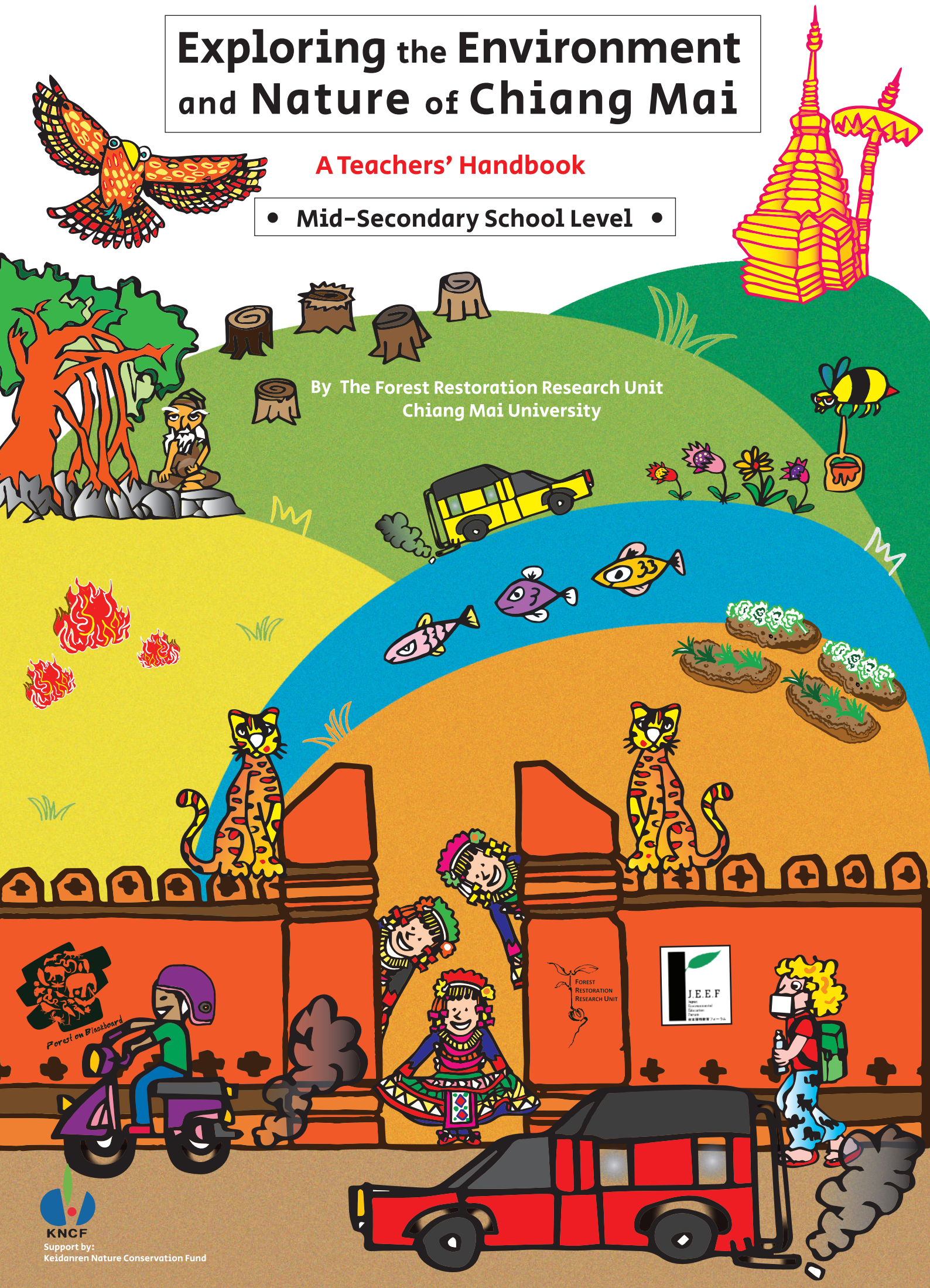
Exploring the Environment and Nature of Chiang Mai

A Teachers' Handbook

• Mid-Secondary School Level •

By The Forest Restoration Research Unit
Chiang Mai University



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Forest Restoration Research Unit

Department of Biology, Chiang Mai University

Forests on Blackboards project

This certificate is presented to:-

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For successfully completing the Forests on Blackboards **Chiang Mai** from E-learning plaform

Six modules with average percent score of **80.00**

Presented on **March 31th 2022**

Dr. Stephen Elliott

Co-Founder & Research Director

https://fob.science.cmu.ac.th/

EXPLORING THE ENVIRONMENT AND NATURE OF CHIANG MAI : A TEACHERS' HANDBOOK

For Secondary Schools

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Forests on Blackboards Project

Sponsored by

Keidanren Nature Conservation Fund

First Edition 2022

FOREST RESTORATION RESEARCH UNIT, 2022. Exploring the Environment & Nature of Chiang Mai: a teachers' handbook. Compilers: Chansai, A., R. Aisao, S. Chairuangsri & S. Elliott, Biology Department, Science Faculty, Chiang Mai University, Thailand.

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Published by The Forest Restoration Research Unit, Biology Department, Science Faculty, Chiang Mai University

ISBN : 978-616-398-688-7

Cover : Doi Suthep & Thapae Gate by Chatri Keth

Eld's Deer. Find out where you can take your class to see them near Chiang Mai in Chapter 6

Contents

Young people have most to gain from environmental conservation

Acknowledgments

This teachers' handbook was produced under the Forests on Blackboards Project FOB (www.forru.org/projects/fob-forests-blackboards-project) by the Forest Restoration Research Unit, Department of Biology, Faculty of Science, Chiang Mai University (FORRU-CMU). The project was funded by the Keidanren Nature Conservation Fund KNCF (Japan) and FORRU-CMU. We are grateful to Mr. Koji Tagi of the Japan Environmental Education Forum (JEEF) for his helpful advice and co-ordination with KNCF throughout this project.

The book was first compiled in Thai, during extensive consultations with local school teachers over several years. We thank the directors and teachers of Navamindarajudis Phayap School, Ban Tungpong School, Ban Namphrae School, Ban Sanpasak School, Yupparaj Wittayarai School, Wattanothaipayap School, Hangdongrathrathupathum, as well as officials from The Secondary Educational Service Area Office for their productive collaboration throughout. We are also grateful to Dr. Pimonrat Tiansawat and Dr. Dia Shannon, from CMU and Mr. Jatupoom Meesena, former FORRU-CMU Field Research Officer, for their valuable contributions.

Under Phase 2 of the project, the book was translated into English, and then further adapted for use in international secondary schools. We thank all those from Prem Centre, Varee International School and Christliche Deutsche Schule Chiang Mai for various comments and suggestions throughout this process and particularly Prem International Centre for helping out with translation (Yuwadee Makpan, Suchaya Santivarakom and Khaekhai Maimaytee).

Forests on Blackboards was founded by Tidarat Chupraphatthasri (FORRU former staff) in 2014, to create environmental education materials for teachers in Kanchanaburi Province, first for primary schools in 2016 and then for secondary schools a year later. We are grateful for her continued inputs into the project, as it has evolved to create similar materials for both Chiang Mai and Krabi Provinces over the past 6 years. Finally, thank you to the head of Doi Suthep-Pui National Park for logistical support and to the Directors and staff of CMU's Doi Suthep Nature Centre, for providing a venue and helping to organize meetings and activities for the Forests on Blackboards Project. Finally we are grateful, as always, to Chiang Mai University for institutional support of this and the many projects FORRU-CMU has undertaken over the past 28 years.

Doi Suthep Nature Study Centre on Huay Kaew Rd - available as a venue for Forests on Blackboards activites: https://www.youtube.com/watch?v=Im9-N4W-jWk

Foreword

We live in an era of the most intense environmental change ever seen in human history. The chaos of global climate change, forest destruction and biodiversity loss are all contributing to what has become known as the "The 6th Mass Extinction"—the most serious environmental crisis of our time. Its impact draws ever closer to us. Even though technological advancements are making our lives more comfortable than ever, they are also keeping us apart from direct experience of the natural word. Consequently, most people lack ecological knowledge, and do not realize how ecological services benefit human lives. The national school curriculum hardly touches upon the topic of nature in general, nor is it well suited to learning about local environmental issues. Although school children in northern Thailand often know about local Lanna cultural heritage, such as the local language, clothes (e.g., Pa Sin Tin Jok), ceremonies (e.g., Yi Peng) or dining (e.g., Khantoke), they know little of Lanna's natural heritage, being able to name but few plant and animal species. And yet we have wonderful wildlife such as Goral, Yellow-throated Marten and Bar-Tailed Pheasant, extraordinary plants such as Sapria himalayana, and spectacular habitats, such as cloud forest on Doi Inthanon. Nature cannot be learnt from textbooks alone, nor by online courses. Without direct experience of the natural world, it is impossible to raise awareness and understanding of it and connect the hearts of children with the environment that sustains them. Although many teachers recognize this problem, and want to build learning experiences that restore relationships between their pupils and the natural environment around them, they often don't know where to start.

I am therefore delighted that, with the help of local teachers, the Forest Restoration Research Unit of Chiang Mai (FORRU-CMU) has put together this manual to promote learning about local nature. I commend the organizers for their hard work in writing this book in an easy-to-read format and for its beautiful design. It is packed with useful information and provides many suggestions for engaging activities in the natural environment. The book is an excellent starting point for teachers to encourage their pupils to explore nature's natural wisdom. It opens the door to connecting children with nature in the real world. I strongly believe that if children get to know and understand the importance of nature as they grow up, they will care for it and get involved in changing society for the better as adults; maintaining and restoring ecological balance, to create better lives for all, and that this precious legacy will be passed on from generation to generation.

Dr. Rungsrit Kanjanavanit

(Mhor Mong, local naturalist)

THIS LESSON DESCRIBES THE PHYSICAL CHARACTERISTICS OF CHIANG MAI THROUGH GEOGRAPHIC MAPS OF DOI SUTHEP AND OTHER IMPORTANT PLACES, TO ENABLE UNDERSTANDING OF VARIOUS GEOLOGICAL AND GEOGRAPHICAL PROCESSES ON EARTH.

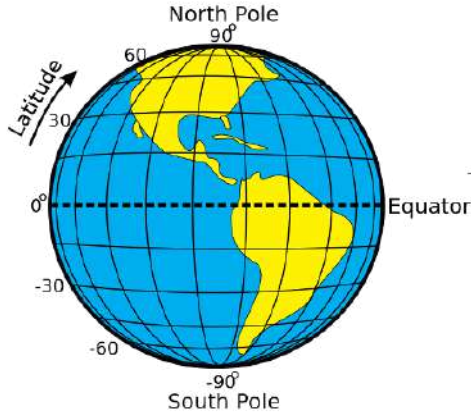
CHAPTER 1

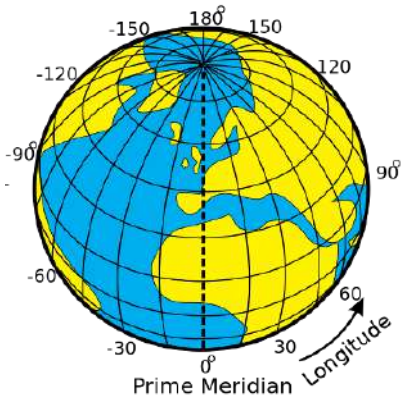
GEOGRAPHY OF CHIANG MAI PROVINCE

PHYSICAL GEOGRAPHY

GEOGRAPHICAL LOCATION

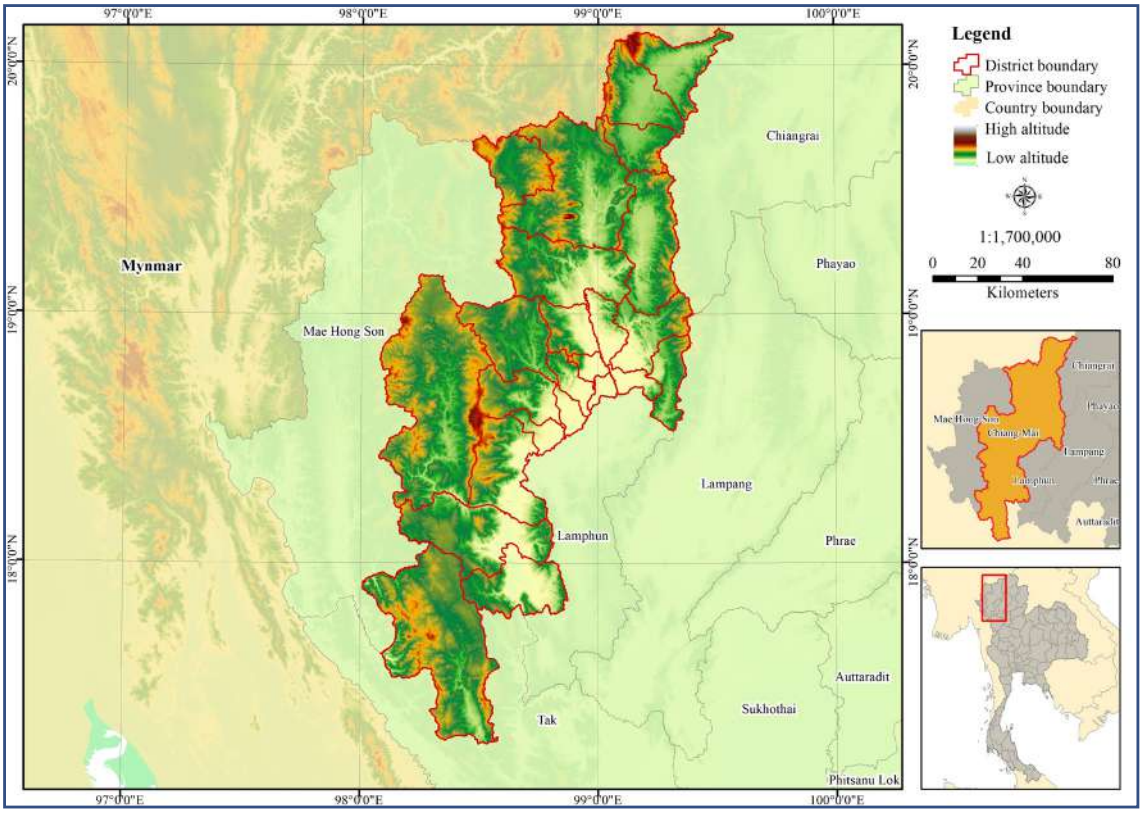
Chiang Mai is located in Northern Thailand, which is part of the Indochina Peninsula, between the equator and the Tropic of Cancer (23.5° North latitude). It is therefore a tropical country. Its location provides ideal weather conditions suitable for plant growth and the development of natural vegetation.





Latitude refers to imaginary parallel lines drawn horizontally on the globe's sphere. There are 180 latitudinal lines, each one running parallel with the equator. The equator is the longest line that divides the Earth into the Northern and Southern Hemispheres.

Longitude or meridian refers to imaginary lines extending vertically from the North Pole to the South Pole, all of equal length. The meridian at 0 degrees divides the world into the eastern and western hemispheres.



Chiang Mai Province Map

TOPOGRAPHY

Chiang Mai mountain range map

Chiang Mai Province comprises two main mountain ranges running roughly north to south, with wide valleys in between. The mountains were pushed up at approximately the same time as the Himalayas and are connected to them. Hence many Himalayan plants and animals can be found here. About 85 percent of the province is considered "mountainous", with the Thanon Thong Chai Mountain Range west of the Ping River (including Doi Inthanon and Doi Suthep) and the Khun Tan Range to the east (including Doi Khun Tan).

The Chiang Mai Basin is between Doi Suthep and Doi Khun Tan.

Chiang Mai City lies in a wide flat valley or "sedimentary basin" with steep mountains on either side. The sediment is eroded soil, carried down from the mountains by streams during rain storms and accumulated over millions of years. The sediment is rich in mineral nutrients, so the farmland of the Chiang Mai Basin is highly fertile.

Mountain range : The Daen Lao Range is another mountain in the top north of Chiang Mai Province. Starting from Doi Phu Muen, Doi Pha Luang and Doi Pha Hom Pok in Mae Ai and Fang districts, it stretches southwest to meet the Thanon Thongchai range.

Sedimentary basin : The Chiang Mai Basin aligns roughly north to south. It is flanked by steep mountains with many streams flowing down to the plains. This continual water flow transports water borne sediments—rubble, gravel, sand, soil and even a little coal—from the mountains to the valley plains either side of the Ping River. Over millions of years these sediments have accumulated to form the floor of the basin; now rich agricultural land.

GEOLOGICAL STRUCTURE

Running down the middle of the Chiang Mai Basin is an active geological fault—a crack in the upper Earth's crust, where the mountain ranges either side are gradually pulling apart and causing the basin floor to sink (this is called subsidence). This has been happening very slowly over the past 60 million years or so. The friction resulting from such massive movements of mountain ranges creates enormous heat and pressure—enough to transform the mineral structure of rocks into "metamorphic" rocks (most recently about 20 million years ago) found on Doi Suthep and Doi Inthanon.

Chiang Mai Basin as seen from the Wang Bua Ban waterfall

Such geological activity is still ongoing, as evidenced by hot springs, found throughout the province, and occasional small earthquakes. It has also resulted in landscape which is very attractive to tourists, including Doi Inthanon, Thailand's highest mountain (2,565 m) and several others, each with their unique beauty.

Doi Inthanon - 2,565 m
From viewpoint in Chomthong District

Doi Luang Chiang Dao - 2,220 m
From Baan Rabiang Dao
Chiang Dao District

Doi Suthep 1,685 m
From the viewpoint overlooking
Ban Hmong Doi Pui, Muang District

CLIMATE

Chiang Mai Province has a seasonally dry tropical climate, with distinct rainy and dry seasons. The average annual temperature is 25.1°C, with average annual rainfall of 1,108 mm in the valleys, rising to double that value in the mountains. The climate is shaped by two "monsoons"— seasonal prevailing winds, blowing from the southwest between May and September, bringing rain (the wet monsoon), and from the northeast between October and April (the dry monsoon):

Lowland forest on Doi Suthep in the rainy season (left) and cool dry season (right)

Southwest monsoons originate from high air pressure to the south, over Indian Ocean, which pushes moisture laden air from the sea northeast into SE Asia. This results in most of Chiang Mai's annual rainfall.

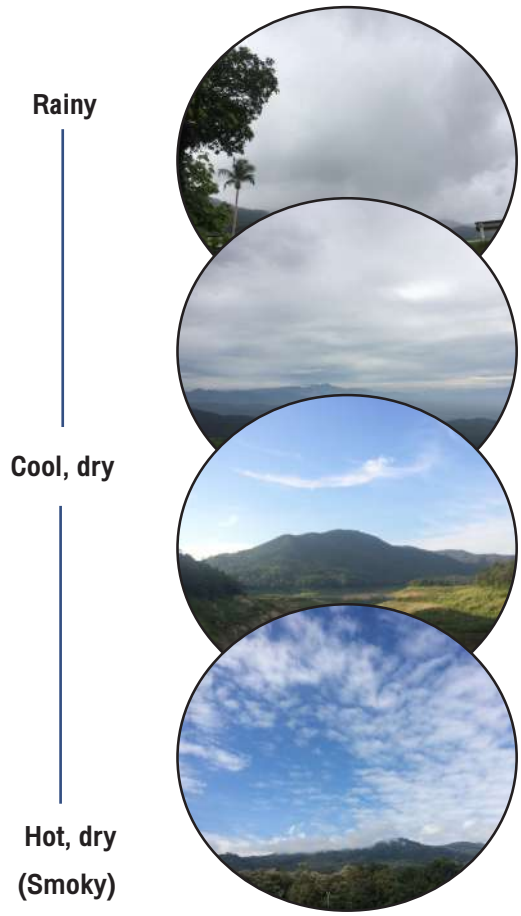
Northeast monsoons originate from high air pressure to the north, over Mongolia and China. This pushes cold dry air southwards, resulting in Chiang Mai's cool season.

Chiang Mai has 3 distinctive seasons

The rainy season begins in mid-May and lasts until October, with more or less daily downpours. Rainfall peaks in August (>200 mm) and gradually declines thereafter.

Starting in November, temperatures fall and there is little rain. The cool temperatures and clear sky, with beautiful views, make this the most pleasant season in Chiang Mai, attracting many tourists. January is the coolest month (average 22°C)

In February, temperatures rise abruptly, peaking in April (average 29°C), creating ideal conditions for forest fires, resulting in smoke haze and dangerously poor air quality. Such unpleasant conditions persist until rain falls in April or May.



