of natural habitat, disease and insect attack may become more severe, leading to loss of species. Increasing temperatures or increased moisture in the air at certain times of year, may enhance the rate of spread of the disease or populations of attacking insects.

This vulnerability assessment does not consider the interdependence of the assemblages or the complex ecology of the forest ecosystems, but only the biological characteristics and climate requirements of the species.

Unlike domesticated crops, which are designed and grown in relative monocultures and in fairly or very exposed situations (e.g., open fields), NTFPs and CWRs live and grow in complex forest or wetland ecosystems. They are generally relatively protected. *Amomum*, for example, requires at least 50% forest cover or shade in order to thrive. Other plants require the opening up of spaces within the forest caused by fallen trees in order to get started, e.g., *Broussonetia*. The climbers require other trees to grow up and support them in the forest. The forest as an overall entity moderates the extremes of temperature and maintains a higher humidity within it than the open fields, and thus the forest provides a "refuge" against the extremes of temperature and drought.

However, once that forest cover and integrity is lost – often as a result of logging, clearance, overharvesting, etc. – then the protection that the forest offers to these NTFPs and CWRs decreases, and the species may well experience the additional stresses of climate change from which they had previously been protected.

In their natural environment, most species have clear seasonal patterns, especially in the climatic conditions of the LMB where there is a marked distinction between wet and dry seasons. They are well adapted to the dry season, when many species go into relative hibernation, shed their leaves, store up food sources in tubers, or aestivate (earthworms), or migrate (honeybees), etc. all against the extremes of the hot, dry season. They can often largely withstand the extremes of drought at the end of the dry season and lowering of soil moisture availability. Often the seeds that they produce can survive several years of dormancy and wait for the best conditions before they germinate – fungi are excellent examples of this strategy; the species can survive periods of extreme climate and take advantage of the climate variability to grow and reproduce when the conditions are less extreme. A number of species, especially the grasses and herbs, climbers, and aquatic plants, are capable of vegetative reproduction and can grow from the rootstock and rhizomes as well as producing seeds. This means that they can also take advantage of different conditions to multiply and spread when seed production is limited.

Thus, there is generally a greater resilience in intact forest and wetland ecosystems to climate change. As conditions change there would be a gradual shift towards species or sub-species and the assemblages that they rely on that can tolerate the changes better. The situation in stressed and modified natural environments will be different, and in these situations more rapid changes in the species and their ecology may be expected. Once a threshold is passed for the ecosystem as a whole then there would be a more dramatic change, loss of the key species, loss of forest cover, and overall transformation of the ecosystem. Usually this threshold is not obvious until the loss has occurred.

What emerges from this review is that the existing status of the threats to the species is more important than the climate change. Habitat loss, changes in land use to agriculture, plantations, aquaculture, deforestation, and over-harvesting are the most important stressors reducing the populations of many NTFPs. Climate change comes as an additional but not necessarily the most important stressor.

Of all the climate changes evaluated by this study, the increase in temperature is considered to be the most important, particularly when this occurs during the flowering, fruiting, and seed dispersal times of year. In this region many of the NTFP plants start flowering at the end of the dry season, which is currently the hottest time of year, and the time of year when climate change predictions show that the increase will be most extreme. For several species, notably in the *Amomum* and *Broussonetia* genera, the increase in temperature predicted for Mondulkiri during the flowering period could push the species beyond their absolute temperature range, even though this would be mitigated by the forest cover. In other provinces considered, the temperature changes are less significant and lie within the biological tolerances of the species, though increased temperature may have an effect upon productivity and fertility.

Changes in rainfall patterns appear to be less significant. For most species in the provinces considered, the increases in annual rainfall are well within the normal range. The patterns of rainfall during the dry season may show a decrease in several provinces, especially in Mondulkiri, and the soil water availability is likely to be reduced during this time. However, unless there are periods of prolonged drought, the normal seasonal patterns of dormancy during the dry season and strong growth during the wet season for most plants will allow them to survive these variations. Even periods of prolonged drought are climatic patterns which many species are adapted to.

Forest fire is seen as an important ecological feature, both positive for renewal and destructive for loss of individual plants, and climate change may enhance the risk of forest fire. If plants are not given the space and time recover between incidents of forest fire they will die out.

For wetland plant species, it would appear that these are the least vulnerable. The increased temperature is moderated by the water and may in fact induce growth of the aquatic plants. Most of these plants are also adapted to periods of drought, and will come back when the flood waters return. They are also well adapted to flood. Some of these species, e.g., *Typha*, are pioneers and may become more invasive in the future.

The mangrove in the genus *Sonneratia* is the only species likely to be affected by sea level rise, strong winds, and storm surge. It is considered vulnerable to this, but if allowed to migrate inland as the seas rise, then it can survive. However, if movement inland is constrained by dyke construction, then it will be more vulnerable.

For the wild rice species as an example of CWRs, they are in a slightly different position in that they are rarely used by rural people in the same way as NTFPs. They may therefore be “forgotten” be everyone except those interested in rice improvement and genetic research. The conservation of these species is not a priority. Nevertheless, the existing status of these plants shows that they are under threat from genetic erosion – mixing of genes with cultivated rice – and also from habitat loss. With the increasing pressure on development of land either for agriculture, urbanization, plantations, or for more general forest clearance, the habitats for these wild rice species are being lost. In terms of climate change threats, the increased temperatures, especially in Mondulkiri, makes wild rice very vulnerable.

Table 14 shows the vulnerabilities of the species considered both to non-climate change threats and to climate change of different NTFP and CWR species in the hotspot provinces. Mondulkiri Province stands out as being the most extreme in terms of both the extent of climate changes and in the vulnerabilities of the species. Chiang Rai stands out as the province where the vulnerability of NTFPs and CWRs to climate change is the least. Gia Lai and Khammouan have an intermediate position. Kien Giang is in a very different situation, and while the threat of sea level rise affects the vulnerability of mangroves, the vulnerabilities of aquatic plants and wild rice species remains low.

From Table 14 it is clear that very many of all the NTFPs are already significantly vulnerable to forest habitat losses and changes in land use, as well as overharvesting, and lack of conservation or sustainable use management. The vulnerabilities of these species to climate change will add to these existing vulnerabilities to other habitat and use threats.

Table 15 and Table 16 show summaries of the findings of the vulnerability assessments for the NTFP and wild rice species in different provinces. These tables highlight the existing conservation or management threats for each species and the main climate change threats.

Table 14: Non-climate change and climate change vulnerabilities of different NTFP and CWR species in hotspot provinces

Province			Kien Giang		Mondul Kiri		Gia Lai		Chiang Rai		Khammouan	
Ecozone			3. Delta Low lying acidic area swamp forest		6. Low-elevation dry broadleaf forest		9. Mid-elevation dry broadleaf forest		4. High-elevation moist broadleaf forest - North		7. Low-mid ele moist broadleaf forest	
NTFP Category	Species	Common name	2. Delta mangroves and saline water		9. Mid-elevation dry broadleaf forest				12. Upper floodplain wetland, lake (CS to VTE)		4. High-elevation moist broadleaf forest - North Indochina	
			Non-CC Vulnerability	CC vulnerability	Non-CC Vulnerability	CC vulnerability	Non-CC Vulnerability	CC vulnerability	Non-CC Vulnerability	CC vulnerability	Non-CC Vulnerability	CC vulnerability
Mushroom	Russula sp	Russula mushroom			High	Moderate	High	Moderate	Very high	Moderate	Very high	Moderate
Grasses/herbs	Ammomum spp	False Cardamom			High	Very high	High	High	High	Moderate	High	Moderate
Aquatic plants	Sesbania sesban	Egyptian pea	Very Low	Moderate					Very Low	Very Low		
	Typha orientalis	Oriental rush	Moderate	Moderate								
	Lepironia articulata	Lepironia Sedge	Moderate	Moderate								
Climbers	Dioscorea hispida	Bitter yam			Moderate	Very Low	Moderate	Very Low	Moderate	Very Low	Moderate	Very Low
Orchids	Dendrobium lindleyi	Orchid			Very high	High	Very high	Moderate	Very high	Moderate	Very high	High
Rattans	Calamus crispus	Rattan			High	Moderate	Very high	Moderate	Very high	Moderate	Very high	Moderate
Shrubs	Broussonetia papyrifera	Paper mulberry			Moderate	Very high	Low	Moderate	Moderate	Moderate	Moderate	Moderate
Trees	Dipterocarpus alatus	Resin tree			High	High	High	Moderate	Very high	High	Very high	High
	Sonneratia casseolaris	Mangrove apple	Moderate	Very high								
Insects	Apis dorsata	Giant honeybee	Moderate	Moderate	Moderate	Moderate	High	Moderate	High	Moderate	High	Moderate
	Oecophylla smaragdina	Red Ants			Moderate	Low	Moderate	Low	Moderate	Low	Moderate	Moderate
Invertebrates		Earthworms	Moderate	Low	Moderate	Moderate	Moderate	Low	Moderate	Low	Moderate	Low
CWRs												
Wild Rice	O. nivara		High	Low	High	High	High	Moderate	High	Moderate	High	Moderate
	O. officinalis		High	Low	High	High	High	Moderate	High	Moderate	High	Moderate
	O. rufipogon		High	Low					High	Moderate		
Landrace rice	O. sativa/prosativa	Floating rice	Very high	An Giang (Low)								