DOI SUTHEP-PUI NATIONAL PARK

Wat Phra That Doi Suthep

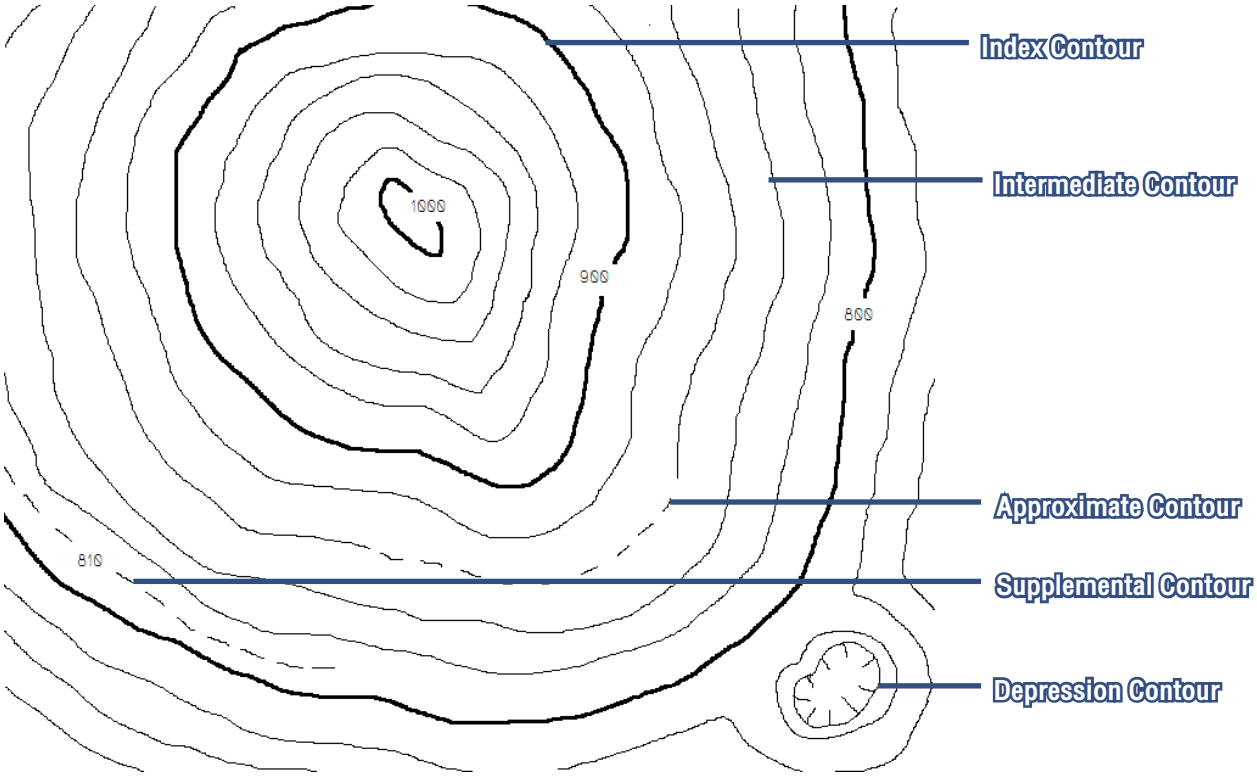
With the golden chedi of Wat Prathat near its peak, Doi Suthep dominates Chiang Mai to the west, casting a shadow over the city every sunset. The mountain is now the centre piece of a 261-sq-km national park, created in 1981, to protect not only the surroundings of the famous Wat Prathat-Doi-Suthep, but also the mountain's diverse ecosystems, from deciduous dipterocarp-oak forest near its base, to evergreen forest around its summit.

The park consists of an isolated double-peaked mountain mostly of igneous rock (granite), with out-crops of sedimentary rocks (limestone, shale, and sandstone) and metamorphic rocks (gneiss and calc-silicate) here and there. Doi Pui is the highest (1,685 m) of the two peaks, but the whole mountain is usually referred to as “Doi Suthep”, the secondary peak. Points of interest include Hmong hill tribe villages and Phuphing Palace, a favourite cool-season retreat of the royal family. It is also an important water catchment area, feeding streams that tumble over waterfalls, which provide attractive picnic and camping sites. The mountain is home to more than 2,200 plant species 326 birds, 500 butterflies, 300 moths, 61 mammals, 28 amphibians and 50 reptiles; all in a park, which covers just 261 sq km.

The park is easily accessed from Chiang Mai City. Huay Kaew (crystal stream) Waterfall (at the end of the road with the same name) and Pah Ngerp are great places to start to explore the mountain's geology.

CONTOUR LINE

A contour line joins points of equal elevation above sea level. They are used to show the 3-dimensional shape of the terrain on a flat map—valleys, plains, hills and mountains etc. The closer the lines are; the steeper the slope, and the further apart they are; the flatter the plain. There are five kinds of contour line:



Types of contour line

1. Index contours - are the boldest (darkest) lines, usually indicating intervals of 100 m elevation.

2. Intermediate contours - between index lines are lighter (or thinner) and usually indicate intervals of 20 m elevation between each line. There are usually four intermediate contours between adjacent index contours.

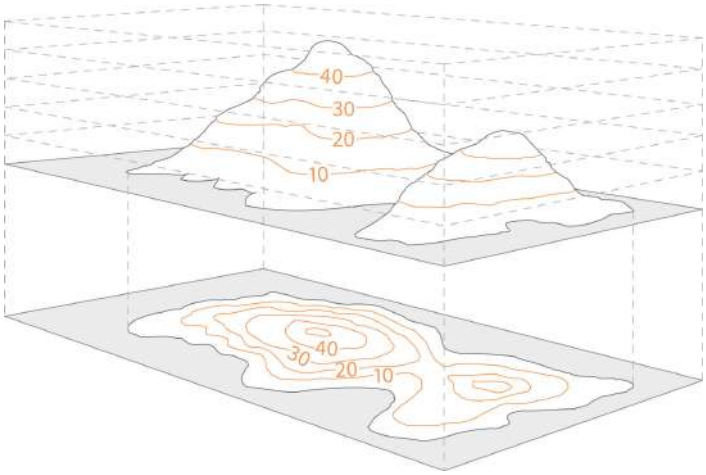
3. Approximate contours - are inserted as an estimated rough guide to elevation, where it is difficult to measure exactly, e.g. when producing approximate maps from blurry aerial photographs.

4. Supplemental contours - are used to add additional small intervals where the land is relatively flat and regular contours are far apart.

5. Depression contours - indicate deep holes.

3D LANDSCAPE MODEL FROM A TOPOGRAPHIC MAP

A map is a visual representation of spatial features on the Earth's surface, both naturally-occurring and man-made. They show spatial relationships among objects and elements and are the basic tools for navigation and land-use planning. They are particularly important for managing and conserving natural resources, which is fundamental to economic development, social issues and politics.

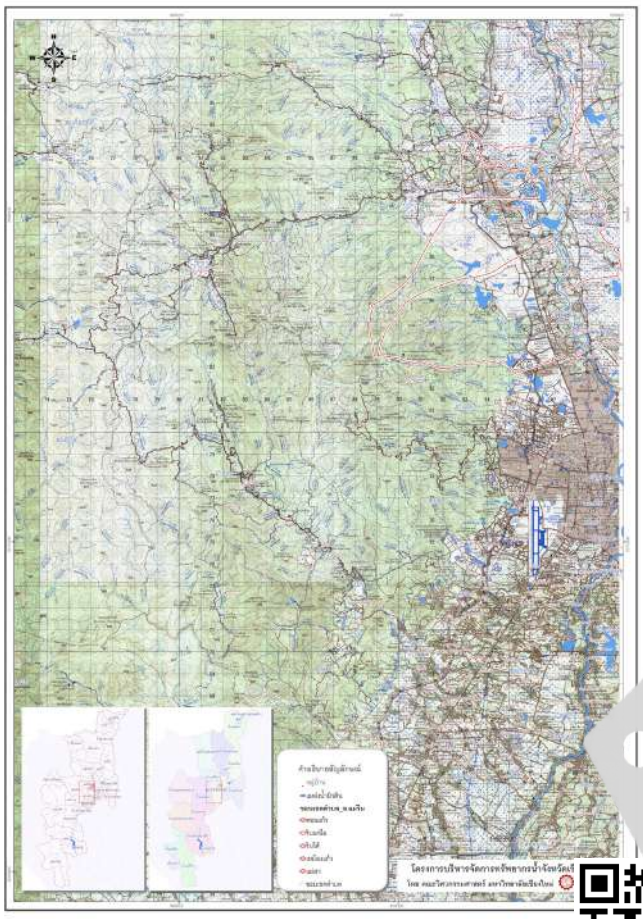


3D map model example

New technologies such as satellites, drones and geographical information systems are now being used extensively to create new maps, keep them up to date and make them widely available, via the internet. Two types of maps are used in mapping models: topographic maps and satellite images.

Topographic maps

A map showing the elevation of the Earth's surface using contour lines referring to sea level. (Try finding a topographic map of Doi Suthep).



Topographical map of Doi Suthep-Pui National Park

Source: Information database system of Chiang Mai Province

Topographic maps can be downloaded from **https://en-us.topographic-map.com/maps/oanf/Chiang-Mai-Province/**
>> Select "OpenTopoMap"

Satellite Images

Images from satellites in orbit around Earth can look like photographs from space, when the visible spectrum is used, but the instruments on some satellites can "see" a lot more, by recording reflected infrared or thermal radiation, well outside the range which human eyes can see. **Try finding satellite images of Doi Suthep.**

Satellite images can be downloaded from the website. **https://www.google.co.th/maps** by selecting a satellite image

If you want a 3D image, you can save the image from Google Earth.

Satellite image of Doi Suthep-Pui National Park

Source: Google Earth

Objectives

1. Learn how to recognize topographic map components.
2. Understand how to work with contour lines.

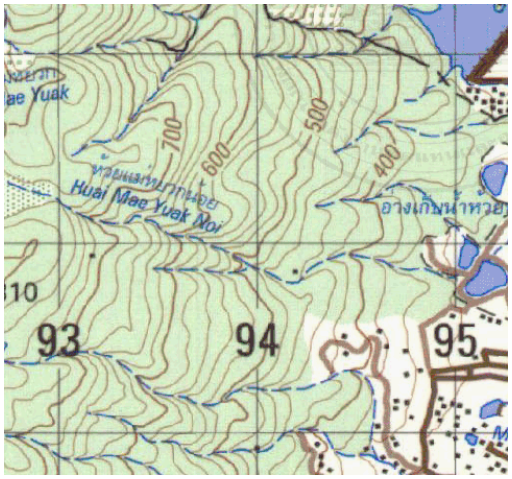
2 hour operating time

Equipment	Amount for 1 group (5 students)
Satellite image	1 piece
Topographic map	1 piece
Extended topographic map	5 pieces
Cardboard	2 pieces
Coloured pencils	1 box
Glue	1 bottle
HB Pencils	5
Scissors	5 pairs
Paint marker pen	1 box

Implementation

1. Divide participants into groups of 5. Students will create a topographic model, from the contour lines of a given topographic map. Teacher distributes a topographic map that has been enlarged approximately 200-400%. Each group selects 4 grid squares adjacent to the 4 grid squares selected by the other groups, so that, when the models are finished all of them will connect with each other. Students should also consult the satellite imagery to help them plan their work.

2. The teacher distributes the rest of the equipment and materials. The students read the instructions, identify the different tasks involved in making the model and divide the tasks amongst themselves.



3. Place the topographic map on the cardboard. Use a pencil to trace each assigned contour on to each piece of cardboard. Then cut the cardboard along the pencil lines. Write the contour elevation on each piece of cardboard so they can be assembled in the correct order.

4. Stack the cardboard pieces in order of ascending elevation and glue them in position. For added effect, paint each layer, using lightest colour for the lowest piece and progressively darker colours ascending.

Take topographic modelling a step further by adding name labels such as Wat Phra That Doi Suthep, the waterfalls or the forest types found at different elevations.

Optional extra: spread a thin layer of plaster of Paris to the model to smooth out the steps before painting and adding name labels.

GEOLOGY

ROCK CLASSIFICATION

Geologists classify rocks into 3 broad types, depending on how they were formed**: igneous, sedimentary, and metamorphic**. Examples of all three can be found on Doi Suthep, making our local mountain a great place to study geology.

Igneous Rocks

Igneous rocks are formed when red hot magma (molten rock) beneath the Earth's crust cools and hardens. There are two main types:

Intrusive igneous rock is formed by slowly cooling beneath the Earth's surface before being pushed up. They contain large, coarse, mineral crystals e.g., granite.

Extrusive igneous rock is formed by the rapid cooling of molten lava on the Earth's surface. This produces small, fine-grained mineral crystals e.g., basalt.

Although hard and cool on the surface, "young" granite may still be very hot deep down. So, granite areas often have hot springs. Water seeps down via cracks. As it reaches hot rocks beneath, it boils and steam pressure forces it up the surface. Geysers occur where the water erupts periodically as steam and spray. Elsewhere, the hot water seeps out more gently as springs. You can see both at San Kamphaeng hot springs.

Granite outcrop near Wat Pha Lat

Granite beginning to erode near Huay Kaew Waterfall

When polished, granite is highly decorative and is used for kitchen and bathroom surfaces and for floor tiles. If it contains a lot of feldspar, granite erodes to form kaolin, used to make ceramics. For example, the ceramic industry in Lampang is based on kaolin, eroded from the granite of Doi Khun Tan.

Kaolin decayed from granite near Mae Yuak Reservoir

Sedimentary Rock

Sedimentary rocks form when particles, eroded from other weathered rocks, are deposited and then compressed by the weight of more particles added on top. The particles may be moved by water (streams and rivers), ice (glaciers) or by the wind. Sedimentary rocks often form in layers called strata. Fossils found in each of the strata can help geologists date when each layer was deposited. Sedimentary rocks found in the Doi Suthep-Pui National Park include limestone, shale, and sandstone.

Limestone is a crystalline sedimentary rock, which forms in shallow seas. So, the tallest limestone mountains today had their origins beneath the sea, hundreds of millions of years ago. Chiang Mai Province has limestone from two different eras:

Limestone in Chiang Dao cave, Chiang Mai Province

"older", 500 million-year-old limestone occurs in Hang Dong and Samoeng districts

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"younger", 300 million-year-old limestone is scattered throughout the districts of Mae On, Chiang Dao and Phrao.

Limestone mountains are perhaps the most beautiful, with steep cliffs and pinnacles, treacherous sink-holes and deep winding caves with stalagmites and stalactites. The limestone formations in the caves of Muang On and Doi Luang Chiang Dao are well-known geological attractions.

In Lampang, limestone is quarried in huge quantities to make cement for the construction industry. In the past, local villagers used it to produce **lime** by heating—a process called **calcination.** Lime is an ingredient of **stucco**—a white paste used to coat the chedis and walls of temples and to make intricate decorative sculptural features. Villagers in Ban Pong, Hang Dong District still produce lime in the traditional way. Their product is regarded as the best lime in the north.

Limestone blocks used to produce lime by villagers in Ban Pong Subdistrict

Shale and sandstone interspersed at Doi Kham, Mae Hia Subdistrict

Shale and sandstone are sedimentary rocks with different grain sizes. Shale has a very fine texture, like flour, while sandstone has a coarser texture, more like sandpaper. These stones are usually scattered as small outcrops amidst large areas of other rocks.

Metamorphic Rocks

Metamorphic rocks were originally igneous or sedimentary rocks, which have subsequently been chemically transformed beneath the Earth's surface, by the enormous heat and pressure generated by shifts in Earth's crust. They may retain some of the characteristics of the original stone, but they also have distinctive new mineral crystals. Metamorphic rocks in Doi Suthep-Pui National Park include gneiss and calc-silicate.

Gneiss is the oldest metamorphic rock found in Doi Suthep-Pui National Park having formed about 600 million years ago. It is a high-grade metamorphic rock, derived from granite. It is recognised by its banded texture, having alternating darker and lighter coloured bands. It is decorative and used in a similar way to granite.

Gneiss near Doi Kham, Mae Hia Subdistrict

Calc-silicate stone Wat Phra Phutthabat Si Roi, Mae Rim District

Calc-silicate forms when hot magma intrudes into limestone. Calc-silicate rocks contain calcium carbonate and silicates, which sometimes form semi-precious gemstones called **garnets**. Since the Bronze Age these garnets have been used in jewellery and as abrasives. When polished, they are mostly reddish and so are sometimes confused with rubies, although they are much less valuable. Garnets can also be black or green.

GEOLOGICAL DISASTER

Landslides occur frequently all over northern Thailand and can result in injury and death, destruction of buildings and loss of farmland. Steep slopes and heavy rainfall during the monsoon are the main reasons why northern Thailand is so prone to landslides. When rain penetrates the soil, It becomes heavier and more slippery. The roots of plants can help to bind the soil together and thus reduce the likelihood of landslides, particularly the deep roots of forest trees. So steep slopes, where the forest has been cut down, are high-risk areas for landslides. The steep sides of road cuttings are another danger area. Clay soils can absorb a lot of water per unit volume, so are more likely to slide, whereas water drains through sandy soils more rapidly and are thus less likely to slide. To prevent landslides, prevent deforestation, and when carrying out construction of roads or buildings, use bulldozers to make slopes more gentle. Lastly, stay away from buildings on steep slopes in the rainy season, especially where the vegetation has been removed.

Landslides and fallen trees blocked the road leading up to Doi Suthep.

CASE STUDY

Landslide

Landslide in Pong Yaeng Subdistrict, Mae Rim District, Chiang Mai Province

Source : http://www.workpointtv.com/news/7439

Early in the morning on June 1, 2016, the route connecting Buak Chan Village and Ban Kong Hae in the Chiang Mai Province was blocked by a landslide, which also crushed Mr. Kasem's house, causing it to collapse. Four cars were also damaged. The village headman made an announcement and about 30 residents came to help remove debris, trees, branches, and mud from Mr. Kasem's house. They also helped remove cars and motorcycles from the mud. The landslide was higher than 1 meter, so backhoes where brought in to help dig up the mud that had piled up on the houses and roads to speed up the clearing and allow travel as quickly as possible.

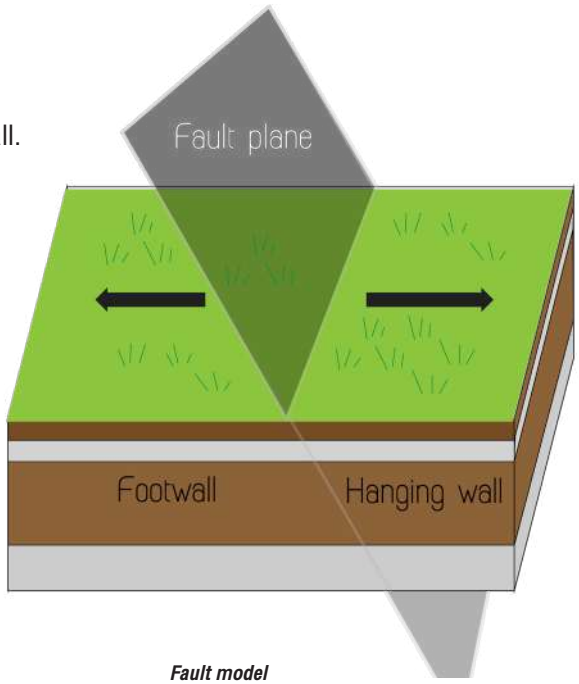
Kasem Koytha, the owner of the house, made a statement saying it had been raining since the early morning for more than two hours before he heard objects hitting the door and wall in front of the house. When he stood up to look, he found that mud had collapsed onto the front of his house from the mountain and crushed a car and 3 motorcycles that were parked in front of the house. Fortunately, no one was in the house when it collapsed.

FAULT

Earth's surface is made of many hard plates floating around (very slowly) on molten magma. The movement of the plates is called plate tectonics A fault plain is where two plates meet either being pushed together or being pulled apart. A fault is a rock fracture, caused by the stress of blocks of rock moving at the fault plane. The block above the fault plane is termed the "hanging wall', whilst the one below the fault plane is termed the "footwall". There are 3 types of fault:

Normal Fault

The hanging wall slides down in relation to the footwall. This fault plane has an average slope of about 60 degrees and is caused by expansion of the Earth's surface. Normal faults are usually the result of stretching (tensile forces) of large areas. The fault is steep and smooth and typically forms a cliff. When a rock plate sinks between two normal faults, a basin is formed. The sinking plate, forming the basin floor is called a "graben", whilst the two plates on either side forming the basin rim are termed "horsts". This explains the topography of the Chiang Mai Basin.