Vulnerability key	
Very high	(red)
High	(orange)
Moderate	(yellow)
Low	(light green)
Very Low	(dark green)

Table 15: Summary of the existing conservation / management threats and climate change threats for NTFPs

Species	Provinces occurring/ considered	Non-CC Vulnerability	CC Vulnerability	Conservation/sustainable management threats	Principal CC threats
Fungi					
Russula virescens	Mondulkiri	High	Moderate vulnerability	• Land concessions within PAs • Deforestation causes loss of habitat • Converting degraded forest to rubber • Illegal logging • Cutting of associated trees (Fagaceae) • Overharvesting • Forest fire • Increase in infrastructures & economic development • No conservation status • Conservation status of its habitats in PAs is very weak	• Extreme drought • Increase in temperature • Drier dry season • Decrease in soil moisture availability • Higher wild fire risk
	Gia Lai	High	Moderate vulnerability		
	Khammouan	High → Very high	Moderate vulnerability		
	Chiang Rai	High → Very high	Moderate vulnerability		
Grasses and herbs					
***Amomum* spp.**	Mondulkiri	Moderate=> high	Very high	• Deforestation, illegal logging and forest clearance causes loss of habitat • Converting degraded forest to rubber • Loss of tree cover (needs more than 50% cover) • Overharvesting in some areas • Cultivation and domestication	• Increased temperatures may be above absolute range, especially during flowering • Decreased rainfall in dry season • Lowered soil water availability at end of dry season • Pollination by honeybees may be affected
	Gia Lai	Moderate=>high	High		• Temperatures may be pushed

Species	Provinces occurring/ considered	Non-CC Vulnerability	CC Vulnerability	Conservation/sustainable management threats	Principal CC threats
	Khammouan	Moderate → High	Moderate	may destroy some areas of wild plants within the forest • Cultivation may reduce pressure on wild stock • Loss of habitat due to increase in infrastructures & economic development and land use conversion • Land concessions within PAs	beyond comfort zone, especially during flowering and fruiting • Productivity may decline because of higher humidity in fruiting season
	Chiang Rai	Moderate → High	Moderate		
Aquatic plants					
Sesbania sesban	Kien Giang	Very low	Very low=> Moderate	• Increased salinity near the coast • Increasing conversion of wetland habitats to agriculture in the basin	• No specific CC threats though may be affected by impacts on pollinators • Changes in other NTFP species may increase human pressure on *S. sesban*
Typha orientalis	Kien Giang	Moderate	Low=> moderate	• Increased salinity near the coast • Habitat loss – conversion to aquaculture and agriculture • Loss of wild stock • Domestication and planting by farmers as commercial crop	• Generally resilient due to: o Pioneer species o Resilient to floods o Survival of buried seeds o Rhizome reproduction
Lepironia articulata	Kien Giang	Moderate	Moderate	• Increased salinity near the coast • Habitat change – land use conversion to aquaculture and agriculture • Invasion of alien species • Possible over exploitation for	• *Lepironia* can adapt to increased temperatures and rainfall and drought conditions • Higher risk of grassland fires

Species	Provinces occurring/ considered	Non-CC Vulnerability	CC Vulnerability	Conservation/sustainable management threats	Principal CC threats
				handicrafts	
Climbers					
Dioscorea hispida	Mondulkiri	Low=> moderate	Very low	This species does not appear to have many threats apart from general loss of its forest habitat due to: • Deforestation causes loss of habitat • Illegal logging • Converting degraded forest to rubber • Land concessions within PAs • Increase in infrastructures & economic development • Land use conversion	• No particular climate change threats • Improved habitat protection and management
	Gia Lai	Low=>Moderate	Very low		
	Khammouan	Low → Moderate	Very low		
	Chiang Rai	Low → Moderate	Very low		
Orchids					
Dendrobium lindleyi	Mondulkiri	High=> Very high	High	• Over-harvesting, • Wild orchid trading, and future increases in demand and market price • Cross-boundary trades • Loss of habitat due to increase in infrastructures & economic development and land use conversion • Land concessions within PAs • Deforestation, illegal logging	Increase in temperature and decrease in dry season rainfall. Increased fire risk. Storms and high winds affect orchids in canopy. Insect pollinators may be affected.
	Gia Lai	High=> very high	Moderate		Increases in dry season rainfall enhance growth with lower risk of fire. Storms and high winds affect orchids in canopy. Insect pollinators may be affected.

Species	Provinces occurring/ considered	Non-CC Vulnerability	CC Vulnerability	Conservation/sustainable management threats	Principal CC threats
	Khammouan	High → Very high	High	• No conservation status for this species; • Conservation status of its habitats (in PAs) is very weak	Increase in temperature and decrease in dry season rainfall. Increased fire risk. Storms and high winds affect orchids in canopy. Insect pollinators may be affected.
	Chiang Rai	High → Very high	Moderate		Increases in dry season rainfall enhance growth with lower risk of fire. Storms and high winds affect orchids in canopy. Insect pollinators may be affected.
Bamboos and Rattans					
Calamus caesius	Mondulkiri	High	Moderate	• Overharvesting for rattan shoots and cane • Future increases in demand and market price • Note that cultivation for canned rattan shoots may reduce pressure on wild stocks • Deforestation and habitat loss • Forest fire • Severe floods • Loss of habitat due to increase in infrastructures & economic development and land use conversion • Conversion to rubber plantations	• Increasing temperature may push *Calamus* slightly beyond its comfort zone • Decrease in rainfall in dry season may reduce fruiting • Increase in fire risk in dry season • Increase in wet season rainfall may affect young seedlings which cannot withstand flooding
	Gia Lai	High=>very high	Moderate		
	Khammouan	High → Very high	Moderate		
	Chiang Rai	High → Very high	Moderate		

Species	Provinces occurring/ considered	Non-CC Vulnerability	CC Vulnerability	Conservation/sustainable management threats	Principal CC threats
				• Land concessions within PAs • Deforestation, illegal logging • No conservation status • Conservation status of habitats (in PAs) is very weak	
Shrubs					
Broussonetia papyifera	Mondulkiri	Low=>Moderate	Very High	• Cultivation is easy and *B. papyrifera* has been used as a regeneration crop after slash and burn • Cultivated plants give better quality bark • Wild plants under pressure because of habitat loss due to: o Illegal logging o Land concessions o Conversion of land use to rubber and other crops o Infrastructure development	• Temperature may increase beyond biological threshold • Water availability during flowering period may be a problem and reduce fertility • Strong winds may break branches • Pollinators may be affected • Attack by insects may be increased
	Gia Lai	Low	Moderate		• Temperature increases may stress the plants, especially in flowering and fruiting periods • Strong winds may break branches
	Khammouan	Low → Moderate	Moderate		Less pressure from climate changes
	Chiang Rai	Low → Moderate	Moderate		Less pressure from climate changes
Trees					
Dipterocarpus alatus	Mondulkiri	High	High	• Over-harvesting, with increased demand and market prices	• Increase of temperature during flowering and fruiting • Seed germination rate may be