Fault model

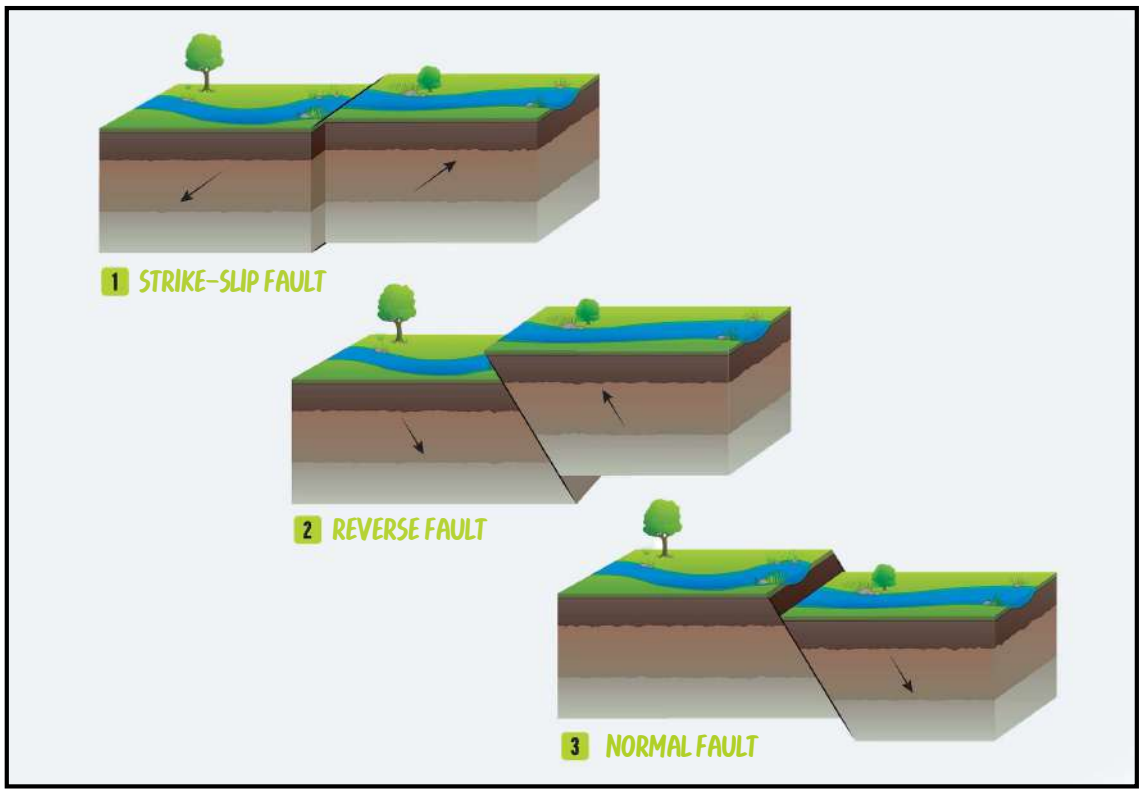
Slickenside Surface at Wang Bua Ban Waterfall

Reverse Fault

Reverse faults are caused when two plates push into each other causing the hanging wall to move up and over the footwall. In this case, the fault plane has an average slope equal to or less than 45 degrees and is caused by "compressional stress". This type of fault causes a fault cliff as well, but such cliffs tend to extend forwards with overhangs. Therefore, they are more prone to rock falls and erosion compared with cliffs caused by normal faults.

Strike-Slip Fault

This kind of fault is caused by horizontal, lateral sliding movement of rock plates. If standing on one side of the fault line and the rock plate on the opposite side moves up to the right then it is called a "Right Strike-Slip Fault", but if it moving towards the left then it is called a "Left Strike-Slip Fault"



Fault types

Source : https://www.offgridweb.com/preparation/seismic-science-prepping-for-earthquakes/attachment/science-of-earthquakes-basic-fault-types/

FAULT MODEL

Models are simplifications of larger complex systems, making them easier to understand. This fault model enables students to visualize the movement of rock plates that cause the faults, which resulted in the origin of Doi Suthep-Pui and the Chiang Mai basin.

Objectives

1. To know how to make a fault model.
2. To use the model to understand how the Chiang Mai basin was formed from normal faults.

2 hours operating time

Media material equipment

Equipment	Amount for all student
Fault model set	1 set
Beads in 3 colour (Different size)	1 set

Instructions for the fault box can be downloaded from **https://fob.science.cmu.ac.th/**

Event guidelines

1. Lead this activity with the question: “why is the topography around Chiang Mai city a basin?”

2. To answer this question, the teacher can demonstrate the formation of basins and the occurrence of normal faults. Ask for volunteers to help move the two ‘stone slabs’ (you can use boxes) apart. The students observe and record the results of the rock layer change. If the earth's crust moves in the form of normal faults, what effects will it have on topography and rock layers?

3. This fault model can also be used to show the occurrence of a reverse fault. Teacher explains the occurrence of a reverse fault by sliding the (box) stone slabs together. Students can observe and record different results.

4. Discuss the results of the two fault model experiments and compare the differences.

Example of recording the results of the experiment

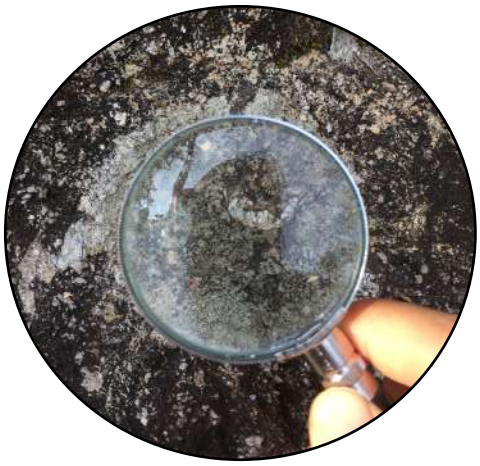
Fault type	Result
Normal fault	This type of fault forms a cliff but does not protrude forward. The area of Doi Suthep is the part of a normal fault that has moved up (horst), but the city of Chiang Mai expanded its area and sank into a basin (graben).

EXPLORE NATURE TRAILS

Take a field trip to Wang Bua Ban Waterfall - Huay Kaew Waterfall Nature Trail, to learn about geography and geology of the local area. Integrate what students have learnt in the classroom with observations in the field. They can learn about the creation of the Chiang Mai Basin by looking for evidence of faults on rocks, looking for rock types or minerals, rock erosion, etc. and explore the nature trails leading to other locations in Doi Suthep-Pui National Park.

Objectives

1. To understand the origin of the Chiang Mai Basin and know the evidence of faults from observing rocks.
2. To be able to use a compass correctly.
3. To classify rocks and minerals found in the study area.
4. To study the pattern of rock erosion.



2 hours operating time

Media material equipment

Equipment	Amount for 1 student
Compass	1 piece
Magnifying glass	1 piece

Event guidelines

Once students have learned about rocks and faults in the classroom, teachers may lead students to learn outside the school by bringing them to Wang Bua Ban Waterfall and Huay Kaew Waterfall. The teachers should prepare to teach on the following topics:

- History of Wang Bua Ban Waterfall.
- Using a compass.
- Faults and the Chiang Mai Basin.
- Characteristics and erosion of rocks in streams.
- Types of rocks and minerals common in rocks.

Related information or worksheets can be downloaded from **https://fob.science.cmu.ac.th/**

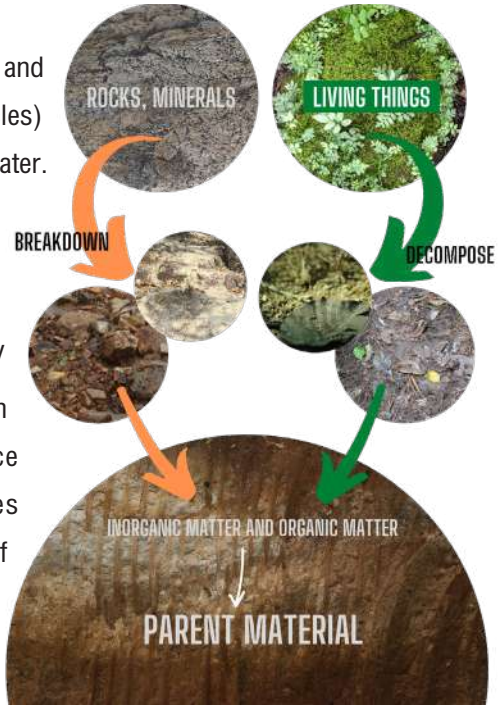
Rock-mineral exploration in Huay Kaew waterfall

SOIL

The soil that we see today is formed from the underlying rock by the action of 3 main types of process operating over millions of years: i) physical breakdown ii) inorganic chemical reactions and iii) interactions with plants and animals (organic processes).

Physical breakdown: the breakdown of rocks into smaller and smaller pieces (eventually becoming the mineral soil particles) occurs when rocks are moved by geological pressure or by water. Temperature fluctuations also cause rocks to flake at the surface, as they expand when heated and shrink when cooling.

Chemical reactions: rocks are composed of many different chemicals, which react with each other when they come into contact, particularly in the presence of water. For example, acidic rain water dissolves limestone, fracturing it into smaller pieces. The dissolving of chemical components of the minerals releases nutrients essential for plant growth particularly compounds containing nitrogen, phosphorus and potassium.



Soil formation process

Organic processes: in all ecosystems on land, all plants and animals eventually end up in the soil when they die, becoming "dead organic matter". Soil organisms such as worms and insects mix the organic matter with the mineral particles. The more organic matter in the soil, the more water it can hold. Organic matter turns rainwater acidic and so it also affects the chemical breakdown of the mineral particles.

Five factors affect soil formation

1. Parent material: Soil is formed by breakdown of the underlying rock or "parent material", which obviously has a huge effect on the resulting soil properties such as colour, texture, structure and chemical properties. Alkaline rocks, such as limestone, produce dark, fine-grained and generally fertile soils. Soils formed from acidic rocks, such as granite and shale, tend to be more coarse-grained, are lighter in colour and lower in fertility.

Soil formation factors

2. Climate: physical breakdown increases with increasing rainfall. Chemical reaction rates increase with increasing temperature. Consequently, in the wet tropics, rocks breakdown into soil much faster than in colder regions. However, high rainfall can also leach soluble mineral nutrients from the soil, leading to lower soil fertility.

3. Topography: the shape of the landscape (valleys, gorges, cliffs and mountain peaks) greatly affects how rocks are exposed to sunshine and rain and therefore how fast soil forms. For example, south-facing slopes receive more sunshine and so heat up more than north-facing ones. The heat speeds up chemical reactions but also dries out the soil which affects soil depth and colour.

4. Organisms: plants generate most of the organic matter in soil, whilst animals are primarily responsible for mixing it with mineral particles. The balance between plant productivity and decomposition determines how much organic matter remains in the soil. Where decomposition rates are slowed by cold or water-logging, peat soil is formed.

5. Time : soil accumulates with time, but can be interrupted by extreme events such as floods, landslides, volcanic eruption,climate change etc. Such events may remove soil, with soil formation starting from scratch again afterwards. So, soil depth depends on the time interval between such events.

Process of transformation of soil parent material

Most rocks are mostly composed of silicate minerals, which, when they break down, make the soil weakly acidic. The exception is limestone, which is composed mostly of calcium carbonate. It breaks down to form alkaline soils with a fine texture.

Granite and other igneous rocks break down to form coarse-grained soils, whose nutrient composition varies according to the proportion of quartz, feldspar and other minerals. If the proportion of quartz is high, the soil is sandy, with low water-retention capacity and can be very high in silicon. This results in plants with strong stems and large, rough leaves because silicon accumulates in plant cell walls If the proportion of quartz is lower, the soil appears more dense and its texture is finer. Such soils are better able to retain soil moisture and they contain higher nutrient levels, which are good for plant growth. Higher levels of alkaline feldspar increases the level of potassium in the soil, which promotes flowering and fruiting. Consequently, many fruit tree orchards—longan, sweet tamarind and litchi—are established on such soils over granite bedrock.

SOIL PROFILE

When digging a hole, you may observe that soil has distinctive horizontal layers (termed "horizons"), which differ in thickness, colour and texture. A full soil profile is a vertical section through the soil from its surface, to where it meets the underlying rock, displaying all the layers. Different processes occur in each horizon. For example mixing with organic matter occurs in the upper horizons, whereas formation of new mineral particles occurs where soil meets bedrock.

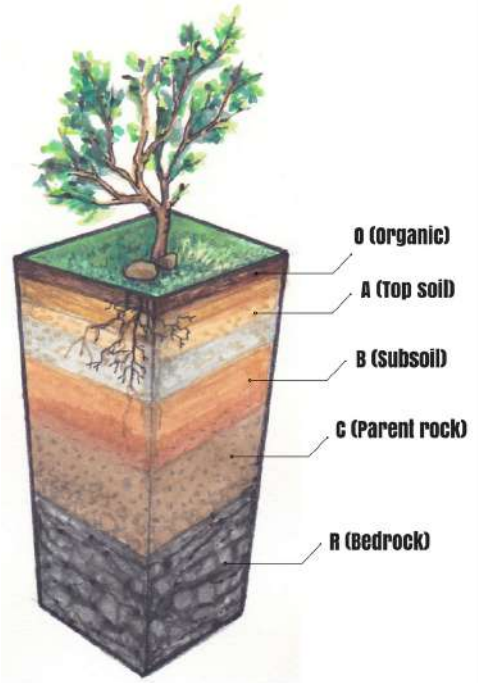
O Horizon: the "O" stands for organic matter. It Is the uppermost layer, where leaf litter and other dead plant material (termed "humus") accumulate, before being mixed into the mineral soil. It is usual dark brown and becomes slightly acidic (producing humic acid), as the organic matter is gradually decomposed by microbes, earthworms and insects.

A Horizon: this is where the organic matter first becomes mixed with mineral soil by termites, beetles, mites, spring-tails, earthworms and many other animals. It is also dark grey-brown, often with large, coarse grains.

B Horizon: this layer is dominated by mineral particles with less organic matter. In northern Thailand it is dominated by iron compounds, so it is reddish like rust.

C Horizon: much deeper down, the C horizon is where soil meets rocks. It is made of tiny rock particles recently shed from the surface of the bedrock. This is where most plant mineral nutrients originate.

R Horizon: this the bedrock or "parent material".



Soil Profile

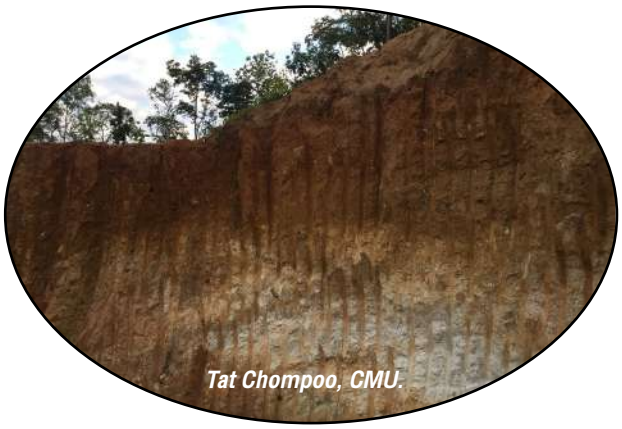
CHIANG MAI SOIL RESOURCES

In northern latitudes, the soil was scraped away by glaciers during the last ice age. So most of the soils there are "young"; less than 25,000 years old. However tropical zones like northern Thailand were unaffected by glaciation and so the soils here are ancient, deep and highly weathered. You can see this at road cuttings where the red soil goes down many metres without reaching the bedrock.

Soil profiles can be observed at roadsides

Examples of soil conditions found in the area of Doi Suthep-Pui National Park


Wang Bua Ban Waterfall


Tat Chompoo, CMU.


Montathan Waterfall


Doi Kam temple

A soil series is a group of soil types, derived from the same original rocks but differing in texture. Soil series are named after a town or landmark near where the series was first recognized. More than 300 soil series have been distinguished in Thailand. For example around Chiang Mai, there's the Hang Dong series, the Doi Pui soil series and the Mae Rim series.

The study of soils is called as "soil science". It involves studying soil profiles in the field ("*in situ*") as well as collecting soil samples and analysing them in the laboratory. Soil science tends to focus on those soil properties that support the growth of plants, especially crops. These include soil pH (acidity and alkalinity) and the concentrations of mineral nutrients. The macro-nutrients, needed by plants in large amounts, are nitrogen, phosphorus and potassium. Secondary nutrients, needed in moderate amounts, are calcium, magnesium and sulphur, whilst trace nutrients, required in tiny quantities include boron, chlorine, copper, iron, manganese, molybdenum and zinc. Soil texture is the most prominent physical soil characteristic. It is the relative percentages of sand (large grains), silt (medium grains) and clay (small grains). Water retention is another important soil property. It is measured as "field capacity" —the weight of water, which can be held in 1 gm of dry soil against gravity. Soils that are rich in clay and organic matter have high field capacity.

BUILD YOUR OWN SOIL PROFILE

True understanding of any system lies in being able to deconstruct and reconstruct it. In this activity, pupils learn about soil profiles by creating their own one in a jar. The activity reinforces understanding of why each layer is where it is and what processes may be going on in each layer.

Objectives

1. To understand the characteristics of soil profiles
2. To reinforce understanding of the processes of soil formation

1 hour operating time

Media materials equipment

Equipment	Amount for 1 group (3-5 students)
A 200-g coffee jar or similar	1
Materials to create each soil horizon (e.g. soil, large/small stones, gravel, sand, dead leaves, moss, etc.)	1 item per person
Stickers (post it) and pen and decorations	5

Preparation

The teacher assigns each student to prepare one small bag of soil material at home for the following day's activities. Different students can be assigned to collect different material types for different soil horizons, so materials for all horizons are available.

Event Guildlines

1.Having completed the lesson on soil profiles, the teacher asks the students to describe and explain the characteristics of each soil horizon.

2. Students are divided into groups of 3 to 5. Each group designs their own soil profile, selecting appropriate materials for each horizon, according to what they have learnt.

3. Students label each soil horizon with stickers on the outside of the jar. They can decorate their bottles with plants or small model animals, representing the ecosystem above, as they wish.

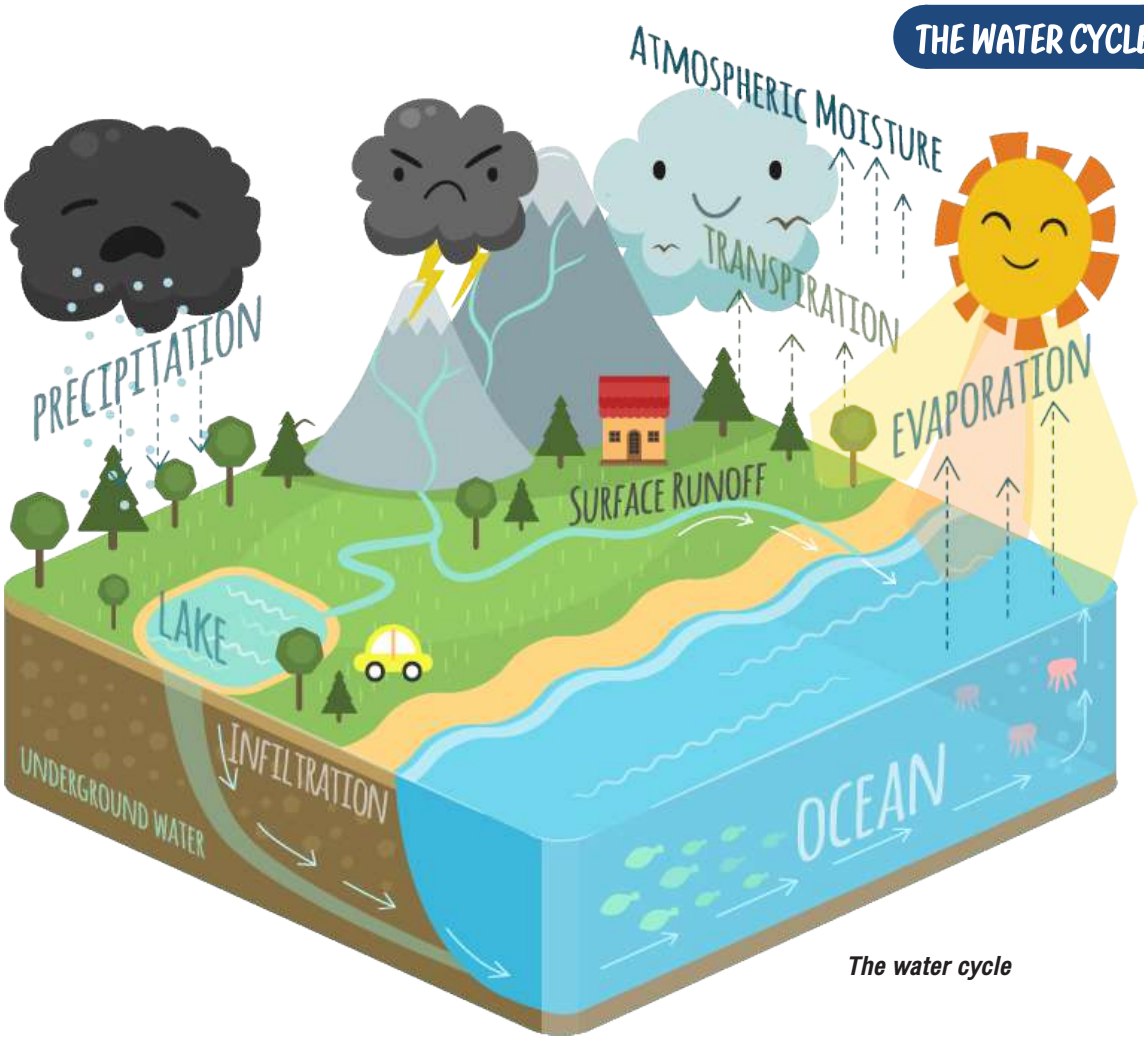
4. Each groups presents their soil profile to the whole class explaining their reasoning in constructing it.

A constructed soil profile - are the horizons layered correctly?

WATER RESOURCES

Water resources are not only essential for human life, they are necessary for every living thing on Earth. Water is the key factor, which makes our planet Earth rich with life. This lesson covers the origin of natural fresh-water sources and how they support all living organisms.

THE WATER CYCLE



The water cycle

Water can exist in three states: i) solid ice, ii) liquid (flowing water) and iii) gas (as water vapour in the atmosphere). Here in warm northern Thailand, ice hardly ever forms, so typically, water on land is liquid. Water evaporates into the atmosphere from the ocean, streams, rivers, lakes and from the soil surface. It also passes into plant roots from the soil and is transported into plant leaves, from where it evaporates through tiny pores in the leaf surface called "stomata". This is called "transpiration". The term "evapo-transpiration" combines evaporation from the soil with that through plants, meaning total evaporation of water from an area of land. When the water vapour in the air cools, it condenses back into tiny water droplets, which coalesce forming clouds and then falling as rain ("precipitation"). At first, rain penetrates into dry soil ("infiltration"), but once the soil becomes saturated, it flows over the surface ("surface runoff"). Soil water can also drain further down to form underground water sources, or it can flow in streams and rivers to the sea, or accumulate in lakes.

Atmospheric moisture

Air humidity is the amount of water vapour in the air. Warm air can hold more water vapour per unit volume than cold air can. This why liquid water drips from air conditioners and ice builds up in freezers. Absolute humidity is measured as grams of water per cubic metre of air. The rate of evapo-transpiration increases as humidity falls and decreases as humidity rises.

Precipitation

Precipitation means any form of water falling from the atmosphere—fog, rain, snow, hail, etc. Hot air near the Earth's surface can hold a lot of water vapour, but as hot air rises, it begins to cool, and can therefore hold less and less water vapour. The water vapour condenses out as tiny droplets which form clouds. As the droplets coalesce, they become heavy and can no long remain suspended in the air against gravity. So they fall as rain or, where the air temperature is below zero as snow or hail.

Infiltration

Rain water infiltrates into soil at a rate dependent on grain size, temperature, rock type and the amount of water already contained in the soil. If the soil is nearly saturated, it can absorb only a small quantity of additional water. Some of the water that penetrates the soil flows into the groundwater layer, but in steep areas where the soil is thin such water may emerge as springs lower down, originating streams and rivers. Infiltration is high where soils are rich in organic matter.

Surface Runoff

Surface runoff occurs when precipitation exceeds the rate of infiltration, particularly where soils are already saturated. Surface runoff flows downhill to the lowest points in the landscape, swelling streams and rivers. As it runs across the soil surface, it picks up soil particles, causing erosion, and when the streams and rivers are full, surface runoff becomes a flood.

Evaporation

Evaporation is the transformation of liquid water into water vapour caused by heat. It therefore increases with increasing temperature and decreases with increasing humidity. Water evaporated from the sea reaches Chiang Mai on the monsoon winds described earlier. However some of the rainfall here is from evaporation from local streams, rivers, reservoirs and the soil surface. Such evaporation is influenced by topography being more rapid on south-facing slopes (which catch more sunshine) then north-facing slopes.

Transpiration

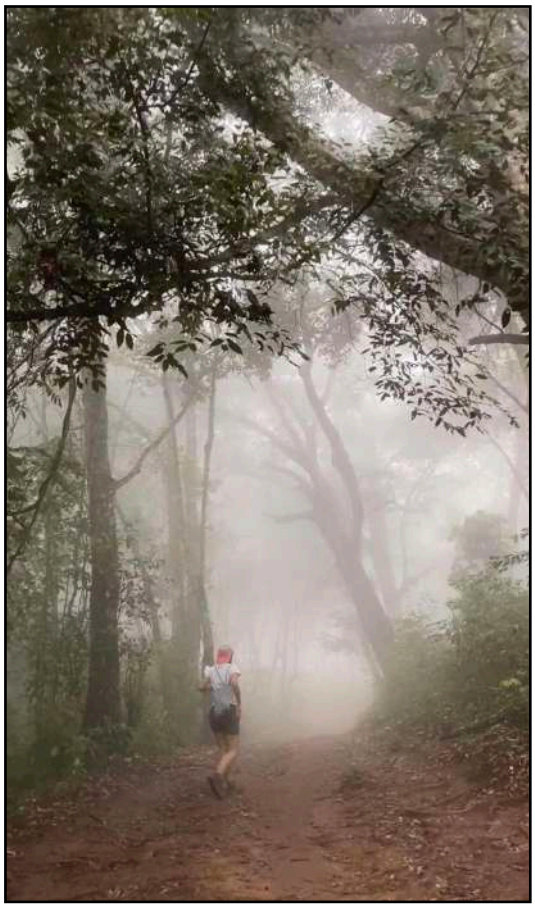
Transpiration refers to the evaporation of water from plant leaves through tiny pores in the leaf surface called stomata. In addition to air temperature, transpiration rates are influenced by the plant's structure (morphology), the density of stomata on the leaves and the angle of the leaves to incident sunlight.

"Hail" is frozen rain. It falls very rarely in Chiang Mai , only on the coldest days of the cool season and it melts within a few minutes of reaching the ground. Find out what cumulonimbus clouds look like - if you see them in the cool season, hail may be on the way. Stay indoors during a hail storm, because some hail stones are large and very hard and they fall with such force, they can easily injure you. But when it's all over, go out and snap some photos! It may be a very long time before you see it again in Chiang Mai.

Fog drip - when forests make rain

Doi Inthanon forms the watershed between the Ping River to the east and the Chaem River to the west, both of which feed the Chao Phraya River, which supplies water to farms of the central plains and to Bangkok. And it is the mountain's upper forest canopy that "captures" a lot of this water through a rare form of precipitation called "fog drip".

Low temperatures at the mountain's summit mean that it is frequently swathed in fog. Fog droplets, are captured by the trees' leaves, before falling as "rain" dripping constantly from the forest canopy and infiltrating the deep, rich forest soil. Fog drip contributes significantly to the input of water to stream flow from the mountain. Without the forest, the fog droplets might very well be blown away and fall as rain elsewhere. Thai folklore, on the other hand, provides a simpler explanation. The mountain is said to be the home of "the spirit who shares water". So if you ever visit Doi Inthanon summit on a foggy day, step inside the forest at the nature trail there. Is it raining, even when outside the forest it is not? That's fog drip.



When forests make rain —fog in the forest canopy

NATURAL WATER SOURCES IN DOI SUTHEP-PUI NATIONAL PARK

Montathan Waterfall

Tat Mok Waterfall

Huay Kaew Waterfall

Mae Sa Waterfall

Mok Fa Waterfall

How streams shape the landscape

The flood plain on either side of the Ping river is composed of alluvial sediment— clay, silt, sand, gravel and even small rocks— eroded from mountain slopes and carried down to the basin floor by streams. The alluvium is deposited lower down, as slope steepness declines and stream flow slows, allowing the particles to sink and accumulate on the stream beds. Over many years, floods and earth movements change the course of streams, leaving behind the alluvium, even though the streams that deposited it may have long since dried up or changed course. The further the distance carried, the greater the decay and the smaller the sediment particle size, such as the fine sand, which forms sand bars or "piers" in the main river in San Sai and Mae Rim Districts. Such sand is dredged and used for construction and to make water-filtration systems. Clay particles are even finer, and river clay is used to produce pottery, such as at the Kung quarry pottery in Hang Dong District.

Floods occur when sediment deposition raises riverbeds, reducing the volume of the river channel. So, when rain storms occur, the river channel is too shallow to hold the sudden increased run-off. The river "bursts its banks" and water spreads rapidly across the flood plain. This happens frequently even in downtown Chiang Mai City.

Alluvial deposition consists of five processes

• Weathering—water and temperature fluctuations change the chemical composition and physical structure of rocks, causing them to break into smaller pieces—fragmentation.

• Mass wasting—rock fragments move downhill due to gravity or rainwater.

• Erosion—movement of water or wind across the surface of rock fragments scrape off smaller particles.

• Transportation—streams move the rock fragments long distances downhill with the speed of movement dependent on the stream flow, which in turn depends on slope steepness.

• Deposition—the sediment sinks and settles to the river bed, as the flow of water slows in flatter areas.

CASE STUDY

Wiang Kum Kam — The Flooded City

The first capital of the Lanna Kingdom, Wiang Kum Kam was built by "Phaya Mangrai" the King of Yonok Nakhonin, in 1286. It is notorious for having been continuously damaged by floods, such that the King subsequently founded Chiang Mai as a replacement. So, it could be said that Chiang Mai City exists as a result of alluvial sedimentation.

The current map of Wiang Kum Kam.

Architectural details once submerged and buried beneath alluvial sediments

Wiang Kum Kam was built on the east bank of the Ping River. Frequent floods brought large amounts of sediments into the city damaging buildings and blocking water channels, making it difficult to maintain. Then one night, in the mid-17th century, during a particularly severe storm, debris blocked the Ping River, causing it to carve a new channel right through the city with great destruction of buildings and loss of life. So Wiang Kum Kam was abandoned and the buildings become buried in sediment and mostly forgotten. Then in 1984, the city was rediscovered and 42 monuments have since been excavated from the alluvial sediments. Today tourists can view the excavated ruins from horse-drawn carriages.

The ruins of Wat That Kao excavated in 1985 from alluvial sediments at Wiang Kum Kam

Tour the ruins in the comfort of a horse-drawn carriage

WHERE DOES YOUR WATER COME FROM ?

Water Is essential for all living things, including humans. In this exercise, students learn to appreciate water, as they explore its journey from mountains to tap. They calculate its value and understand the importance of conserving the watersheds where it originates.

Objectives

1. To learn about the origins of water resources.
2. To appreciate the need to conserve watershed areas.
3. To calculate the value of water used in their own homes.

1 hour operating time

Media materials equipment

Equipment	Amount for 1 student
Notebook and pen	1 set
Pencil	1 piece

Event guidelines

1. The teacher reviews the information presented above on the water cycle.

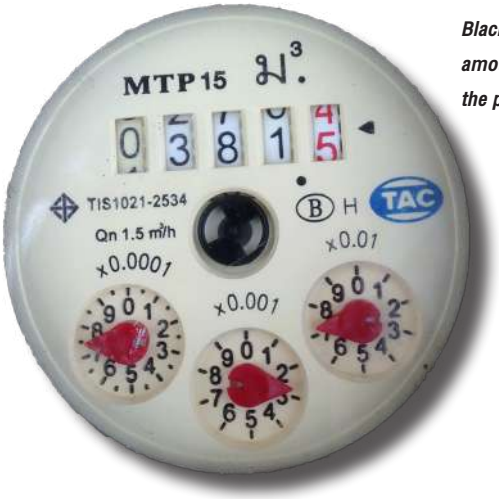
2. The teacher encourages students to investigate where the water in their homes comes from. Rural students may trace water pipes to a nearby well or stream. Urban students should be encouraged to ask the water company officer when he/she comes to read the metre.

Treatment stages of piped water in cities

3. In urban areas, arrange a trip to the local water company to allow students to understand the treatments needed to make water clean and safe before it is piped into houses.

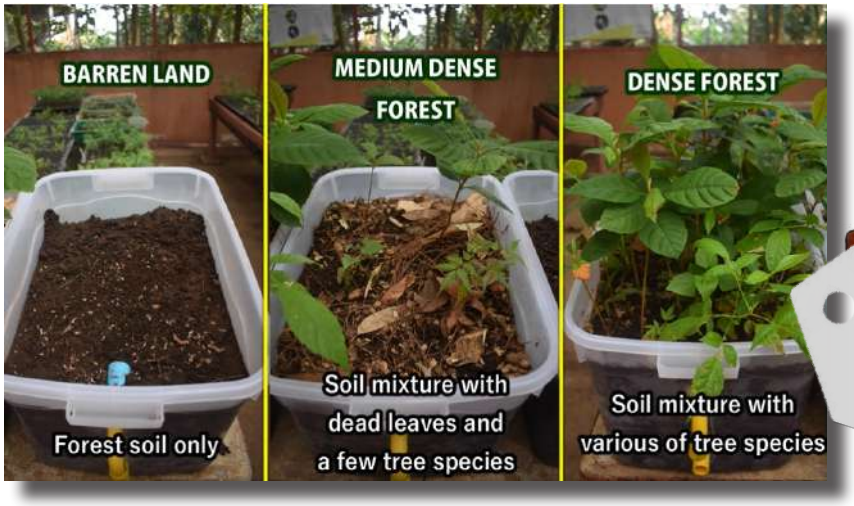
4. Ask the students to find out where are the original sources of water (accessed by the water company). The teacher should explain the benefits of having forests on watersheds and ask what would happen to water resources, if watershed forests were removed.

5. Students should also be encouraged to calculate water bills, by reading their home water meter monthly. Find out the charge for 1 cubic meter of water (the unit price) indicated on the water bill. Multiply the units consumed by the unit price. Then add the general service fee (usually about 30 baht) and ask the students to calculate the VAT (7% of the total charge).



Black is total water consumption (m^3). To find out the amount of water used, subtract the current total from the previous month's total.

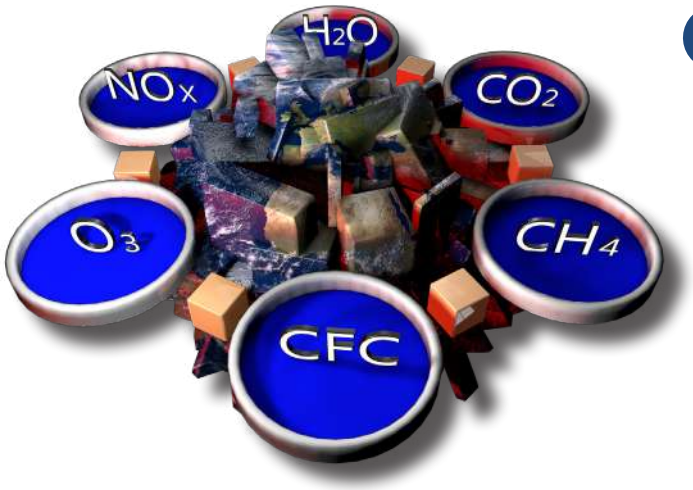
Optional extra - construct a watershed model - demonstrate how vegetation cover affects soil erosion and sedimentation.



For instructions please see
https://youtu.be/xJ_1YsQU7aU

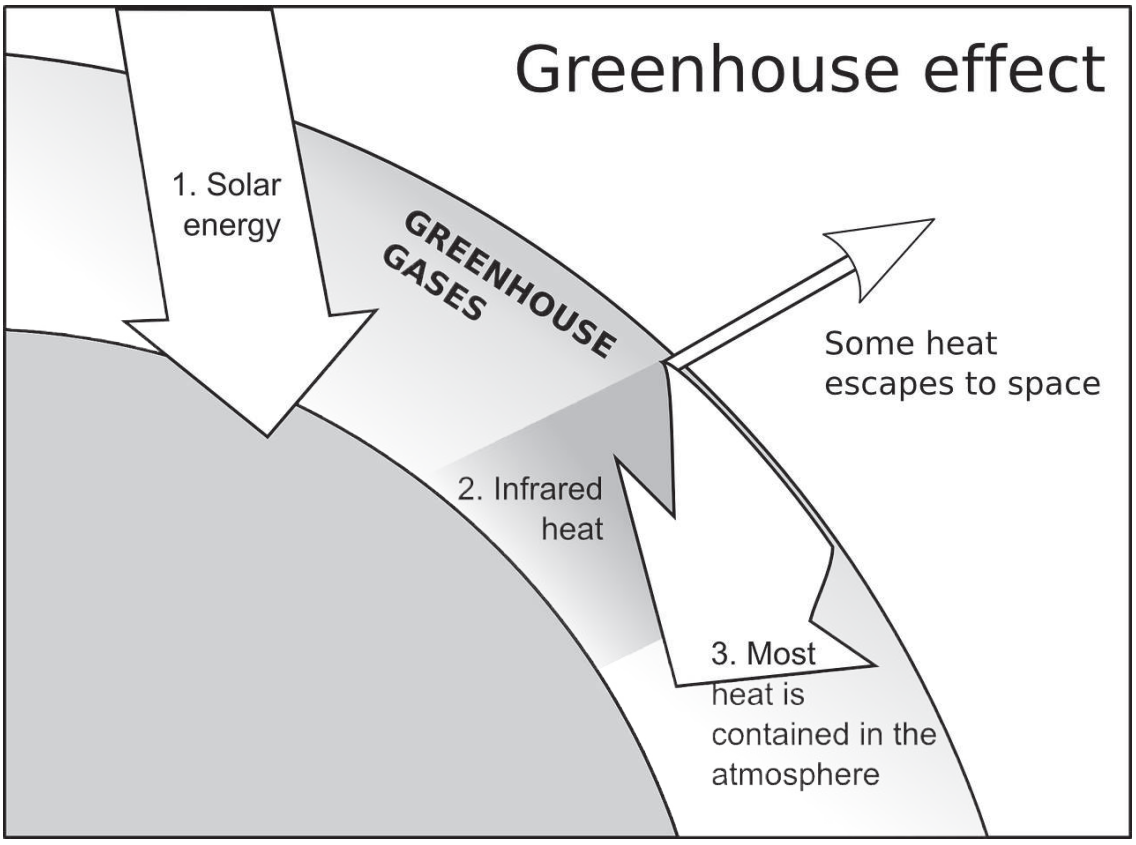
THE GREENHOUSE EFFECT

Short-wave radiation from the sun easily passes through the atmosphere and heats up earth's surface. Most of this heat radiates from Earth's surface back into space, as long-wave thermal radiation. However, some atmospheric gases can absorb this heat, radiating it back towards Earth's surface. These heat-trapping gases are called **greenhouse gases**. Without them, Earth would be an icy planet—in fact 33 degrees C cooler than today, and it would support very few plant and animal species. The problem is that human activities are emitting huge quantities of greenhouse gases, causing Earth to **overheat** and resulting in changing weather patterns.



THE MAIN GREENHOUSE GASES

- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Water vapour (H_2O)
- Nitrous Oxide (N_2O)
- Chlorofluorocarbons (CFC)
- Ozone (O_3)



Greenhouse gases diagram

Where do the greenhouse gases come from?

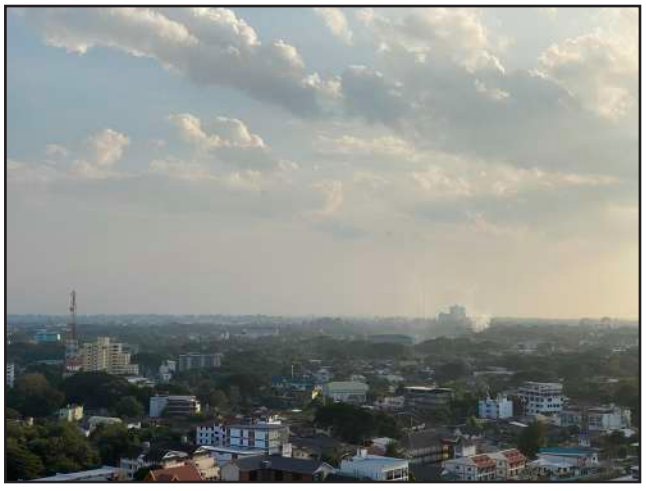
Most human-generated carbon dioxide comes from burning fossil fuels (coal, oil and natural gas), to generate electricity and for transportation—road vehicles, ships, planes etc. A lot also comes from replacing forests (which store carbon as wood) with other land uses. Most methane comes from agriculture. It is produced by micro-organisms in rice paddy fields and in the stomachs of livestock (cows, pigs, sheep etc.). Increased evaporation from the surface of oceans, as they heat up, increases atmospheric water vapour. Nitrous oxide comes mostly from overuse of fertilizers. CFCs are chemicals used in refrigerators and air conditioners. They are released when those appliances are scrapped.

Global Climate Change (GCC)

The greenhouse effect will result in a lot more than just warmer weather. The melting of polar ice sheets will raise sea levels by several meters, inundating coastal cities (including Bangkok). Forest fires will become more common. Extreme weather events—droughts, floods and storms—will become more frequent and severe. Many plant and animal species will not be able to survive these changes and may go extinct.

How will Chiang Mai be affected?