Species	Provinces occurring/ considered	Non-CC Vulnerability	CC Vulnerability	Conservation/sustainable management threats	Principal CC threats
				• Improper tapping techniques and hole maintenance during and after oil and resin extract • Forest fires • Natural enemies are longhorn beetles and other insect pests • Deforestation, illegal and commercial logging • Land concessions within PAs • Habitat loss due to encroachment and land use change • Increase in infrastructures & economic development • Conservation status and management of its habitats is very weak	impaired • Seedlings more vulnerable to increased temperature and drought • Increase in attack by longhorn beetles • Increased risk of forest fire • Increased risk of high winds and storms may damage trees
	Gia Lai	High	Moderate		
	Khammouan	High → Very high	High		
	Chiang Rai	High → Very high	High		
Sonneratia spp.	Kien Giang	Moderate	Very high	• Some harvesting for timber • Increased human collection if other plants are stressed by increased temperature • Planned coastal dyke in Kien Giang will prevent mangroves from expanding inland when sea level rises	• Sea level rise • Strong wave action • Coastal erosion
Insects					
Apis dorsata	Mondulkiri	Moderate	High	• Not a priority for national conservation • Overharvesting of honey driven by increase in market	• Timing of flowering of preferred plants may be altered • Increased temperatures and

Species	Provinces occurring/ considered	Non-CC Vulnerability	CC Vulnerability	Conservation/sustainable management threats	Principal CC threats
				demand and price • Declining extent of forest cover in the basin • Increasing human modifications of landscapes, infrastructure – roads and other development • Increasing use of pesticides and agrochemicals in the region • Loss of migration stopover points • No conservation status for this species • Management and conservation of bee habitats in PAs generally weak	decreased water availability • Bees may leave the area earlier at end of dry season to lower areas with more moisture
Apis dorsata	Kien Giang	Moderate	Moderate		
Apis dorsata	Gia Lai	Moderate=>High	Moderate		• Mean max temperature increases and increased dryness at end of dry season may mean that bees leave area earlier
	Chiang Rai	Moderate → High	Moderate		• Increased frequency of storms
Red ant, *Oecophylla smaragdina*	Mondulkiri	Low=>Moderate	Low	• Overharvesting - collection of ant eggs is destructive driven by increase in market demand and price • Forest fires • Deforestation, illegal logging • Land conversion to rubber and other crops • Habitat loss due to infrastructure and economic development • No conservation status for this species • Conservation status of its	• Increased temperatures considered to be within comfort zone, but max temps may affect red ants slightly • Drier dry season and reduced water availability likely to enhance red ant population • Increased risk of wild fires may damage colonies • More frequent storms and high winds may affect nests • Increased rainfall/moisture in wet season may increase disease
	Gia Lai	Low=>Moderate	Low		
	Khammouan	Low → Moderate	Moderate		
	Chiang Rai	Low → Moderate	Low		

Species	Provinces occurring/ considered	Non-CC Vulnerability	CC Vulnerability	Conservation/sustainable management threats	Principal CC threats
				habitats is very weak	
Invertebrates					
Earthworms	Mondulkiri	Moderate	High	• Natural predators - ducks, chicken, birds, frogs, toads, rats, snakes, leeches, beetles, fish • Soil moisture content is important – if too low they can lose internal water and die • Too much soil moisture, flooding, forces them to come to surface – if exposed to sunlight will die	• Increase in temperature • Less rainfall • Less soil moisture availability, especially during dry season will harden life, growth, movement and activities of earthworms • Higher rainfall during wet season months will make earthworms more vulnerable
	Gia Lai	Moderate	Moderate		
	Khammouan	Moderate	Low		
	Chiang Rai	Moderate	Low		

Table 16: Summary of existing threats and climate change threats for wild rice species

Species	Provinces occurring/ considered	Non-CC Vulnerability	CC Vulnerability	Conservation/sustainable management threats	Principal CC threats
Wild rice					
Oryza granulata	Not assessed				

O. nivara	Mondulkiri	High	High	• Genetic erosion
				• Habitat destruction and loss –
				  o development projects
				  o irrigation
				  o land use change
				  o shift to monoculture
				  o human habitation
				  o urbanization
				• Lack of recognition of conservation value
					• Increase in temperature exceeds optimal temperature at all stages of life cycle
					• Decrease in water availability during early flowering
					• Increase in % of drought years
					• Decrease in rainfall and
					• Increase in wild fire risks

	Gia Lai	High	Moderate		• Slight increase in temperature beyond optimal • Higher rainfall in all wet season months may increase depth of flooding – *O nivara* is short stemmed. • Bigger and more frequent storms
	Khammouan	High	Moderate		
	Chiang Rai	High	Moderate		
O. officinalis	Mondulkiri	High	High	• Genetic erosion • Loss of habitats through rapid economic development and urbanization • Intensive monoculture • Fragmentation of habitat • Lack of recognition of conservation value	• Increased temperature • Decreased dry season rainfall • Decreased soil water availability • Drought
	Gia Lai	High	Moderate		
	Khammouan	High	Moderate		
	Chiang Rai	High	Moderate		
O. ridleyi	Not assessed				

Species	Provinces occurring/ considered	Non-CC Vulnerability	CC Vulnerability	Conservation/sustainable management threats	Principal CC threats
O. rufipogon	Kien Giang	Low => High	Low	• Lack of recognition of conservation value • Loss of habitat due to increasing conversion to agriculture • Genetic erosion due to genetic flow between cultivated rice and wild rice in proximity	Considered to be resilient to climate changes predicted
Floating rice	Kien Giang	Very low=> very high	Low	• Last 50 hectares remain in Mekong Delta in Vietnam • Low yields and decreasing interest by farmers to plant floating rice with very small areas cultivated	• Floating rice is considered resilient to climate change and can withstand prolonged flooding

6 SYNTHESIS FOR ADAPTATION MECHANISMS FOR NTFPS AND CWRS

The non-CC and climate change vulnerabilities of the different species are aggregated for all hotspot areas and plotted on a chart in Figure 6. This shows that a significant proportion of the species considered fall into the High Non-CC and High CC Vulnerability quadrat. This placement helps in determining the priority of actions for the different species across the LMB. Thus:

- Species falling in the **bottom left quadrat (Low-Low)** –namely *Dioscorea* (climber) and *Sesbania* (aquatic plant) – probably do not require significant attention at the moment.
- Species falling in the **bottom right quadrat (High-Low)** – namely *Calamus* (rattan), Red ants, Honeybees, Earthworms, and wild rice (CWR) – need attention to protect the species and its habitat and encourage more sustainable harvesting, rather than specific climate change adaptation measures.
- Species falling in the **top left quadrat (Low–High)** – namely *Typha*, *Lepironia* (aquatic plants), and *Broussonetia* (shrub), require greater attention to climate change adaptation measures, although most of these species do have moderate non-CC vulnerability. Attention should be paid in the hotspot areas where these species are considered to be more at risk from climate change.
- Species falling into the **top right quadrat (High-High)** – namely *Sonneratia* (mangrove), *Dipterocarpus* (tree), *Amomum* (grass/herb), *Dendrobium* (orchid), and *Russula* (fungus) – need attention both to protection of the habitat and management for sustainable use **and** specific climate change adaptation measures, especially in those hotspot areas where they are considered to be most at risk from climate change.

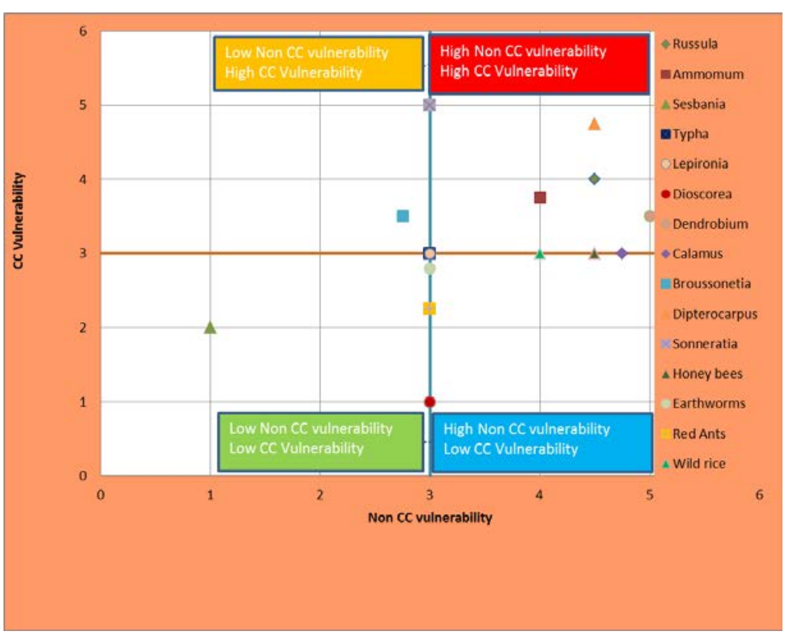


Figure 6: Plot of Non-CC and climate change vulnerabilities for NTFPs and CWRs aggregated for all hotspots

A summary of the adaptation recommendations for the different species under consideration is shown in Table 17. These different options for enhancing the resilience of NTFP and CWR species may be generalized and grouped under several headings. These are discussed below and short, medium, and long term interventions identified. Some actions are applicable at several time scales. The adaptations that can be taken at the community level are highlighted, as are those which will require national level action.