Temperatures will increase by 2-4 degrees Celcius by the end of the century. Dry seasons will become even drier, much hotter and last longer. Rainy seasons will become shorter, but the amount of rain falling in them will probably increase (causing floods). Chiang Mai is particularly vulnerable to the predicted increase in forest fires, since increased smoke-haze in the dry season will most likely increase respiratory diseases (asthma, lung cancer etc.). Evergreen forests will shrink in area, whilst deciduous forests will spread.



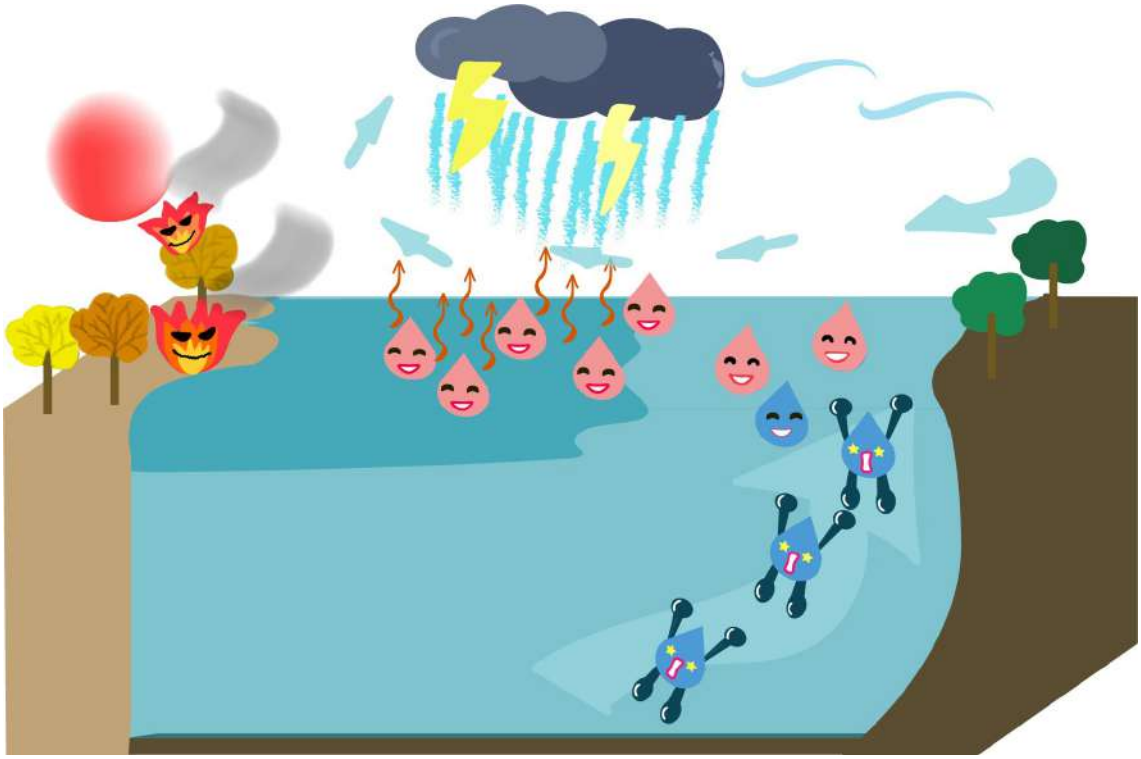
Smake-haze in Chiang Mai city

Climate is a global system. So, changes in one part of the world can drastically alter the weather thousands of kilometres away. For example, Chiang Mai's weather is greatly affected by the ocean currents of the Pacific, as far away as the western coast of South America. Changes in these ocean currents, can mean the difference between a scorching hot dry season, with devastating forest fires and a mild, damp one.

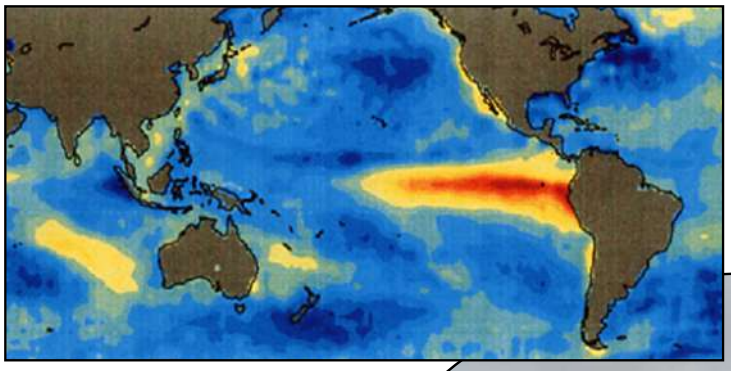
El Niño

An El Niño event occurs when the surface of the central and eastern Pacific Ocean becomes substantially warmer than usual, as **trade winds**, which usually blow from the Americas eastwards toward Asia, weaken or even reverse direction. No-one really knows why this happens, but it allows a great mass of warm water from the central Pacific to move east toward the Americas, blocking the normal up-welling of cooler, nutrient-rich waters from the deep along the west coasts of Central and South America. The regular circulation of the air above the tropical Pacific Ocean is disrupted, causing high-pressure systems of the eastern Pacific to weaken and pulling hot, dry air into Southeast Asia.

El Niño events occur roughly every two to seven years, as the warm cycle alternates irregularly with cooler periods in the eastern Pacific (called La Niña). After a build-up period of many months, El Niño typically peaks between November and January. In northern Thailand, the dry season that follows such a peak is always much hotter and drier than usual and forest fires, along with the smoke pollution they cause, are always more severe. The prolonged El Niño of 2015-16 resulted in some of the worst forest fires even seen around Chiang Mai. So, if you hear of an El Niño event, brewing in the SE Pacific in November, you might want to consider a holiday away from Chiang Mai the following March.

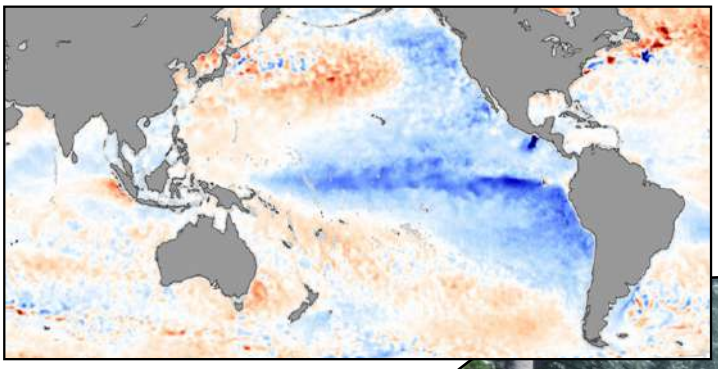


El Niño — warm water from the central Pacific Ocean moves west replacing the cold water up-welling along the coast of S. America. A few months later there are droughts and forest fires in Southeast Asia.



An El Niño event, viewed from space with thermal cameras, showing hot water in the central Pacific, moving towards South America in November.

Following such an event, the subsequent dry season in Chiang Mai, is usually super hot, with many forest fires and severe smoke pollution.

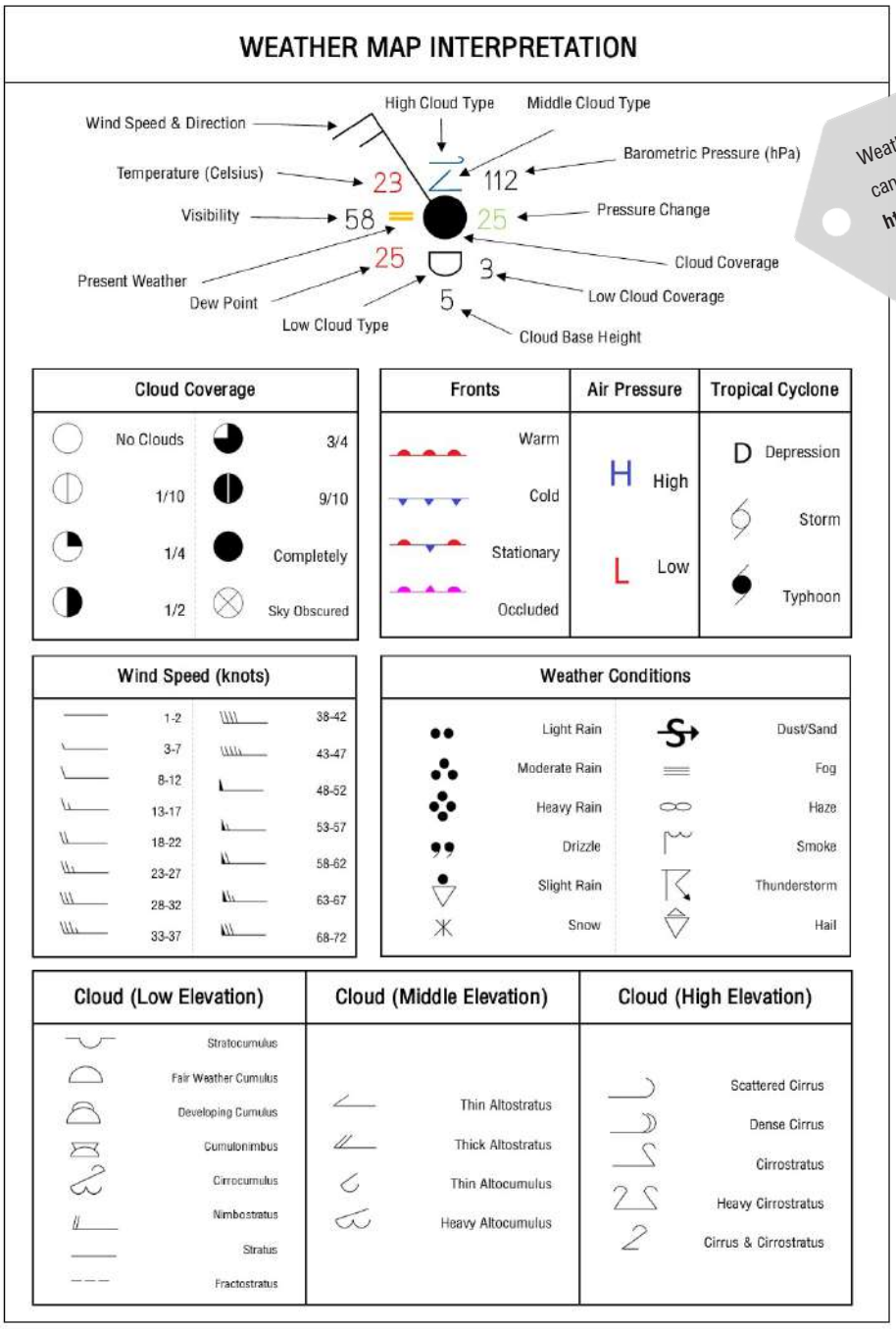


La Niña events are the opposite, when unusually cool water accumulates in the mid Pacific. This results in warm wet winds blowing into Southeast Asia subsequently.

Following a La Niña event, the subsequent cool season in Chiang Mai is usually much cooler and longer than usual. The rainy season arrives early and the rains are heavier than usual, often resulting in floods.

WEATHER MAPS

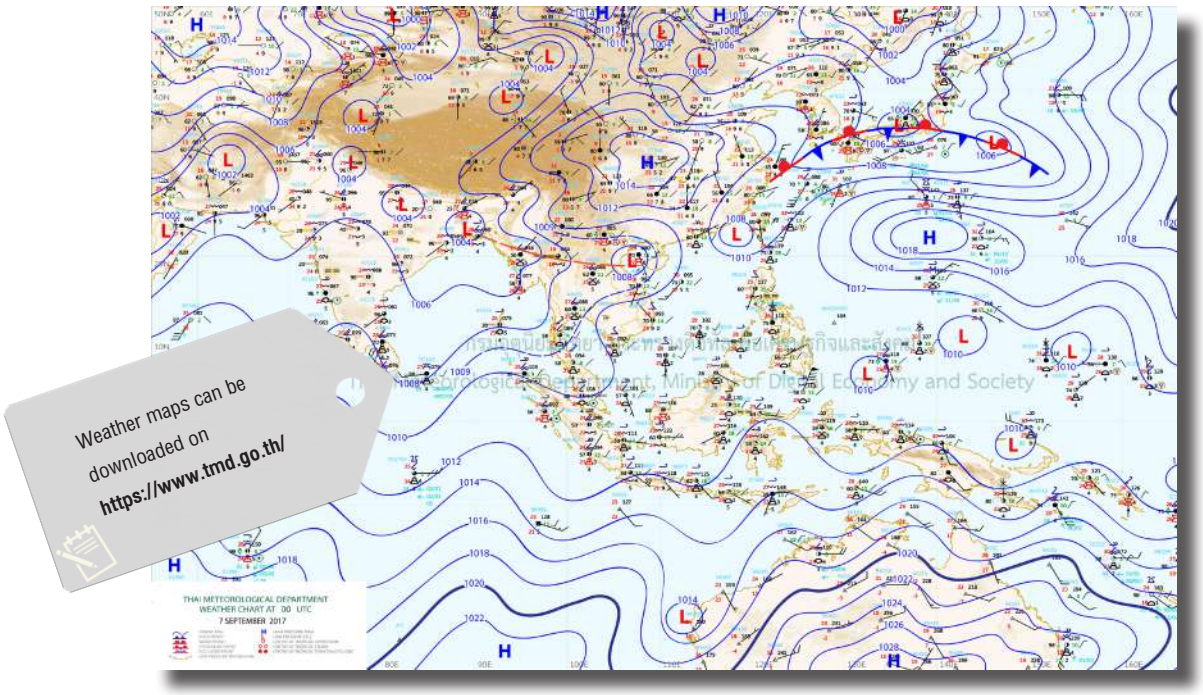
All over the world, thousands of people from a multitude of organizations, collect **meteorological data** from weather stations, on land and at sea, including, air pressure, wind speed and direction, temperature, relative humidity, precipitation (rainfall or snow), solar radiation, visibility, etc. These data are used to compile an ever changing computerized global weather map, which weather forecasters use to predict the weather several days in advance. Weather data are represented on maps as various numbers, codes and symbols as follows:



Weather-map symbols can be downloaded from **https://fob.science.cmu.ac.th/**

Weather-map symbols

Weather map



Source: Meteorological Department

Notice the lines drawn at various points on the weather map. Isobars ∿∿ are lines joining points of equal atmospheric pressure. Air pressure is displayed in hectopascals (hPa). Such lines are used to predict wind direction, since air flows from high- to low-pressure areas. Closely packed isobars indicate a steep gradient in air pressure—the steeper the gradient, the stronger the wind. High-pressure cells (H) are cool, dry and cloudless. Low-pressure cells (L) are hotter and more humid, causing air to rise, forming clouds and therefore increasing the chances of rainfall.

Objectives

1. To develop an ability to read and understand weather maps.
2. To use weather maps to make basic forecasts.

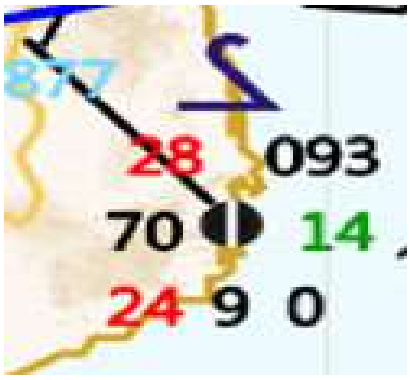
1 hour operating time

Media material equipment

Equipment	Amount for 1 group (3-5 students)
Weather map	1 sheet
Weather map symbol key	1 piece
Pen	3 piece
Notebook	1 book

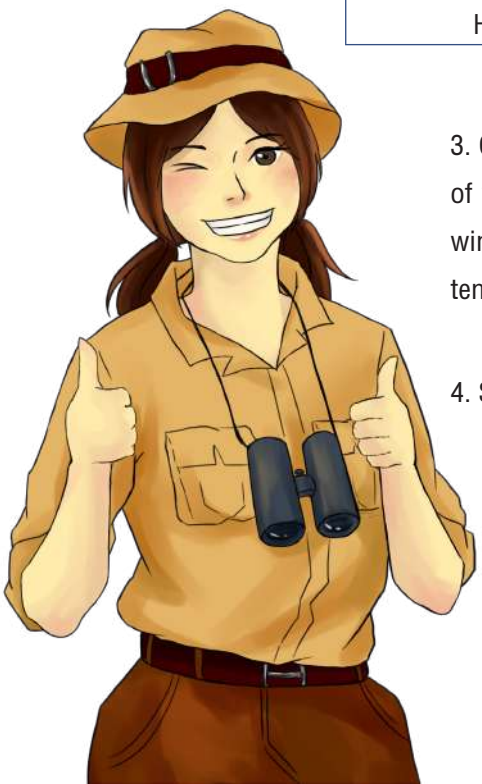
Event guidelines

1. The teacher explains the use of weather maps for weather forecasting and the meanings of the weather-map symbols.



2. Distribute one weather map per group and assign each group one weather station on the map. The students then interpret the weather conditions at the station from the numbers and symbols as in the example here.

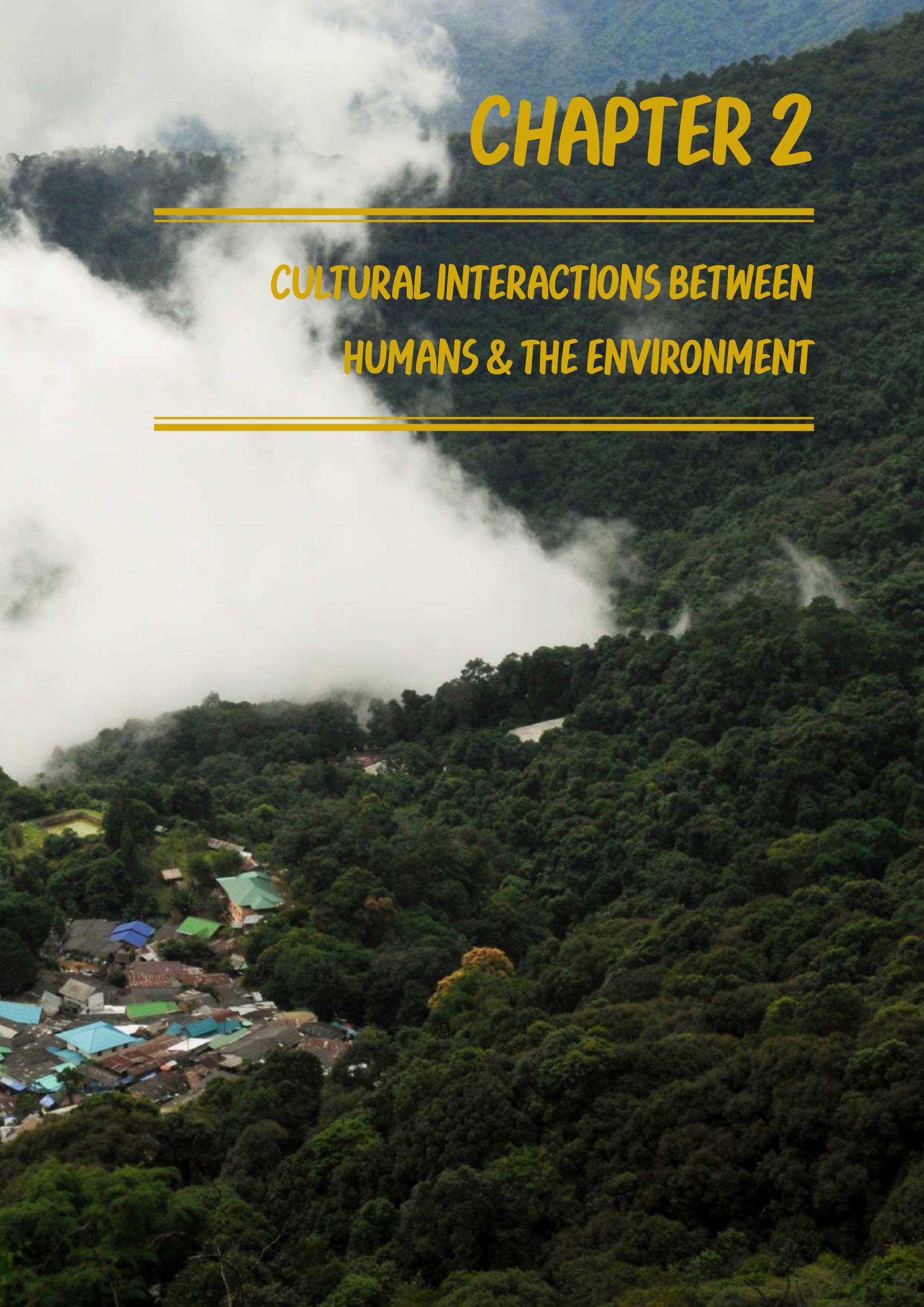
Weather Map Symbol	Recorded data
Wind speed and direction	3-7 km/h from north-west
Temperature	28 °C
Visibility	7 km.
Dew point temperature	24
Cloud base height	9
Low clouds covered	0
Cloud	9 parts
The amount of air pressure change in the past 3 hours	1.4 hPa
Sea surface air pressure	1009.3 hPa
High clouds	Cerostratus does not fill the sky.