The adaptation options can be grouped into the following categories:

- Habitat protection
- Habitat rehabilitation and reforestation
- Water management of habitats
- Species protection
- Sustainable management of NTFP harvesting
- Domestication and cultivation of NTFPs
- Monitoring and research
- Selection of resilience within species
- Assisted movement of species at risk and shift of habitat

6.1 HABITAT PROTECTION

Habitat protection is the most fundamental conservation measure for all these NTFPs and CWRs. If the forest or wetland area where they live is damaged through deforestation, illegal logging, drainage, and land use change for monoculture plantations and agriculture, the species will be under threat. If the species is already stressed because of habitat damage or loss, climate change will add to that stress and potentially push the species to local extinction.

The principal habitats where NTFPs and CWRs survive are in protected areas. Increasingly, pressure for development on all other land is changing the land around such protected areas significantly, so that they are no longer suitable for many NTFPs and CWRs. Protected areas themselves are also under threat from similar pressures and poor management leads to further degradation.

Habitat protection may be provided within the protected area system, but sometimes key habitats have been left out of the national protected area system. In such cases, the protected areas may need to be extended so that the coverage of the protected area system includes the key habitats. In any case, protected area management is often neglected, under-funded, and in need of strengthening. The protected area may be poorly managed, with habitats continuing to degrade, and natural resources being non-sustainably removed.

Some of the measures identified in this review include the following adaptation strategies.

Recommended adaptation measures

Short term

- Increase the effectiveness of 'Protected Area Systems' and the management of existing protected areas in order to reduce deforestation, commercial and illegal logging, encroachment, forest fires, land use change, intensive mono-cultivation, and habitat deterioration and loss

- Ensure protection of forest from logging and other destructive practices
- At areas with strong waves, wave-breaking structures are needed to protect the young trees from being destroyed by waves (specific to mangroves)
- Protect and conserve natural habitats and important ecosystems for wild rice

Medium term

- General protection of forest habitats to ensure survival of wild plants
- General protection of wetland habitats
- Advocacy to establish and strengthen the management of protected areas
- Increase the coverage of 'Protected Forests' in order to maintain the integrity of habitats and to safeguard existing wild populations at national and local levels
- Increase the effectiveness of 'Protected Area Systems' in order to reduce deforestation, land use change, intensive mono-cultivation, habitat deterioration and loss
- Protection for identified stopover points for honeybees

Long term

- Enhance and increase habitats appropriate for particular species considered to be at risk
- Increase the effectiveness of 'Protected Area Systems' and the management of existing protected areas in order to reduce deforestation, commercial and illegal logging, encroachment, forest fires, land use change, habitat deterioration and loss
- Increase coverage of 'Protected Forests' in order to maintain the integrity of habitats and to safeguard existing wild populations

6.2 HABITAT REHABILITATION – REFORESTATION

If protection of the habitats is an essential part of ensuring resilience of NTFPs to climate change, the rehabilitation of habitats, both forests and wetlands, is essential for ensuring their survival both in protected areas and outside. Many habitats are already degraded and reforestation is necessary to restore them so that they can continue to provide the shelter for the assemblages of plants. It is clear, from the above discussion about the importance of these associations of plants and animals, that a variety of mixed key species should be chosen for replanting. The choice may follow the principles of the "framework species method", which is designed to restore diverse forest ecosystems on degraded forestland for biodiversity conservation or environmental protection. Framework species are fast growing with dense shading crowns that rapidly shade out competing weeds, and are attractive to seed dispersing wildlife, especially bats and birds.

"The method depends on some tract forest patches or remnant forest trees, surviving fairly close to planted plots, to provide a source of seeds. In addition, reasonably dense population of seed dispersing animals must occur in the vicinity. This can be achieved by planting a mixture of 20-30 native forest species (including fruit bearing species). Tree planting restores basic ecosystem structure and function, whilst seed-dispersing wildlife re-establishes biodiversity and the original tree species composition of the forest. If either of these two elements is missing from the surrounding landscape, natural regeneration within framework species plots may be unreliable. On such sites, if the initial planting of framework tree species failed to stimulate natural regeneration, subsequent planting of additional tree species may be necessary."[31]

Recommended adaptation measures

Short term

- Restore and rehabilitate deteriorated forests. Increase forest canopies, crown covers, and shady areas

Medium term

- Reestablish mangroves along the coast through planting and natural regeneration
- Establish multi-species mangrove forest to cope with storm damage
- Establish the 'buffer zone' for existing forest areas in order to allow natural shift of forest distribution under future climate change
- Increase and support reforestation and afforestation programs / projects/ activities
- Enrichment planting of flowering plants at honeybee stopover points

Long term

- Include *Typha* in new protected areas and/or reintroduce *Typha* to existing protected areas
- Through land use planning, leave enough space for establishment of mangroves along the coast, including relocation of the planned coastal dyke further inland

6.3 WATER MANAGEMENT IN HABITATS

Water management measures are important both for the continued functioning of wetlands, but also for maintaining soil moisture. Soil moisture availability is a critical factor in the survival of most NTFP species, and many of the most important species found in the forest have a preference for areas that are wetter, e.g., near streams in the forest. Increased risk of drought is likely to change these areas of higher moisture in the forest. Thus the construction of check dams in streams will reduce the rate of run-off and soil erosion while maintaining ground water levels. At this level, water management is a very local adaptation measure, the structures are small and easy to construct and maintain.

Wetland management and coastal zone management also requires attention to water management to maintain enough fresh water for the wetland habitat. At a wider level, this requires watershed management to ensure that sufficient good quality water is available, balanced with the other uses. In parts of the Mekong Delta where the extensive canal system drains the land, some protected areas tend to dry out, to the detriment of the overall forest habitat. In other areas, where the risk of fire is high, ground water levels may be maintained artificially high.

In mangrove areas, the proposed dykes to counter sea level rise, may cut off areas for expansion of the mangroves, and the provision of sluice gates to allow the normal movement of saline waters will be necessary for long-term growth of the mangroves in these areas.

[31] Forestry Administration/Cambodia Tree Seed Project/DANIDA, 2005. Guidelines for Site Selection and Tree Planting in Cambodia

Recommended adaptation measures

Short term

- Build 'check dams' to maintain and increase soil moisture availability within the forests, especially during dry season months, to maintain ground water levels near areas that may tend to dry out, and to reduce wild fire risk
- Protect water courses near stands of *Amomum*
- Improve management of hydrology in peat areas of Kien Giang to prevent the canal system in protected areas from drying out the peat, which results in decreased flowering of *Melaleuca* trees
- Build check dams on key canals to prevent drainage of water at end of dry season

Medium term

- Build 'check dams' to maintain and increase soil moisture availability within the forests, especially during dry season months, and to reduce wild fire risk
- Strengthen and systemize the overall watershed management for forest and water resources conservation
- Develop 'wet season refuge' for earthworms in order to reduce their vulnerability to heavy rainfall, flooding, natural predators, and human threats

Long term

- Plan sluice gates together with the coastal dyke to allow saline water to move in and out of the coastal dyke to provide habitat for mangroves and *Sonneratia* to migrate inland

6.4 SPECIES PROTECTION

Species protection may be necessary in order to ensure that baseline pressures are reduced. At the national level, it may be that official protection is required, so that pertinent species are designated on the national protected species lists, with the necessary regulations and penalties for their illegal collection and trade. Examples of this would be the protection of wild orchids.

Protection may also be given through the recognition that these are important species; that attention is paid to their conservation in biodiversity action plans and plans for other developments. Examples for this type of protection would be the floating rice varieties, and greater attention to protecting wild honeybees. Specific conservation programs can be developed for these species.