3. Observe and describe the types of low-pressure centres and the effects of weather on the local area. Forecasting the direction and movement of wind. For example, Thailand is near low-pressure cells (L) causing high temperatures and high chances of heavy rain.

4. Summarize the results of the weather forecast and discuss in the class.

THIS LESSON FOCUSES ON LOCAL CULTURAL INTERACTIONS BETWEEN HUMANS AND THE ENVIRONMENT. IT EXPLORES THE HISTORIC RELATIONSHIP BETWEEN CHIANGMAI CITY AND NEARBY MOUNTAINS. IT ALSO HELPS STUDENTS UNDERSTAND LOCAL CULTURES AND LIVELIHOODS, INCLUDING THE USES OF NATIVE PLANT SPECIES, THUS ENCOURAGING THEM TO BECOME INVOLVED IN CONSERVING NATURAL RESOURCES AND THE LOCAL ENVIRONMENT.



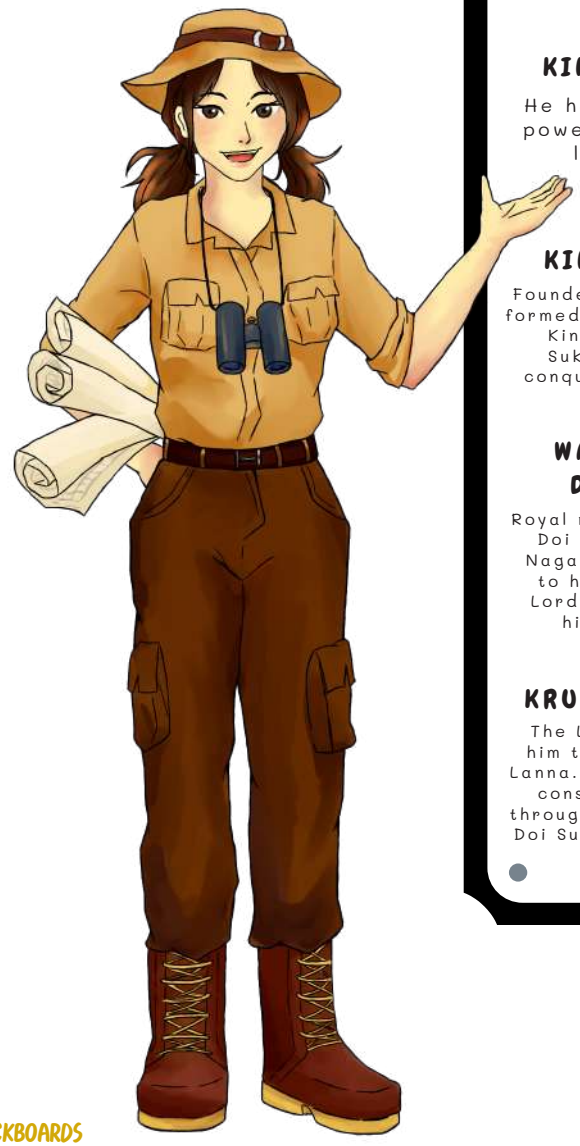
CHAPTER 2

CULTURAL INTERACTIONS BETWEEN HUMANS & THE ENVIRONMENT

HISTORY OF CHIANG MAI

"In the shadow of Doi Suthep, blessed with rice, customs, traditions and beautiful wild flowers, lies the magnificent Nakhon Ping."

According to this slogan, Doi Suthep is the symbol of the Chiang Mai (or "Nakhon Ping", the city's old name). The mountain is connected to the long history of the people in the area. It represents their cultural diversity and their recent efforts to conserve the region's biodiversity by making it a national park in 1981. This chapter will discuss the beliefs, ways of life and the culture of Chiang Mai and its people in relation to Doi Suthep.



A BRIEF HISTORY OF

CHIANG MAI

PU SAE AND YA SAE

Lawa ancestral spirits. The Lawa was the first tribe to settle in Lanna, the area known today as Chiang Mai.

WASUTHEP

The son of Pu Sae and Ya Sae completed religious rituals leading to monkhood. The mountain "Doi Suthep" is named after this famous hermit monk.

QUEEN CHAMADEVI

Related to the Wasuthep hermit, ruled with great wisdom and Haripunchai's citizens prospered

KING VIRANGKA

He had a supernatural power to shoot spears long distances

KING MENGRAI

Founder of Chiang Mai. He formed an alliance with the Kings of Phayao and Sukhothai to aid his conquest of Haripunchai

WAT PHRA THAT DOI SUTHEP

Royal monastery located on Doi Suthep, a 306-step Naga staircase was built to honor a relic of the Lord Buddha (a piece of his shoulder bone)

KRUBA SRIWICHAI

The Lanna people called him the saint or merit of Lanna. He accomplished the construction of a road through the dense forest of Doi Suthep to Wat Prathat

A Brief history of Chiang Mai

THE LEGEND OF PU SAE AND YA SAE

According to ancient documents, Pu Sae and Ya Sae are Lawa ancestral spirits. The Lawa tribe was the first to settle in Lanna, the area known today as Chiang Mai. The story says that when the Buddha visited the people, who were living in the forest around Doi Kham (on the lower slopes of Doi Suthep), he asked them why they had not built a city there. They said it was because they were afraid of two ogres, Pu Sae and Ya Sae (Grandfather and Grandmother Sae), who roamed the forest and ate human flesh. The Buddha met with the ogres, who at first wanted to eat him, but he showed them compassion and how to be peaceful. He taught them about Buddhism and asked them to follow some of the religion's basic principles, such as not killing or eating meat, but Pu Sae and Ya Sae found this difficult to follow. They asked the Buddha, if they were not allowed to eat humans, could they consume beef once a year instead. Consequently, the Lawa people began to bring Pu Sae and Ya Sae buffalo meat, so the ogres would not eat humans. No longer fearing for their lives, the Lawa began to build settlements in the area.

Most of Chiang Mai citizens are no longer Lawa, but they still respect the ancient traditions. In May every year, they bring a buffalo to the forest near Wat Doi Kham as a gift for the spirits of Pu Sae and Ya Sae, and they ask the spirits to protect the city and its people from harm. Chiang Mai's guardian spirits are from the same forest which provided Chiang Mai's early citizens with water, food and resources when the city was being founded. So, this ancient annual ritual re-affirms the close connection between city and forest.

The shrine of Pu Sae and Ya Sae below Doi Kham Temple

WASUTHEP – THE HERMIT MONK OF DOI SUTHEP

The shrine of the Wasuthep Hermit at Doi Kham Temple

Wasuthep is believed to have been the son of Pu Sae and Ya Sae. Unlike them, he was better able to adopt to a Buddhist lifestyle. He asked the Buddha to ordain him as a Buddhist monk and went with 4 companions to Himmapan (the heavenly forest), where they practiced **asceticism** (self-denial of worldly pleasures) and completed religious rituals leading to monk-hood. After that, he moved to a small cave on a mountain then called Doi Ujchubanphot, where he practiced meditation in the forest. People began to call the mountain "Doi Suthep" after this famous hermit monk. Today a nature trail leads from the main highway above Wat Prathat Doi Suthep to the cave where it is thought Wasuthep meditated.

Hermit monks still sometimes meditate there in the evergreen forest of Doi Suthep. Again, from this legend, we can see a close connection between nature and the cultural identity of Chiang Mai people.

THE LEGEND OF QUEEN CHAMADEVI

Monument to Queen Chamadevi. Lamphun City

The story of Queen Chamadevi originates from around mid-8th century AD. She was almost certainly a real person, but little is known about her real life. All we have are legends, which relate how when she was just 3 months old, a giant bird swooped down and flew her to where Wasuthep meditated on Doi Ujchubanphot. The hermit monk adopted the baby girl, named her "Vi", and educated her until she was 13 years old. Looking at her horoscope, Wasuthep saw that her destiny was to become a queen. So, he made a raft and sent her down the Ping River to Lawo (Lopburi today), where the Mon King and Queen raised her as their daughter. The Mon were a highly cultured people, who had migrated to Lopburi from Burma.

Meanwhile, Wasuthep planned Haripunchai City (Lamphun) on the east bank of the Ping River, laid out in the shape of a conch shell. A few years later, the monk requested the Lawo King to send Princess Chamadevi back, to rule over the new city as Queen. So, Chamadevi travelled back up the Ping River by boat to Haripunchai, where, a few days after her coronation, she gave birth to twin boys. She ruled with great wisdom and Haripunchai's citizens prospered.

THE LEGEND OF KING VIRANGKA

The King Virangka Monument at Mon Long

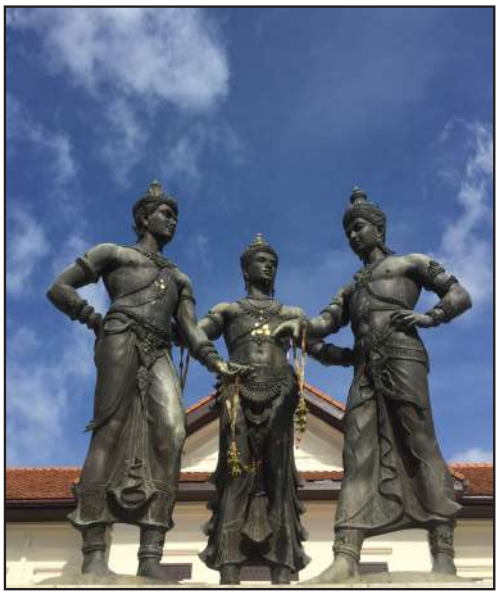
At around the same time that Queen Chamadevi was establishing Haripunchai, King Virangka led the Lawa tribe in the forests of Doi Suthep. When he first met the beautiful and cultured Queen Chamadevi, he fell instantly in love with her and asked her to marry him. The Queen asked him to wait, since she had just given birth to the twins. But as years passed, King Virangka lost patience and stormed Haripunchai with his army, only to be defeated by the Queen's twin sons mounted on a magical elephant. The Queen feared that King Virangka would return with a bigger army. So, again she agreed to marry him, this time, only

if he could throw a spear from the summit of Doi Pui (the uppermost peak of Doi Suthep) to anywhere within the walls of Haripunchai, a distance of about 30 km. He was allowed three attempts. King Virangka accepted the challenge, since, unbeknown to the Queen, he possessed supernatural strength. On the first attempt, the spear landed just outside the city wall. The Queen, now realizing the King's super-power, decided to sabotage his efforts with sorcery. She made a magical hat out of her under-garments and sent it to the King, as he prepared for his second throw. No sooner had King Virangka put on the hat, than it sapped away his super-strength. The second spear flew only a few kilometres, landing near the foot of Doi Suthep (Nong Sanam). Finally realizing that the Queen would never marry him, the Lawa King threw the third spear straight up into the air, tore off his shirt and allowed the spear to fall and pierce his chest, killing him instantly. He died, literally, of a broken heart. It is written that his entourage laid his body to rest on another peak "close to" Doi Pui summit. Today, there is a small chedi called Sungkhoo, near Doi Suthep peak, a little way down from Doi Pui summit. Could this be the final resting place of the love-sick Lawa King? This story perhaps symbolizes the conflict between of human civilization (represented by the cultured Mon) and forest (represented by the forest-dwelling Lawa).

KING MENGRAI AND THE FOUNDATION OF CHIANG MAI

Born in 1239 AD, King Mengrai was the 25th King of the Royal Dynasty of the Kingdom of Hiran Nakhon Ngoen Yang. Whilst in Fang city (north from Chiang Mai), he learned how wealthy the city of Haripunchai had become, by trading along the Ping River. Consequently, he schemed to conquer the city. First, he formed alliances with the Kings of Phayao and Sukhothai, to ensure that they would not object to his territorial expansion. He then sent a Lawa spy named Ai Fa to Haripunchai to gather intelligence, before capturing the city in 1292. But he didn't stay long. He appointed Ai Fa to govern Haripunchai, so he could establish another new city called Wiang Kum Kam in 1294 AD.

Unfortunately, the new city was frequently flooded (see page 31), so the King selected a new location for his capital— this time by considering signs from nature, white deer unafraid of wolves, an albino mouse living in a fig tree, water draining from Doi Suthep into the Ping River and a stream encircling the area. Chiang Mai was built as a walled city 1.8 x 2.0 km. Canals diverted water around the city and an aqueduct carried water from Huaykaew ("crystal stream") over the city's NW corner. A marshland was retained to the northeast, to absorb flood water. Again, we see close links between city and nature in historical tales. The newly unified Lanna—Kingdom of a Million Rice Fields—thrived, with Chiang Mai as its capital.



The monument of the Three Kings in the centre of Chiang Mai City

THE FOUNDATION OF WAT PHRA THAT DOI SUTHEP

Phra That Doi Suthep is a royal monastery, located on a sub-peak well below the summit of Doi Suthep. The story of its foundation starts when a monk, Sumanthera, found a sacred relic with magical powers a piece of the Lord Buddha's shoulder bone. The 6th King of Lanna, Phaya Kuena, invited him to bring the relic to Haripunchai (Lamphun), where it miraculously broke into two pieces. The smaller piece was enshrined at Wat Suan Dok in Chiang Mai. The King placed the larger piece on the back of a magical elephant. The elephant climbed up Doi Suthep, but before reaching the top, it stopped, trumpeted three times and died. The King interpreted this as a sign from nature and he ordered the temple, Wat Prathat Doi Suthep, to be built on the spot: "Prathat" meaning "a relic of the Lord Buddha". Later, a 306-step Naga staircase was built, leading up to the temple. Around the original stupa, now covered in gold, a large complex of buildings has since been built and the temple has become Chiang Mai's most visited tourist attraction. Nature led the way in creating the temple, but today the pressure of tourism is causing serious degradation of nature around it.

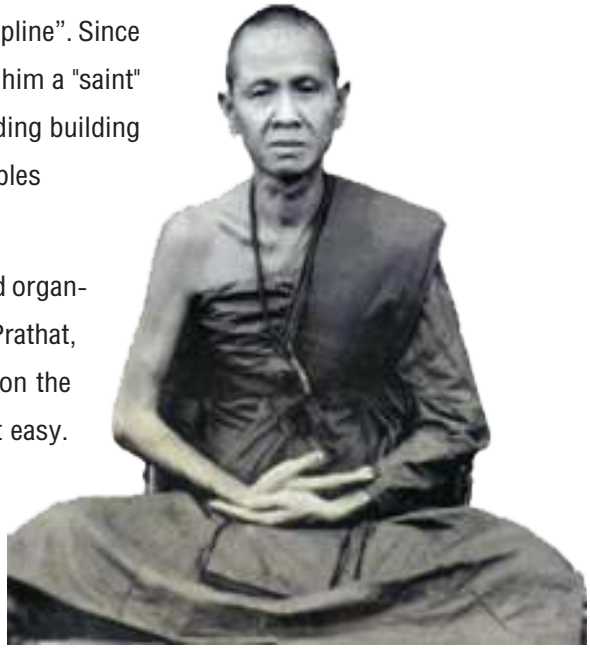
Statue of the legendary elephant

The Naga Staircase

The golden stupa of Wat Prathat Doi Suthep with a relic of the Lord Buddha inside

THE LEGEND OF KRUBA SRIWICHAI

Born during a mighty thunderstorm in 1878, Kruba (teacher) Sriwichai became a fully ordained monk when he was 21, nicknamed "Siriwityo Bhikku", which means “to have good ethics and strict discipline”. Since he was such a good role model, the Lanna people called him a "saint" or "merit of Lanna". He accomplished many things, including building a bridge across the Ping River and restoring several temples



Kruba (teacher) Sriwichai

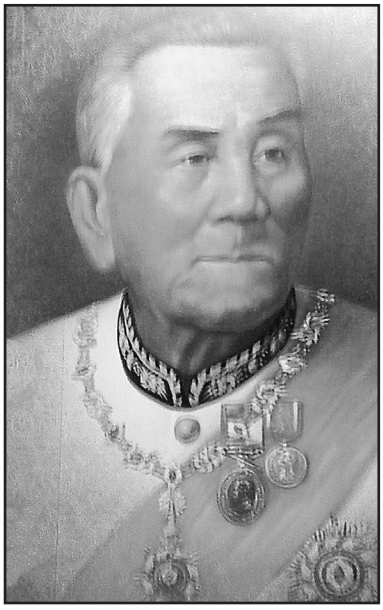
However, he is most famously known for engineering and organizing the construction of a road up Doi Suthep to Wat Prathat, to make the temple more accessible to devotees. Work on the road started on 9th November 1934, but the task was not easy. There were no machines, only human labour to clear the pathway through dense forest, up steep slopes, and to level the road. With no support from the government of the day, the monk inspired thousands of villagers to participate in the project, with each village group constructing just a few metres of the road.

The first car up Doi Suthep

Those who could not work, provided food for the labourers or donated money at an almshouse set up for the purpose. As a result of this massive collaborative effort, the 11-kilometre road was completed in just 5 months and 22 days. The first car up Doi Suthep (now preserved at Wat Ban Pang, Lamphun) carried Kruba Sriwichai and the last prince of Lanna, Chao Kaew Nawarat up to the temple on April 30th 1935. The revered monk was also a rebel, being jailed several times for opposing central control of religious affairs from Bangkok. It was one of the last acts of defiance against incorporation of the Lanna Kingdom into modern-day Thailand.

How Lanna became part of Thailand

1802 - Following destruction and depopulation, as a result of war with Burma, Lanna became a vassal state of Siam (Thailand's former name), ruled by a King, appointed from Bangkok. Chiang Mai sent tributes to Bangkok, but retained control over local affairs.

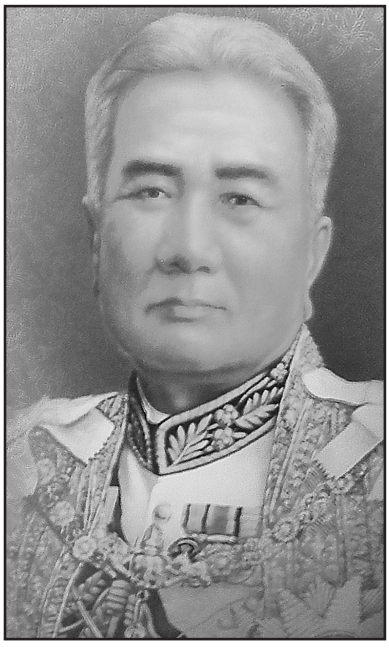


Inthawichayanon, last King of Lanna

1860's-70's - British imperial power advanced eastwards through Burma. The British Borneo Company started logging operations in Lanna (1864). Fears grew that Britain would annex Lanna into their Burmese territories

1870-97 - Inthawichayanon, regarded as the last King of Lanna, reigned until his death in 1897. He lost control of the region's forest resources (particularly teak wood) and the revenue from them, as Bangkok courts placated the British with logging concessions and even their own legal system; a consular court for trials of any criminal cases that involved subjects of the British Empire. His ashes are interred on the summit of Doi Inthanon.

1886 - Following rumours that Queen Victoria planned to make herself godmother of Inthawichayanon's daughter, Princess Dara Rasmi, King Chulalongkorn (King Rama V of Siam) sent his brother, Prince Bijitprijakara, to Chiang Mai to convey the King's proposal of marriage to the Princess. In 1886, she moved to the Grand Palace in Bangkok, becoming King Rama V's Princess Consort. The marriage became symbolic of the joining of the two kingdoms.



Kaew Nawarat, Chiang Mai's last Prince Ruler

1899 - Siam formally annexed Lanna, designating it a large administrative unit, called a "Monthon", named Monthon Phayap (meaning "northwest"), covering the provinces of Chiang Mai, Lamphun, Mae Hong Son, Lampang, Chiang Rai, Nan and Phrae.

1939 - Prince Kaew Nawarat, (King Inthawichayanon's 6th son) the final Prince Ruler of Chiang Mai died. The title is abolished, under the government of Plaek Phibunsongkhram. Siam is renamed as Thailand.

In the 1960's, the growing human population of Thailand's northern highlands began to have a detrimental impact on the environment. The mountains were mostly inhabited by "hill tribes"—Hmong, Akha, Lisu, Lahu and others, many having migrated into the region to escape political turmoil in neighbouring countries. They practiced **shifting cultivation**, clearing and burning the forest, then planting and harvesting crops for a few years, before depletion of soil nutrients and prolific weed growth rendered the land unproductive. Fields were then left **fallow** (uncultivated) for up to 25 years, to allow the soil to recover, before being cleared for crop-growing once more. As the human population grew, fallow periods became shorter and the system became unsustainable. Deforestation spread and the watersheds became unstable; floods, soil erosion and landslides became more frequent and severe.

Another problem was that opium—a drug made from poppies—became a major crop, even though it became illegal to grow the poppies in 1958. Opium can be converted into heroin; a highly addictive drug, which is illegal in most countries, because its use causes serious social and medical problems. International pressure grew for Thailand to eradicate opium production.

His Majesty, King Bhumibol Adulyadej (Rama IX) took a leading role in addressing the opium problem. During the cool season, the Royal Family often stayed at Phuping Palace on Doi Suthep. In 1969, during one of these visits, the King visited the nearby Hmong community of Ban Doi Pui. There, he became concerned by the poor living conditions and poverty in the village, and the deforestation caused by opium-poppy cultivation. Realizing that alternatives to opium production must be found, he first encouraged the planting of peach trees. Not only were peaches a high-value crop, but the trees' roots would help to reduce soil erosion on steep slopes. His Majesty gave 200,000 baht to Kasetsart University, to establish a research centre near Phuping Palace. There, scientists worked to improve cultivation of temperate fruit trees, particularly to develop varieties suited to local conditions. Later that year, the Royal Project was founded, to improve rural living standards and address environmental degradation. Gradually, forest clearance for poppy cultivation declined.

"One of the reasons underlying the creation of the project was humanitarianism; the desire that these people, living in remote areas, should become self-supporting and more prosperous. A further reason, which is very important, is that the hill tribes are people who use agricultural methods which, if left unchecked, could bring the country to ruin. In other words, they cut down trees and practice 'slash and burn' methods, which are totally wrong. If we help them, it is tantamount to the country in general having a better standard of living and security."

His Majesty King Rama IX on 10th of January 1969, at the Faculty of Agriculture, Chiang Mai University

EXPLORE LANNA HISTORY AND CULTURE

Whether history or legend, these stories highlight relationships between humans and the environment. Some symbolize dependency of Chiang Mai citizens on nature (e.g., Pu Sae Ya Sae and the foundation of Chiang Mai City), whereas others may represent conflict between city and forest (King Virangka and the road up Doi Suthep).

Objective

1. Build relatability to the legends described by visiting places associated with them

Operating time - variable depending on the site(s) visited and distance etc.

Media material equipment

Equipment material	Amount for 1 group (2 per group)
Notebook	2 books
DSLR or Cellphone camera	1 camera
Guide book	2 books

Ideas for places to visit

• Find a shrine to Pu Sae and Ya Sae located below Wat Doi Khum. Then visit Doi Khum. How many of these can you find? … small statues of Pu Sae, Ya Sae, Wasuthep and King Virangka throwing his spear and large statues of Queen Chamadevi and her magical elephant.

Find him at Wat Doi Khum

• Visit Wat Phra That Doi Suthep—find out where the Buddha relic is now and a statue of the elephant, which carried the relic to the temple's location. Locate a mural of the first car to ascend Doi Suthep.

• Find the cave on Doi Suthep (Tum Reusi), where it is thought Wasuthep practiced meditation (this involves a steep but short hike through the forest, so be prepared).

• Visit Wat Chiang Mun, the first temple King Mengrai built in Chiang Mai – find there the story of his victory over Haripunchai, pictured on the wall, as well as a depiction of the Pu Sae Ya Sae legend.

• Visit Lamphun—find the statue of Queen Chamadevi and the temple in her name. Look there for a picture of King Virangka throwing the first spear.

LOCAL CULTURE WITH NATURAL AND ENVIRONMENTAL CONSERVATION

"Culture" is derived from relationships between humans and their environment. Each area has distinctive cultural diversity, based on the local environment. Spiritual beliefs also play a role in the development of cultural diversity. In this lesson, we will contrast the culture of city people with that of one of the local hill tribes—the Hmong.

WHO ARE THE HMONG ?

The Hmong ethnic group migrated into northern Thailand in several waves, dating all the way back to the mid-1600's AD. They came from China, Myanmar and Laos, fleeing war, racial discrimination and political unrest. In Thailand's remote northern mountains, they found fertile agricultural land and security from persecution. They are the second largest ethnic minority in Thailand, after the Karen. There are two groups: the Hmong Jua or Blue Hmong (Moob Ntsuab) and the Hmong Deer or White Hmong (Moob Dawb). The two groups differ in their language, dress, and housing. However, with the adoption of Thai social culture, particularly by the younger generation, differences between the tribes have become less distinct. The Hmong are now classified as an ethnic group with their own customs, cultures and traditions.

Hmong ladies in their finest traditional costume, participating in a New Year ritual

WHO ARE KON MUANG ?

The Kon Muang (literally "city people") are a mix of ethnic groups who gradually adopted a common identity over centuries. Following the foundation of Lanna, the Kingdom was populated by Mon, Tai Yuan and several other ethnic groups. Over centuries, their languages and cultures merged, and they unified under Buddhism. During the 1700's, the Burmese repeatedly invaded and destroyed much of Chiang Mai City.

Kawila, appointed King of Chiang Mai, after helping to repel the Burmese

Chiang Mai's citizens fled to the hills. Aided by the Siamese army, local chieftain, Kawila, repelled the Burmese several times. So, in 1802, King Rama I appointed him as the "King of Chiangmai". Kawila set about rebuilding Chiang Mai and repopulating it. He persuaded the city's original inhabitants to come down from the hills, but they were not enough. Therefore, he brought in war captives, from Shan State (eastern Myanmar): Tai Yai, Tai Yong and Tai Khoen people, to reconstruct the city's defences, and revive the local economy. Around that time, Chiang Mai's original citizens started calling themselves "Kon Muang", to distinguish themselves from the new comers.

NATURAL RESOURCE CONSERVATION ACCORDING TO FAITH

People of northern Thailand have respect for nature, because nature supports livelihoods and provides water. Having this belief since childhood connects people with forests and water sources, whether they live in the city or in the hills. Local people's attitudes towards nature are expressed through rituals, which raise awareness of the need for conservation, often by expressing gratitude towards nature.

The Hmong

The Hmong traditionally practice **animism**—the belief that everything: plants, animals or even rocks posses inner spirits, which if respected appropriately will provide protection or good fortune. Animistic rituals are passed down through generations. They are usually led by a **shaman**, who is able to interact with the spirits.

At Ban Mae Sa Mai, Mae Rim District, such rituals were modified, when the community started to get involved in restoring forest on degraded land near their village in the 1990's. In February every year, at the beginning of the dry season, villagers ask **guardian spirits** to protect their forests from fires and to conserve their water resources for agriculture. They made offerings of tea and whisky to the spirits**,** who lived in the biggest tree in the ancient forest behind their village—a *Schima wallichii* tree (in the same plant family as tea, Theaceae) in Dong Saeng Forest. There are four spirits, each with a different function: one protects humans and animals, one ensures land fertility, one protects the forest and one guards the way to the underworld. If the forest does not burn, over the subsequent dry season, then a pig is sacrificed in May or June in another ceremony.

The pig's blood is offered to the spirits to thank them for their help and protection during fire-prevention activities.

Thus, a traditional ritual has been adapted to address modern environmental problems—forest fires and smoke pollution. The ritual also unifies people to work together on solutions—planting trees, constructing fire breaks, fire-prevention patrols and fire fighting. Culture is not constant. It continuously adapts to changing circumstances.

Following a successful fire-prevention season, the shaman of Ban Mae Sa Mai, summons the spirits by banging a gong, to thank them for a successful fire-prevention season. The ceremony provides an opportunity for villagers and officials to socialize and plan forest-restoration activities over the subsequent rainy season.

Kon Muang

The Kon Muang rely heavily on water resources, to support both their lowland agricultural systems and city life. This is woven into their spiritual life through the Khun Nam ritual, which venerates the spirits of streams and rivers—the Phi Khun Nam. The Kon Muang believe that streams originate from big old trees in ancient forests, high in the mountains, within which live the Phi Khun Nam. This is not so far from scientific ecology. Although water does not actually flow *from* trees, trees do add organic matter to the soil (in their leaf litter), which enables watershed forest soils to absorb and store large quantities of water; often enough to keep streams flowing throughout the dry season (see Chapter 1). During the Khun Nam ritual, performed in May or June, villagers thank the spirits for providing water for food production, and ask them to bless the land with enough rain to keep water flowing all year round. It involves making small offerings of food and incantations at spirit houses, constructed of local natural materials, beside key points in the water-distribution system (reservoirs, channels etc.). Afterwards the villagers eat together and discuss how to maintain the water distribution system—small reservoirs, channels and pipes etc. called "muang faai", and how to fairly distribute water when supplies are limited. Water management is implemented by the "laam-faai", a small committee, elected by the villagers, responsible for regulating water use and for ensuring that irrigation channels do not become clogged with silt or vegetation They also select the most auspicious time for the Khun Nam ritual and organize it.

Natural resource conservation according to the science of the King Rama IX

During the 1990's, to coincide with the Golden Jubilee of King Rama IX, many projects were implemented to address degradation of watersheds and to improve the livelihoods of villagers living within them. The Royal Project Foundation collaborated with the Royal Forestry Department to establish the "Royal Forestry Project" to restore and conserve natural resources and the environment by controlling agricultural land use and by promoting forest-tree planting and natural forest regeneration. The project aimed to reduce soil erosion and included construction of water-conservation systems and earth check dams (strengthening muang faai systems). Village wood lots were planted to supply villagers with fuel-wood, as a substitute for cutting forest trees. The project "Plant a Forest to Honour the King" (Plook Pah Chalerm Prakiat) aimed to restore forest ecosystems to 8,000 km^2 nationwide, by planting native forest tree species. All over the country, communities and NGOs joined to plant trees, often sponsored by private sector companies and supported by government agencies. The project firmly establishing the concept of forest ecosystem restoration in Thai society.

DISCOVER CULTURE-CONSERVATION CONNECTIONS

In northern Thailand, people's livelihoods and well-being are closely connected with healthy forests and the upland watersheds they protect. However, that connection may be weakening, due to increasing population density, causing over-consumption of natural resources (especially water) and pollution. Furthermore, spiritual beliefs, which have help to maintain a balance between humans and nature for centuries, are gradually being replaced with modern ideas. The purpose of this exercise is to encourage students to explore the spiritual beliefs and rituals of various ethnic groups, and their use as mechanisms for regulating interactions between humans and nature.

Objectives

1. To increase awareness of the diversity of spiritual beliefs, related to human-nature interactions, amongst the various ethnic groups of northern Thailand.

2. To explore the roles of such beliefs in conserving natural resources.

1 hour operating time

Media material equipment

Equipment material	Amount for 1 group (3 per group)
Poster paper	3 paper
Magic marker pen	3 pens
Portable laptop or cellphone	1 device

Event Guildlines

1. The teacher reviews the material presented in the previous pages. Only two ethnic groups are mentioned—what about the others?

2. The teacher divides the class into small groups and asks each group to select a different ethnic group (Karen, Akha, Lahu, Lisu, Lawa etc.).

3. Each group searches the internet for rituals or beliefs of their chosen group. The teacher guides key-word selection.

4. The teacher asks students to consider how such rituals or beliefs might influence behaviour towards forests, water and wildlife and depict the interaction(s) with words and/or drawings on the poster paper.

5. Students present their work to the whole class and respond to feedback from their classmates.

6. The teacher facilitates an overview discussion of the students' presentations, guiding them towards understanding the similarities and differences among the beliefs of diverse ethnic groups. How might changes in modern day life impact such beliefs and affect use or misuse of natural resources.

FOREST PLANTS AND LIVELIHOODS

CHANGING LIVELIHOODS OF THE HMONG

Years ago, the Hmong grew opium poppies in small forest clearings and practiced slash-and-burn (shifting) agriculture. Today, however, they have adopted modern agricultural techniques, growing vegetables (cabbage, lettuce, carrots etc.), fruit trees (e.g., litchi) and corn, on permanent fields, and raising a few pigs and chickens. The Hmong are adaptable businessmen, readily changing the crops they grow in response to changing market demands and forming relationships with people outside their communities to pursue business opportunities.

As they become more integrated into the national economy, their dependence on forests, as sources of forest products, has been much reduced. But their need to conserve watershed forests, to supply irrigation water for agricultural production, has increased. Many Hmong communities have also diversified their economies, by venturing into agro- or eco-tourism, setting up home-stay accommodation for tourists who seek low-impact, low-cost experiences in natural settings. For example, Ban Khun Chang Kien, a small Hmong community on Doi Suthep, has turned the annual blooming of wild cherry trees into a seasonal tourist attraction. They provide transport to the sites and sell snacks, drinks and meals to the visitors every January.

Cherry-blossom tourism boosts the economy of Ban Khun Chang Kien every January

HMONG TRADITIONAL MEDICINE

HMONG MEDICINAL PLANTS

Despite developing modern livelihoods, many Hmong people still consult traditional healers (shamans), when sick, particularly those unable or reluctant to access modern health-care facilities. Shamans combine spiritual beliefs with the use of medical plants, often collected from nearby remnant forest, to concoct remedies that address both physical and mental aspects of illness. Such traditional remedies are closely guarded secrets, passed on verbally from older shamans to young apprentices. Shamans must not overcharge for their services and are sworn to maintain the confidentiality of their patients.

KON MUANG

Spirit house

A peacock adorns Wat Doi Khum

The Kon Muang combine Buddhism with spiritualism. They have high regard for mountains as holy places. They construct spirit houses in gardens or in significant places around towns and villages, where offerings of food or figurines are made, in the belief that good spirits will take up residence and bring them good luck or protect them from misfortune. The Kon Muang have a strong sense of community, which is enhanced by gathering together for distinctive performing arts, particularly music and dance. Links with nature can be seen woven into the patterns of traditional textiles—flowers, leaves, elephants, buffalo, etc. and in the decorative architecture of Buddhist temples. Today, many academics and NGOs work hard to preserve this culture, including local traditions and rituals, which are believed to bring happiness, good luck and longevity, not only to individuals, but also to their families.

TAKING ADVANTAGE OF THE PLANTS OF PEOPLE

Despite an excellent modern health-care system, provided through Chiang Mai's many hospitals, many Kon Muang still consult local folk healers, to ward off diseases (preventative medicine) and for complementary treatments, with herbal remedies, when ill. As with most traditional medicine systems, herbal remedy recipes are passed down verbally through generations and are rarely recorded on paper. The remedies are usually administered in combination with ceremonies designed to unify body and mind (the holistic approach) and strengthen patients' natural ability to fight diseases. Domestic fruits, vegetables, herbs, and spices feature heavily in such remedies, which is in line with modern-day medical thinking that increased consumption of fruit and veg is part of a healthy life style.

Fruit, veg, herbs, and spices used for kon muang culture

COLOURS FROM NATURE – USING NATURAL DYES

For centuries, villagers in northern Thailand have used extracts from 70 or more plant species, to dye traditional textiles. Various plant parts are used: roots, bark, wood, leaves, flowers and fruits. For example, the Hmong use indigo (from leaves of *Strobilanthes cusia*) to dye hemp-fibre skirts with intricate patterns in deep blue, whereas the Kon Muang use it for traditional "morhom" shirts. Indigenous knowledge of the plants used and dyeing procedures are passed down through generations. This activity introduces students to some of this indigenous knowledge by using plants to dye a shirt.

Objective

1. Learn how to dye cloth using plants and appreciate the value of indigenous knowledge.

2 hour operating time

Media materials and equipment

Equipment material	Amount for 1 group (5 per group)
The part of the plant that will be used to dye the fabric	1 kind/species
A white cotton shirt, cloth bag, or handkerchief	1 piece per person
A pot for dyeing the fabric	1 per person
Salt	1 tablespoon
Rubber band	5 - 10
Alum	50 grams

Implementation

1. Before class, the students are asked to search the internet for plant materials used to make natural dyes in northern Thailand, listing the plant name (local and scientific) and habitat, plant part used and the colour of the dye.

2. The teacher asks the students to present their findings to the class and, if appropriate, leads a field trip to a local market to search for some of the products—and purchase some turmeric powder (which is always available). Whilst at the market also search for naturally dyed fabrics as examples.

Elephant mahout wearing morhom

Fabric preparation

1. Back in class tie cotton fabric tightly with the rubber bands. The dye will not penetrate tied parts, so the idea is to try to create a pattern of dyed loose cloth and non-dyed tightly tied stripes.

2. Soak the bundle in alum solution (50 g alum per litre of water) for about 5 minutes, then wring out the solution from the cloth as much as possible. Alum chemically binds to both cotton fibres and to dye molecules, So this step is necessary to get the dye to stick to the cotton.

How to dye fabric using turmeric colour

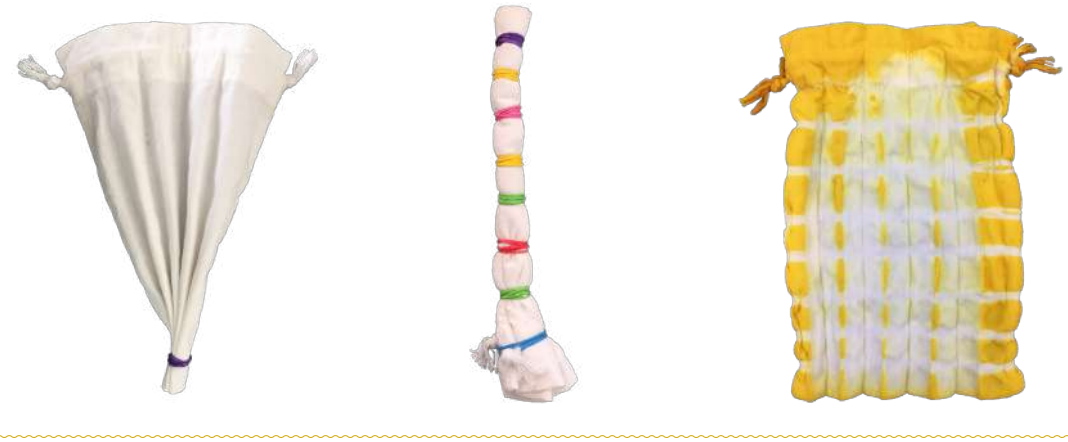
1. Boil 1 litre of water in a big old pot—one which will never be used for cooking again. Add 5 tablespoons of turmeric power, or (if you can find it in the market) a handful of chopped turmeric rhizome and 1 tablespoon of salt. Salt increases colour absorption.

2. Place the cloth bundle into the boiling dye for at least 5 minutes turning it with a wooden spoon every so often.

3. Remove the bundle from the pot. Allow to drain. Then rinse it thoroughly with cold water. Untie, rinse again and hang to dry.

*NB: homemade naturally dyed items are not colour-fast. The colour may come off in the wash. So, please tell students to launder the item in cold water, **without any other clothes**. Iron on lowest heat setting.*

Examples of some patterns to experiment with



List of plant components used to dye fabrics

Local Name	English Name	Scientific Name	Part Used	Colour
Kamin	Turmeric	Curcuma longa	Rhizome	Yellow
Ton Hom	Assam Indigo	Strobilanthes cusia	Leaves	Dark blue
Kanoon Pah	Wild Jack Fruit	Artocarpus lacucha	Fresh fruit	Purple
Ton Suk	Teak	Tectona grandis	Leaves	Light red
Maprao	Coconut	Cocus nucifera	Cocnut shell	Brown
Mah Muang	Mango	Mangifera indica	Leaves and bark	Yellow
Ton Wah	Java Plum	Syzigium cumini	Fresh furit	Purple
Ma Gluea	Ebony	Diospyros mollis	Bark	Black



***Strobilanthes cusia* - indigo from the leaves; teak - red dye from leaves; coconut shells - brown dye**


https://today.line.me/th/v2/article/zM8pVk


https://www.chiangmainews.co.th/page/archives/592227/


https://www.chiangmainews.co.th/page/archives/953274/

Naturally dyed products

Collecting products from trees without harming them

Ministerial regulation no,19 (B.E. 2507) - Forest Act, B.E 2484

Collection of restricted forest products

Peeling bark from trees can easily kill them if you don't take care, so the government has come up with some regulations to ensure that bark is collected sustainably.