In other instances the protection may be more local, so that existing stands of a particular species may receive protection. The identification of honeybee migration routes and stopover points that need protection might be an example of this. Another example may be the protection of genetic stocks of wild rice from genetic erosion from cultivated species in locations where the wild rice is found.

Finally there are the in situ and ex situ conservation approaches for species protection. Seedbanks may be required to provide the seeds for future rehabilitation of the species in both short and medium term where they have become degraded, or in the longer term when climate change has had significant impacts on the range.

Recommended adaptation measures

Short term

- Ensure that culture practices do not threaten wild stock
- Conduct inventories and map existing populations of *Typha*
- Better conserve and safeguard the existing wild populations in protected areas, promote and enhance in-situ conservation
- Strictly control and properly manage wild orchid trading and cross-boundary trading
- Protect exposed plants from strong winds where possible
- As a key pollinator honeybees should receive more conservation attention and higher priority national conservation status

Medium term

- Environmental education
- Consider and take actions to put wild *Dendrobium lindleyi* on protected plant list
- Better conserve and safeguard the existing stands in protected areas, promote and enhance in-situ conservation
- Protect and reintroduce the species in the wetland protected areas where they naturally occurred in the past
- Floating rice should receive a national protection status for conservation both in situ and ex situ

Long term

- Collect seeds, establish seedbank, and produce seedlings and saplings for in-situ conservation and re-introduction to deteriorated forest areas
- Collect seeds and establish seedbank for ex-situ conservation

6.5 SUSTAINABLE MANAGEMENT OF NTFP HARVESTING

One of greatest of the pressures upon many NTFPs, after habitat change and loss, is destructive harvesting of the products and overharvesting. In some cases harvesting of NTFPs is non-destructive, e.g., collection of fruit and seeds, but in other cases the whole plant may be destroyed, e.g., collection of bark and roots, or where the main stem has to be cut down. If this happens then the stock of that plant in the location may be threatened. In addition to destructive practices, pressure from increasing numbers of people collecting the product can contribute to overharvesting to the extent that the plant could become very rare or even locally extinct. The added pressure of rising value of NTFPs, especially for export, means that even more people may wish to harvest these products.

Sustainable management of these NTFP resources is likely to become increasingly important both as a means to ensure the continuity of valuable community resources, but also to encourage resilience in the plants to climate change. Sustainable management may mean the development of non-destructive collection and harvesting, or the agreement of limits for collection each year, and/or the setting aside of areas of the forest for regeneration of the plants. It may also involve the development of processing techniques that reduce wastage and improve quality so that smaller quantities of the plant can be collected for higher value.

This is the main mechanism for involvement of local communities in climate change adaptation. It is a mechanism that actually does not require discussion of the impacts of climate change at all, because it makes sense in terms of ensuring the continuity of a valuable resource.

The development of more sustainable harvesting and processing practices is the same as would be undertaken for any commercial agricultural crop. It requires a clear understanding of the biology and ecology of the NTFP and what constitutes a sustainable harvest, research development into harvesting and processing techniques, as well as discussion and negotiation with and between community members on their application. It is not enough to promote sustainable harvesting, there has to be a clear incentive for its use otherwise the original destructive methods will continue.

Overharvesting may be the result of local people collecting more of the product, but it often results from people coming in from outside the locality, often from urban areas to harvest product in season. People outside the local communities need to be aware of less destructive harvesting techniques and the limits to which the product can be collected. They are less easy to influence and to ensure compliance with local agreements on practices and limits. If collection by outsiders makes up a significant proportion of the harvest, then raising awareness and agreements need to be reached with the wider community.

Recommended adaptation measures

Short term

- Organize sustainable use of the plant by local community members
- Ensure harvesting practices are sustainable and avoid over-exploitation
- Encourage and support the attempt and effort of local communities to achieve 'sustainable harvest' and to develop 'sustainable harvesting systems' of wild mushroom *Russula virescens* and avoid over-exploitation
- Apply handicraft making and *Lepironia* harvesting techniques that use less raw materials and avoid damages to the plant to reduce pressure on resource harvest
- Encourage and support the attempt and effort of local communities to achieve 'sustainable conservation' of *Dendrobium lindleyi*
- Encourage and support the attempt and effort of local communities to achieve 'sustainable harvest' and to develop 'sustainable harvesting systems' of rattan and avoid over-exploitation
- Improve oleoresin harvesting techniques, develop proper tapping and hole maintenance methods in order to reduce vulnerability to extreme events
- Encourage and support the attempt and effort of local communities to achieve 'sustainable harvest' of red ants and their eggs by establishing and managing sustainable harvesting systems
- Encourage and support the attempt and effort of local communities to achieve 'sustainable harvest' of earthworms

Medium term

- Improve marketing to increase profit margin of handicraft making

6.6 DOMESTICATION AND CULTIVATION

Another way of reducing pressure on the wild stock of NTFPs is through cultivation and domestication of the plants. This is being applied in a number of species already such as cardamom and paper mulberry, orchids, mushrooms, etc. Cultivation has a number of advantages for the producer; the plants are grown in a clearly identified place, so ownership is more evident and collection is less time consuming. The quality of the product is often better and achieves a higher value.

However, cultivation in situ may mean that some parts of the forest ecosystem are disturbed and dedicated to cultivation of only one species. For example, there are concerns that cultivation of cardamom in clearings in the forest is becoming more destructive of the forest ecosystem. With increasing concentration of the plant, the problems of disease and pest attack increases. Cultivation outside of the forest boundary can also be done as in the case of plantations of paper mulberry.

Not all NTFPs can be domesticated and cultivated, and some depend to such a large extent upon the forest ecological assemblages, which are impossible to recreate in an artificial environment.

A different perspective on cultivation practices is the influence on the genetic integrity of the wild stock. Wild rice stocks are under threat from cultivation of commercial stocks almost as much as commercial seeds may be contaminated by "weedy rice". Where wild rice stocks are known to exist and recognized as important in situ genetic resources, it may be necessary to restrict the interactions with cultivated stocks. In a somewhat similar way, the use of agricultural chemicals along the seasonal migration routes and known stopover points for honeybees may need to be modified to reduce the risks to honeybees.

Recommended adaptation measures

Short term

- Ensure that culture practices do not threaten wild stock
- Promote and support organic farming, integrated farming systems, and environmentally friendly agricultural systems

Medium term

- Promote and support the cultivation projects/programs for *Russula virescens* in order to reduce pressure on wild populations
- Regulation of agricultural chemicals around honeybee habitats
- Prevent genetic erosion by ensuring that there is no cultivated rice in the proximity of the wild rice

Long term

- Support cultivation for ex-situ conservation and trading in order to reduce pressure and demand on wild populations
- Support rattan cultivation/plantations for ex-situ conservation and commercial uses in order to reduce demand and pressure on wild populations
- Encourage and promote the plantation of *Dipterocarpus alatus* in reforestation and afforestation programs/projects at community, national, and regional levels

6.7 RESEARCH AND MONITORING

Adaptation of NTFPs and CWRs will need additional scientific research into the basic biology and ecology of the plants and animals concerned. This review has highlighted the shortage, often complete absence of information that can be used to make predictions about the vulnerabilities of many of the species, and the likely impacts and the ways in which they may adapt to changes in climate. For many of the species concerned, the typical habitat and climate requirements are still unknown, and this information is essential in planning adaptation strategies.

Similarly the predictions of impacts that climate changes will have need to be followed to see if they are occurring. Populations of key plants and animals need to be monitored to record changes and responses to climate change. It will be important to try and separate out the impacts of climate change from the impacts of other pressures upon these populations. The rates of disease or pest infestation may also change as a result of climate change, and these ecological linkages should be explored.

Monitoring may also help to identify stocks of plants that appear to have greater resilience to climate change effects such as heat stress or drought. The provinces where these are likely to be highest, e.g., in Mondulkiri, would be a good location to investigate this. Such stocks of plants can then be directly selected for restocking the plants in these and in other locations in the future.

Recommended adaptation measures

Short term

- Identify and protect 'specific habitats' of *Russula virescens*
- In Mondulkiri and Gia Lai, where there appears to be increased vulnerability, monitor individuals for signs of increased heat stress and lack of water during flowering

Medium term

- Monitor stands of *Amomum* to observe changes in productivity and disease or insect infestation at higher temperatures
- In Mondulkiri, conduct monitoring research to identify stands of *Amomum* that appear to be more resilient to temperature for possible transplanting
- *Typha* is a strong wetland plant competitor and could become invasive - its expansion should be monitored and kept in check
- Research into migration patterns and stopover points for *Apis dorsata*
- Inventory and research on *Oryza nivara* habitats, existence, and its ecological requirements
- Inventory and research on *Oryza officinalis* habitats, existence, and its ecological requirements

Long term

- Research on ecological characteristics of *Russula virescens* and of its specific habitats
- In other locations, monitor the effects of increasing temperature on the productivity and survival of the plants

6.8 SELECTION OF RESILIENCE WITHIN SPECIES

A subsequent action to the research and monitoring described above could be the longer-term development of resilience within species through selective breeding of individuals that show resilience traits to the changes in climatic conditions. This would only really apply to those species that are in the process of domestication.

A variation of this would be to consider the different species or sub-species within the same genus that occur in different parts of the LMB and consider transplanting a more resilient species, e.g., *Amomum krevanh* that occurs in Mondulkiri for *A. uliginosum* species that is the predominant species in Gia Lai in order to prepare for increasing temperatures in that part of the basin.

Recommended adaptation measures

Long Term

- Identify individual plants in Mondulkiri that appear to have resilient traits against increased temperatures and water stress, and take root stocks/seeds to develop in nurseries
- If there are signs of morbidity, lowered productivity, or reduced fertility:
    - Actively transplant some rootstock to higher elevations in forest
    - Consider bringing in stock from plants in Mondulkiri, or other provinces already exposed to higher temperatures
- Consider replacement of different *Amomum* species that thrive at the predicted temperature and water availability ranges

6.9 ASSISTED MOVEMENT OF SPECIES AT RISK AND SHIFT OF HABITAT

This is also a subsequent step based on the research and monitoring and selective breeding, and may be considered as a long-term strategy for assisting important NTFP habitats to adapt to climate change. The principal behind this is that the natural evolution of habitat in an area depends upon the success and failure of the seeds of various plant species that are transported there. If the conditions are right the seeds will germinate and the plant will become successful along with others that form the ecological assemblage that defines the habitat.

With climate change it is likely that the plants that characterize the habitat are not able to adapt at the same rate as the climatic conditions are changing, and the habitat will shift, becoming less stable ecologically, with some species dying out and others coming in.

The natural approach to facilitating habitat shift is to provide the forest with "buffer zones" in which to re-establish itself as the climate changes. The existing forest areas should not be confined artificially. Part of the problems facing protected areas is that development occurs right up to the boundary of the protected area and there is no space for the evolving habitats to shift to the new climatic conditions. Buffer zones around protected areas need to be established to allow for this shift. Clear biodiversity corridors are needed to allow the movement of both plants and animals to re-establish themselves in more favorable conditions.

There is a classic example of this in the mangrove forests of Kien Giang, where their movement inland in response to sea level rise may be inhibited by the construction of sea walls and dykes, without adequate flow of saline water.

The opportunity that adaptation strategies might consider in the long-term is the assisted shift of habitat, transplanting species that appear to have greater resilience to the predicted changes in climate, especially in forests that have been degraded. It would be ecologically dangerous to attempt this with good quality and relatively intact forests – these should be allowed to adapt on their own. However, where the forests have been degraded and rehabilitation is being considered, a modified framework species approach could be applied, looking ahead to what the climatic conditions are likely to be like. Forests that are growing in similar conditions, with similar soils and hydrology, could be identified, seeds of framework species collected and seedlings grown and transplanted into the new location.

Recommended adaptation measures

Long term

- Select favorable locations, e.g., where ground water is likely to remain available and use these areas for cultivation
- Establish the 'buffer zone' for existing forest areas in order to allow natural shift of forest distribution under future climate change
- Plan sluice gates together with the coastal dyke to allow saline water to move in and out of the dyke to provide habitat for mangroves and *Sonneratia* to migrate inland
- Consider bringing in stock from plants in Mondulkiri, or other provinces already exposed to higher temperatures
- In Mondulkiri, where the threat to *B. papyrifera* is highest, consider replanting at higher elevations with more resilient stock or accept that this plant may disappear

Table 17: Summary of recommended adaptation options for each species of NTFPs and wild rice species

Species	Range of adaptation options Short term	 Medium term	 Long term
Fungi			
Russula virescens	• Encourage and support the attempt and effort of local communities to achieve 'sustainable harvest' and to develop 'sustainable harvesting systems' of wild mushroom *Russula virescens* and avoid over-exploitation • Identify and protect 'specific habitats' of *Russula virescens* • Build 'check dams' to maintain and increase soil moisture availability within the forests, especially during dry season months, and to reduce wild fire risk • Increase the effectiveness of 'Protected Area Systems' and the management of existing protected areas in order to reduce deforestation, commercial and illegal logging, encroachment, forest fires, land use change, and habitat deterioration and loss	• Increase 'Protected Forests' in order to maintain the habitats and to safeguard the existing wild populations • Restore and rehabilitate deteriorated forests. Increase forest canopies, crown covers, and shady areas • Establish the 'buffer zone' for existing forest areas in order to allow natural shift of forest distribution under future climate change • Promote and support the cultivation projects/programs for *Russula virescens* in order to reduce pressure on wild populations	• Research on ecological characteristics of *Russula virescens* and of its specific habitats • Enhance and increase habitats appropriate for *Russula virescens*
Grasses and herbs			
Amomum spp.	• Ensure protection of forest from logging and other destructive practices • Protect water courses near stands of *Amomum* • Build check dams to maintain ground water level near areas that may tend to dry out • Ensure harvesting practices are	• Monitor stands of *Amomum* to observe changes in productivity and disease or insect infestation at higher temperatures • Monitor forest around stands of *Amomum* to observe reproduction, dispersal of seed, and success of young plants	• If there are signs of morbidity, lowered productivity or reduced fertility: o Actively transplant some rootstock to higher elevations in forest o Consider bringing in stock from plants in

Species	Range of adaptation options		
	Short term	**Medium term**	**Long term**
	sustainable • Ensure that culture practices do not threaten wild stock	• In Mondulkiri, conduct monitoring research to identify stands of *Amomum* that appear to be more resilient to temperature for possible transplanting	Mondulkiri, or other provinces already exposed to higher temperatures • Consider replacement of different *Amomum* species that thrive at the predicted temperature and water availability ranges
Aquatic plants			
Sesbania sesban	• No specific adaptation measures	• General protection of wetland habitats	
Typha orientalis	• No specific adaptation measures • Conduct inventories and map existing populations of *Typha*	• But note *Typha* is a strong wetland plant competitor and could become invasive • Expansion should be monitored and kept in check	• Include *Typha* in new protected areas and/or reintroduce *Typha* to existing protected areas
Lepironia articulata	• No specific adaptation measures, but address current stresses • Organize sustainable use of the plant by local community members • Apply handicraft making and *Lepironia* harvesting techniques that use less raw materials and avoid damages to the plant to reduce pressure on resource	• Advocacy to establish and strengthen the management of the Phu My Nature Reserve. • Improve marketing to increase profit margin of handicraft making • Environmental education	
Climbers			
Dioscorea hispida	No specific adaptation measures	General protection of forest habitat	

Species	Range of adaptation options Short term	 Medium term	 Long term
Orchids			
Dendrobium lindleyi	• Better conserve and safeguard the existing wild populations in protected areas, promote and enhance in-situ conservation • Increase the effectiveness of 'Protected Area Systems' and the management of existing protected areas in order to reduce deforestation, commercial and illegal logging, encroachment, forest fires, land use change, and habitat deterioration and loss • Encourage and support the attempt and effort of local communities to achieve 'sustainable conservation' of *Dendrobium lindleyi*. • Strictly control and properly manage wild orchid trading and cross-boundary trading	• Increase 'Protected Forests' in order to maintain the habitats and to safeguard existing wild populations • Restore and rehabilitate deteriorated forests. Increase forest canopies and crown covers in order to provide more habitats for *Dendrobium lindleyi* (as well as other wild orchids) • Build 'check dams' to maintain and increase soil moisture availability within the forests, especially during dry season months, and to reduce wild fire risk • Increase and support reforestation and afforestation programs / projects/ activities • Consider and take actions to put wild *Dendrobium lindleyi* on protected plant lists	• Support cultivation for ex-situ conservation and trading in order to reduce pressure and demand on wild populations
Bamboos and Rattans			
Calamus caesius	• Build 'check dams' to maintain and increase soil moisture availability within the forests, especially during dry season months, and to reduce severe floods • Encourage and support the attempt and effort of local communities to achieve 'sustainable harvest' and to develop 'sustainable harvesting systems' of rattan and avoid over-exploitation	• Better conserve and safeguard the existing stands in protected areas, promote and enhance in-situ conservation • Increase the effectiveness of 'Protected Area Systems' and the management of existing protected areas in order to reduce deforestation, commercial and illegal	• Establish the 'buffer zone' in order to allow natural shift of forest distribution under future climate change • Support rattan cultivation/plantations for ex-situ conservation and commercial uses in order to reduce demand and pressure on wild populations

Species	Range of adaptation options		
	Short term	**Medium term**	**Long term**
		logging, encroachment, forest fires, land use change, habitat deterioration and loss	
Shrubs			
Broussonetia papyifera	• In Mondulkiri and Gia Lai, where there appears to be increased vulnerability, monitor individuals for signs of increased heat stress and lack of water during flowering • Protect exposed plants from strong winds where possible • In Khammouan and Chiang Rai, where *B. papyrifera* appears to be less vulnerable, no specific actions	• Generally protect forest habitat to ensure survival of wild plants • Identify individual plants in Mondulkiri that appear to have resilient traits against increased temperatures and water stress, and take root stocks/seeds to develop in nurseries • Select favorable locations, e.g., where ground water is likely to remain available and use these areas for cultivation	• In Mondulkiri where the threat to *B. papyrifera* is highest, consider replanting at higher elevations with more resilient stock, or accept that this plant may disappear • In other locations monitor the effects of increasing temperature on the productivity and survival of the plants
Trees			
Dipterocarpus alatus	• Encourage and support the attempt and effort of local communities to achieve 'sustainable harvest' and avoid over-exploitation • Improve oleoresin harvesting techniques, develop proper tapping and hole maintenance methods in order to reduce vulnerability to extreme events • Increase the effectiveness of 'Protected Area Systems' and the management of existing protected areas in order to reduce deforestation, commercial and illegal logging, encroachment, forest fires, land use change, and habitat	• Better conserve and safeguard the existing stands in protected areas, promote and enhance in-situ conservation • Increase 'Protected Forests' in order to maintain the habitats and to save existing wild populations • Strengthen and systemize the overall watershed management for forest and water resources conservation	• Establish the 'buffer zone' for existing forest areas in order to allow natural shift of forest distribution under future climate change • Encourage and promote the plantation of *Dipterocarpus alatus* in reforestation and afforestation programs/projects at community, national, and regional levels • Collect seeds, establish seedbank, and produce seedlings and saplings for ex-situ conservation and re-introduction to

Species	Range of adaptation options		
	Short term	**Medium term**	**Long term**
	deterioration and loss • Build 'check dams' to maintain and increase soil moisture availability within the forests, especially during dry season months		deteriorated forest areas
Sonneratia spp.	• Reestablish mangrove along the coast through planting and natural regeneration • At areas with strong waves, wave breaking structures are needed to protect the young trees from being destroyed by waves • Establish multi-species mangrove forest to cope with storm damage		• Through land use planning, leave enough space for establishment of mangroves along the coast, including relocation of the planned coastal dyke further inland • Plan sluice gates together with the coastal dyke to allow saline water to move in and out of the coastal dyke to provide habitat for mangroves and *Sonneratia* to migrate inland
Insects			
Apis dorsata	• As a key pollinator, honeybees should receive more conservation attention and higher priority national conservation status • Improve management of hydrology in peat areas of Kien Giang, to prevent canal systems in protected areas from drying out of peat, which will decrease flowering of *Melaleuca* trees • Check dams on key canals to prevent drainage of water at end of dry season	• Research into migration patterns and stopover points for *Apis dorsata* • Protection for identified stopover points • Regulation of agricultural chemicals • Enrichment planting of flowering plants at stopover points	

Species	Range of adaptation options		
	Short term	**Medium term**	**Long term**
Red ant, *Oecophylla smaragdina*	• Encourage and support the attempt and effort of local communities to achieve 'sustainable harvest' of red ants and their eggs by establishing and managing sustainable harvesting systems • Ensure that the harvesting techniques are proper and avoid over-exploitation	•	• Increase the effectiveness of 'Protected Area Systems' and the management of existing protected areas in order to reduce deforestation, commercial and illegal logging, encroachment, forest fires, land use change, habitat deterioration and loss
Invertebrates			
Earthworms	• Promote and support organic farming, integrated farming systems, and environmentally friendly agricultural systems • Encourage and support the attempt and effort of local communities to achieve 'sustainable harvest' of earthworms	• Build 'check dams' to maintain and increase soil moisture availability within the forests, especially during dry season months and prolonged droughts • Develop 'wet season refuge' for earthworms in order to reduce their vulnerability to heavy rainfall, flooding, natural predators, and human threats	• Increase 'Protected Forests' in order to maintain the habitats and to safeguard existing wild populations • Increase the effectiveness of 'Protected Area Systems' in order to reduce deforestation, land use change, intensive mono-cultivation, habitat deterioration and loss • Restore and rehabilitate deteriorated forests. Increase forest canopies, crown covers, and shady areas • Strengthen and systemize the overall watershed management for forest, land and water resources conservation
Wild rice			

Species	Range of adaptation options		
	Short term	**Medium term**	**Long term**
O. nivara	• Protect and conserve natural habitats and important ecosystems where *Oryza nivara* grows • Increase the effectiveness of 'Protected Area Systems' in order to reduce encroachment, land use change, intensive mono-cultivation, fire events, habitat deterioration and loss	• Increase 'Protected Areas/Ecosystems' in order to maintain the habitats and to safeguard existing wild populations • Inventory and research on *Oryza nivara* habitats, existence, and its ecological requirements	• Collect seeds and establish seedbank for ex-situ conservation
O. officinalis	• Protect and conserve natural habitats and important ecosystems where *Oryza officinalis* grows • Increase the effectiveness of 'Protected Area Systems' in order to reduce encroachment, land use change, intensive mono-cultivation, fire events, habitat fragmentation, deterioration and loss	• Inventory and research on *Oryza officinalis* habitats, existence, and its ecological requirements • Increase 'Protected Areas/Ecosystems' in order to maintain the habitats and to safeguard existing wild populations	• Collect seeds and establish seedbank for ex-situ conservation
O. rufipogon		• Protect and reintroduce the species in the wetland protected areas where they naturally occurred in the past • Prevent genetic erosion by ensuring that there is no cultivated rice in the proximity of the wild rice	• Collect seeds and establish seedbank for ex-situ conservation
Floating rice		• Floating rice should receive a national protection status for conservation both in situ and ex situ	

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- www.fao.org/forestry/nwfp - database of NTFPs
- http://www.fao.org/forestry/64431/en/ - this is the digest of literature on NWFPs
- http://www.fao.org/forestry/edibleinsects/65425/en/ - for edible insects
- http://www.ent.wur.nl/UK/Edible+insects/Worldwide+species+list/ - lists edible insect species throughout the world
- www.protectedplanet.net – descriptions of protected areas around the world
- www.wdpa.org – World Database on Protected Areas
- http://ebsa.cbd.int/ - key biodiversity areas
- www.birdlife.org/action/science/sites - Important bird areas
- www.plantlife.org.uk/wild_plants/important_plant_areas - important plant areas
- www.hcvnetwork.org – High Conservation resource network
- www.worldagroforestry.org – database of agroforestry crops
- www.tropicalforages.info – database of forage crops
- http://ecocrop.fao.org/ecocrop/srv/en/home – database on ecological requirements of many crop species
- www.iucnredlist.org – Red List of threatened species also go to http://maps.iucnredlist.org
- www.ibatforbusiness.org - tool for business to identify areas and species close to areas of operation
- www.iucnredlistofecosystems.org – under development
- www.issg.org/database/welcome - global invasive species
- www.theplantlist.org = working list of all plant species
- http://www.catalogueoflife.org
- www.eol.org = Encyclopedia of Life
- www.tropicos.org = Tropicos® was originally created for internal research but has since been made available to the world's scientific community. All of the nomenclatural, bibliographic, and specimen data accumulated in MBG's electronic databases during the past 25 years are publicly available here. This system has over 1.2 million scientific names and 4.0 million specimen records.
- www.efloras.org – database of flora from different countries
- www.Mushroomexpert.com
- http://www.knowledgebank.irri.org/ rice knowledge bank by IRRI including wild rice taxonomy
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- http://zipcodezoo.com/
- http://en.hortipedia.com/wiki
- http://en.uuuwell.com
- http://www.cwrdiversity.org/home/ FAO database of crop wild relatives

ANNEXES

ANNEX 1 FORMAT FOR SPECIES VULNERABILITY QUESTIONAIRES

Species baseline vulnerability worksheet

Species name							
Expert team							
Wetland name and location							
Variable	**Adult Score**	**Juvenile Score**	**Egg/Seed Score**	**Characteristics of the Species**		**Confidence**	**Comments**
1. What is the **population** size within the LMB?		na	na	1 2 3	- With in LMB the species is common - Intermediate between Large and Small - With in the LMB the species is rare		
2. What is the **populations trend** in the LMB in the last 50 years?		na	na	1 2 3	- The population is increasing - The population is staying the same - The population is decreasing		
3. What is the **geographic range** size in the LMB ?		na	na	1 2 3	- The species is widespread in the basin - Intermediate between Large and Small - The species is within a small/restricted range		
4. What is the **range size trend** in the LMB in the last 50 years?		na	na	1 2 3	- The range is increasing - The range is the same - The range is decreasing		
5. Can the species **reproduce** fast?		na	na	1 2 3	- Many offspring, many times a year - Many offspring, once a year - few offspring once a year.		
6. Is the species a generalist or specialist?			na	1 2 3	- Generalist - Intermediate - Specialist		
7. Does the species need a lot of habitat?				1 2 3	- Requires a small habitat - Requires a moderate habitat - Requires a large habitat		
8. Is the species able to disperse?				1 2 3	- Can move long distances easily - Can move short distances easily - Can not move very far.		
9. How does the species survive current floods?				1 2 3	- Recovers fast - Recovers medium - Recovers slow		
10. How does the species survive current droughts?				1 2 3	- Recovers fast - Recovers medium - Recovers slow		
11. Are there threats to survival from humans use?				1 2 3	- The species has low value - The species has medium value - The species has high value		
12. Are there threats to survival from non-humans interactions?				1 2 3	- Is not affected - Is slightly affected - Is highly affected		
13. Does the wetland have effective management?				1 2 3	- Highly effective - Moderately effective - Not very effective		
14. Does the species have a national conservation status?				1 2 3	- Not priority - Priority - High priority		
15. Does the species have a IUCN Redlist status				0 1 2 3 4 5 6	- Not evaluated - Data deficient - Least Concerned - Near Threatened - Vulnerable - Endangered - Critically endangered		
16. additional question specific to this species				1 2 3	- less vulnerable - more vulnerable		
17. additional question specific to this species				1 2 3	- less vulnerable - more vulnerable		
Average score	=AVERAG	=(AVERAG	=(AVERAG			=AVERAGE(G8:G62)	

Species climate change analysis worksheet

Species name	+'S Baseline'!B6:G6
Expert team	0
Wetland name and location	0

Variable	Adult Score	Juvenile Score	Egg/Seed Score	Score and definitions		Confidence	Comments
Threats from climate change							
1. Is temperature change considered to be an issue				1 2 3	- Temperature change is not an issue. - **Temperature change is a moderate** - temperature change is a serious issue		
2. Is exposure to drought an issue?				1 2 3	- Precipitation changes is not an issue. - **Moderate exposure to drought** - **major drought issues**		
3. Is exposure to flood an issue?				1 2 3	- Precipitation changes is not an issue. **Moderate exposure to flood** **Major flood issues**		
4. Is exposure to hydrological change an issue?				1 2 3	- Hydrological change is not an issue - **Moderate hydrological exposure** - Major hydrological exposure		
5. extreme weather events - typhoons and high winds?				1 2 3	- Extreme weather is not an issue - **Moderate exposure to extreme events** - major exposure to extreme events		
6. additional questions specific to the species				1 2 3	- less exposure Moderate exposure to fire - more exposure		
Exposure to climate change							
1. Are microhabitats or refugia available to reduce exposure to temperature change				1 2 3	- Temperature exposure is not an issue. - **Refugia are available** to buffer impacts - There is **little option** for the species to find shelter in refugia		
2. Are microhabitats or refugia available to reduce exposure to drought?				1 2 3	- Precipitation changes is not an issue. - **Refugia are available** to buffer impacts - There is **little option** for the species to **find shelter in refugia**		
3. Are microhabitats or refugia available to reduce exposure to flood?				1 2 3	- Precipitation changes is not an issue. - **Refugia are available** to buffer impacts - There is **little option** for the species to **find shelter in refugia**		
4. Are microhabitats and refugia available to reduce exposure to hydrological change?				1 2 3	- Hydrological change is not an issue - **Refugia are available** to buffer impacts - there is **little option for the species to find shelter in refugia**		
5. Are microhabitats or refugia available to reduce exposure to extreme weather events?				1 2 3	- Extreme weather is not an issue - **Refugia are available** to buffer impacts - there is **little option for the species to find shelter in refugia**		
6. additional questions specific to the species				1 2 3	- less vulnerable - more vulnerable		
Sensitivity to climate change							
7. Does the species have a wide **heat** tolerance ?				1 2 3	- Tolerant to a broad range - Tolerant to an intermediate range - Tolerant to a narrow range		
8. Does the species have a wide **precipitation** tolerance?				1 2 3	- Tolerant to a broad range - Tolerant to an intermediate range - Tolerant to a narrow range		
9. Does the species have a wide **hydrological** tolerance?				1 2 3	- Tolerant to a broad range - Tolerant to an intermediate range - Tolerant to a narrow range		
10. Is the species sensitive to **associated risks** from other species?				1 2 3	- Tolerant to a broad range - Tolerant to an intermediate range - Tolerant to a narrow range		
Adaptive Capacity							
11. Does this specie have **reproductive traits** that will allow it to bounce back from the new climate exposure				1 2 3	- pretty sure it can - 50/50 chance - pretty sure it cannot		
12. Does this species have **habitat traits** that will allow it to bounce back from the new climate exposure				1 2 3	- pretty sure it can - 50/50 chance - pretty sure it cannot		
13. Is the population big enough and with enough **genetic diversity** to withstand the new climate exposure?				1 2 3	- pretty sure it can - 50/50 chance - pretty sure it cannot		
14. Does the species have **behavior** that will allow it to **adapt** to the new climate?				1 2 3	- can acclimatize to the new climate - intermediate between High and Low - has little ability or opportunity to acclimatize		
15. Is there sufficient **habitat connectivity** to allow organisms to reach appropriate habitat/climate space/refugia?				0 1 3	- pretty sure it can - 50/50 chance - pretty sure it cannot		
16. Is there **adequate time** to allow an individual to develop adaptive changes?				0 1 3	- pretty sure it cannot - 50/50 chance - pretty sure it can		
17. Will baseline stress be increased by the new climate in the LMB?				1 2 3	- pretty sure they will not - 50/50 chance - pretty sure they will		
18. additional questions				1 2 3	- less vulnerable - more vulnerable		
19. additional questions				1 2 3	- less vulnerable - more vulnerable		
Total score	#DIV/0!	#DIV/0!	#DIV/0!		Average Confidence	#DIV/0!	
#DIV/0!	#DIV/0!				#DIV/0!	#DIV/0!	

Overall species vulnerability worksheet

Species name	0
Expert team	0
Wetland name and location	0

	Scores	Confidence
Species Baseline Vulnerability	#DIV/0!	#DIV/0!
Species climate change vulnerability	#DIV/0!	#DIV/0!
Overall Vulnerability	#DIV/0!	#DIV/0!

Overall vulnerability score	#DIV/0!
Overall vulnerability description	#DIV/0!

Overall confidence	#DIV/0!
Overall confidence description	#DIV/0!

National Conservation Status	not Evaluated
IUCN Global Conservation Status	not Evaluated

Category interval 0.4	Low	High
Very Vulnerable to climate change	2.7	3
Vulnerable to climate change	2.3	2.6
No affect	1.9	2.2
Enhanced by climate change	1.5	1.8
Greatly Enhanced by climate change	1	1.4

Climate change Threats

Climate Change in the Wetland Area

Describe the main threats to the species in the location from climate change

Future weather

1	Rainfall	
2	Temperature	
3	Hydrology	
4	Extreme weather events	
5	How will the wetland change as a result of climate change	