Clause 12 - peeling bark from live trees

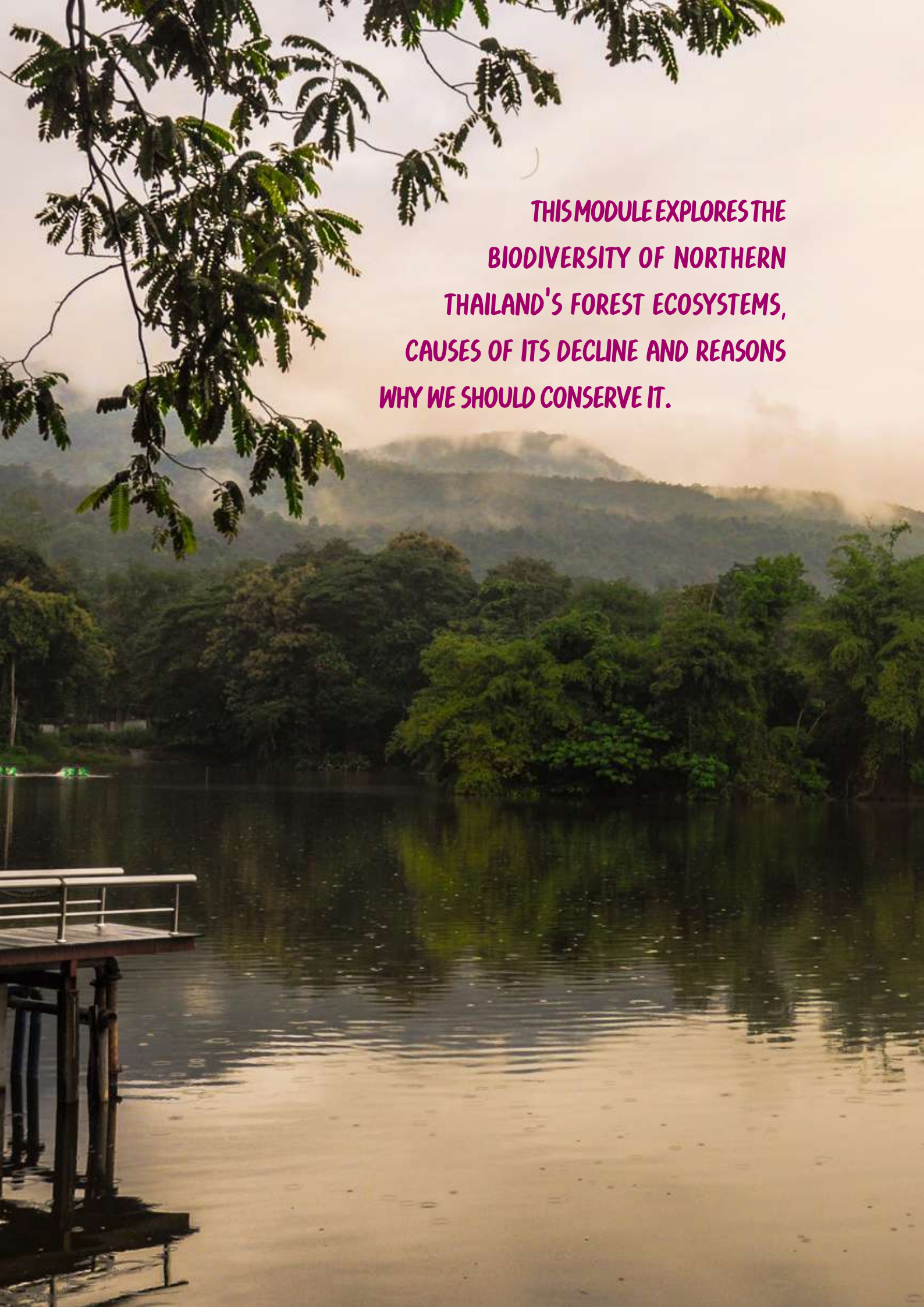
1. Bark can be peeled only from large trees (different minimum sizes for different species are specified in the regulations) - that's because small trees are easily killed by bark peeling, whereas larger ones are more resilient.

2. Peel the bark along the length of the trunk. Not less than 50 cm above the ground and do no peel the bark anywhere above the lowest branch.

3. The peeling wound must not be longer than 80 cm or wider than 20 cm and must be further than 30 cm away from other peeling sites and not at the same horizontal level.

4. Apply bitumen or other anti-fungal preparations to the wound to prevent infection.

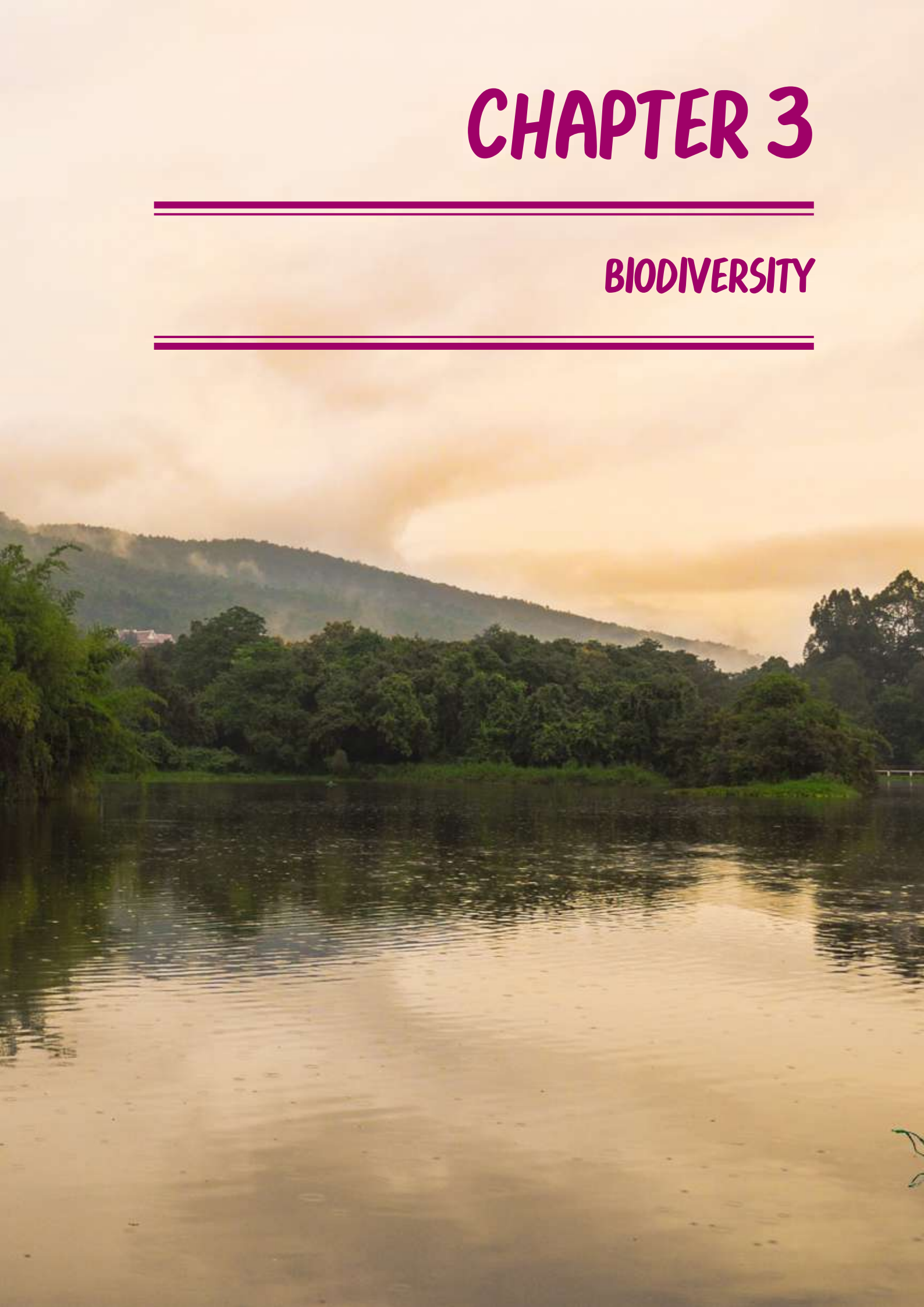
5. Must not peel the bark that has been fully peeled unless the bark grows again.



THIS MODULE EXPLORES THE BIODIVERSITY OF NORTHERN THAILAND'S FOREST ECOSYSTEMS, CAUSES OF ITS DECLINE AND REASONS WHY WE SHOULD CONSERVE IT.

CHAPTER 3

BIODIVERSITY



BIODIVERSITY – THE VARIETY AND VARIABILITY OF LIFE ON EARTH AT ALL LEVELS– FROM GENES AND CELLS TO SPECIES AND ECOSYSTEMS

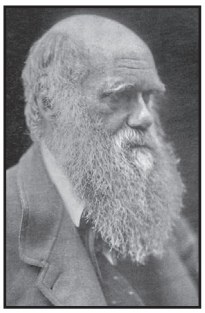
GENETIC DIVERSITY

Genetic diversity is expressed as variations in characteristics within species. For example, consider the enormous variation in appearance of different breeds of domestic dogs, even though they all belong to a single species (*Canis familiaris*). In agricultural fields, different varieties of rice (*Oryza sativa*) are grown in different places. Farmers select which rice variety to grow, based on characteristics which suit them to local climatic and soil conditions and make them resistant to diseases.

Genetic diversity is the basis for evolution of species through natural selection. When plants and animals reproduce, they pass on their genes to the next generation. Genes that best enable the offspring to survive, grow and reproduce in the local environment are passed on to future generations. In contrast those that are expressed as characteristics unsuited to local conditions may cause early death and/or failure to reproduce. So, such genes are unlikely to be passed down the generations; they gradually disappear from the population.

Genetic variability within a species is essential for survival of the species, especially when environmental conditions are changing (e.g., global climate change). When an epidemic strikes, it may kill many individuals, but if there is genetic variability within the population, then it is likely that *at least a few* individuals carry the genes for resistance; they will survive to pass on those genes to future generations. Thus the species avoids extinction. This is why conservation projects try to protect large, genetically diverse, plant and animal populations. For example, trees planted for forest restoration projects are grown from seeds collected from many individual trees. This maintains genetic diversity amongst the planted trees so that at least some of them survive climatic changes or diseases.

Charles Darwin was an English naturalist who established the theory of evolution by natural selection. He based his theory on his collections of plant and animal species in S. America (most famously the Galapagos Islands), S. Africa, New Zealand etc., whilst sailing around the world aboard The Beagle—observing small differences among similar species in different places. He also studied how breeders of dogs and pigeons change the physical characteristics of those species. He published his theory in the book "**On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life**" in 1859. It was controversial at the time, since it challenged the biblical creation story in Genesis.



Charles Darwin and his study in Downe House where he wrote "On the Origin of Species"

SPECIES DIVERSITY

Plant and animal species have traditionally been recognized by their outward appearance—differences in their physical characteristics (morphology) e.g. the external size shape and colour of their body parts. This is called **phenotype.** However these days, species are commonly defined by analysis of their DNA—the genetic code within the nucleus of every living cell, which determines both the physical form and chemical composition of plants and animals. This is called **genotype**.

Wildlife in Thailand - top left clockwise: Leopard Cat (Prionailurus bengalensis); Lar Gibbon (Hylobates lar); Sooty-Headed Bulbul (Pycnonotus aurigaster); Hog Deer (Hyelaphus porcinus) and Asian Elephant (Elephus maximus).

Species Richness

A simple count of the total number of species recorded in an ecosystem, regardless of how common or rare each species is. For example: if 30 plants are found in Ecosystem A and 20 are found in Ecosystem B, then Ecosystem A has higher species richness.

Species Evenness

High species evenness occurs where most species are represented by a similar number of individuals. Low species evenness occurs where there are a few common species and many rare ones.

Species Diversity

Species diversity is a mathematical combination of species richness and evenness. Tropical habitats typical have high species diversity, because abundant sunlight and water create ideal conditions for plant growth, which supports many herbivore species and the carnivores that feed upon them (Chapter 4).

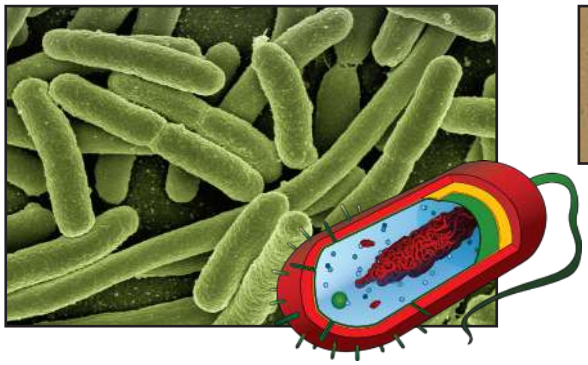
It is estimated that there are 8.7 million species on Earth,of which only about 1.7 million have been scientifically described. They are divided into 5 kingdoms.

Kingdom	Attributes	Estimated no. of species on Earth
1. Monera	1. Single-celled organisms with no membranes around cell organelles	11,000
2. Protista	1. Simple structure 2. No embryo stage	36.400
3. Fungi	1. No chlorophyll 2. The cell wall is made of chitin or cellulose. 3. Hypha - grow as thin filaments	611.000
4. Plantae	1. Make food through photosynthesis 2. Plant cells have cellulose cell walls	298,000
5. Animalia	1. Animal cells do not have cell walls	7.8 million

Micro-organisms

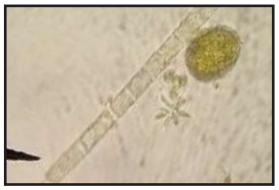
Kingdom Monera

Electron microscope



Kingdom Protista

Light microscope



Collect water and a little sediment from a pond and put a drop on a glass slide and observe under a light microscope.

Kingdom Fungi

Look for mushrooms and toadstools in forests and gardens.

Kingdom Plantae

Herbs e.g. sweet basil

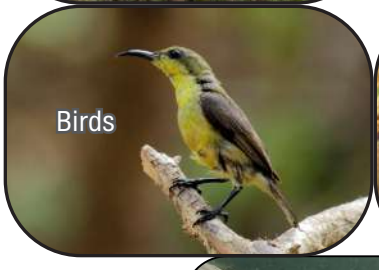
Non-flowering (ferns) and flowering (e.g. orchids)

Trees and shrubs: woody (e.g. teak)

Climbers: woody lianas, non-woody vines

Kingdom Animalia

Vertebrates - have back bones



Invertebrates - no back bones

Bernard - https://commons.wikimedia.org/w/index.php?curid=40744352

EXPLORE THE DIVERSITY OF PLANTS AND SMALL CREATURES

Many kinds of plants and small animals can be found in and around schools, gardens and residential areas. This activity is about encouraging curiosity among students, to look for nature in the everyday environment. It will help them to understand the diversity of natural habitats close to home and the plants and animals that inhabit them.

Objectives

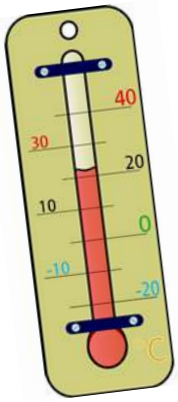
1. To observe and appreciate the diversity of living organism around us
2. To develop a basic ability to classify species into broad groups.

2 hour operating time

Media material equipment

Equipment	Amount for 1 group (3-5 students)
Data sheet (Paper)	1 sheet
Magnifying glass	1
Mini white paper tray	3 trays
Trowel	1
Thermometer and ruler	1

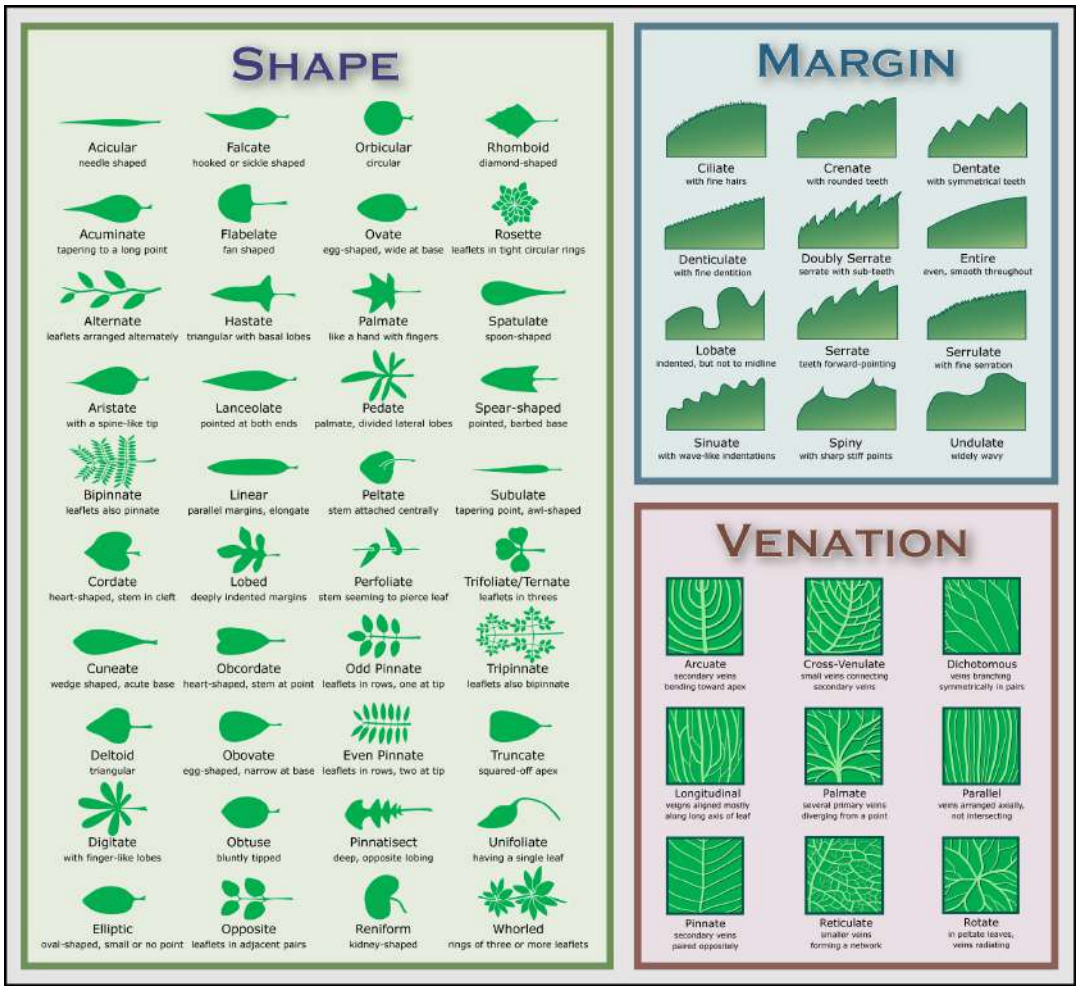
Implementation guidelines



1. Select different habitats in or around the school grounds: e.g. garden, lawn, sports field etc. including one aquatic habitat e.g. pond or drainage ditch. Divide students into groups of 3-5, and assign each group to different locations, covering all habitats.

2. Ask the students first to describe the physical conditions of their assigned habitat; wet or dry, shaded or exposed, soil condition colour texture, etc. and measure the temperature above and below the soil surface.

3. To measure plant-species richness, the students can count and draw the different types of leaf shapes they can see in 1 square metre, measure them and use the chart below to identify the leaf shape.



Leaf morphology

McSush - https://commons.wikimedia.org/w/index.php?curid=7681206

4. Collect a soil sample and spread it out on the white tray to see worms and insects that emerge. Count and sketch each different animal. Use the hand lens to examine the body shape and structure. In the class room, examine the samples under a binocular microscope, if the school has one.

5. In the aquatic habitat collect water and sediment samples and examine them on the white tray. A small pond net may be helpful extracting aquatic invertebrates. This chart: **https://www.macroinvertebrates.org/** is useful to identify aquatic invertebrates to Order level. Use a monocular microscope, if your school has one, to reveal microscopic animals and algae.

6. Students present their drawings and species counts to the class. Which habitat has the higher species richness and why? How might a more accurate and comprehensive species count be carried out?

THE BIODIVERSITY OF DOI SUTHEP

Doi Suthep supports remarkably high biodiversity. More than 2,200 plant species have been recorded on the mountain. About 60% of them are herbs and vines (non-woody) and 35% are trees or woody climbers; the rest are shrubs. Evergreen forest, near the top of the mountain (around Tum Reusi – Chapter 4), supports highest plant diversity—930 species, whilst deciduous forest near the foot of the mountain is home to "only" 533 species. About 20% of the mountain's plant species are rare or endangered. To put this figure into perspective: the whole of the United Kingdom (an area 1,000 times larger than Doi Suthep) supports only about 1,400 native plant species.

Animal species that live on Doi Suthep include at least 326 birds, 500 butterflies, 300 moths, 61 mammals, 28 amphibians and 50 reptiles, all in a national park, which covers just 261 km^2. Many of these animals play crucial ecological roles in the reproductive ecology of plant species by carrying out pollination and seed dispersal. Animals also influence plant communities by modifying the habitat to favour certain plant species or exclude others.

Crocodile Salamander - one of 28 Amphibians on Doi Suthep

Chestnut rat - one of 61 mammals on Doi Suthep

James Franklin Maxwell 1945-2015 – Champion of Doi Suthep's Diverse Flora

The high diversity of plants on Doi Suthep was revealed by botanist, J. F. Maxwell (known simply as Max). Max started working at Chiang Mai University in 1987, first at the Pharmacy Faculty, focusing on medicinal plants and moving to the Biology Department in 1992, to work on the floras of various mountains in northern Thailand. The accessibility of Doi Suthep-Pui National Park, adjacent to CMU campus, provided him with a unique opportunity to compile one of the most complete floras of any area in northern Thailand.

It was the first flora to be computerized as a database, enabling the plant communities to be analysed by habitat, plant type etc. with levels of detail and thoroughness that went well beyond those of Max's previous flora projects. The result was published as the "**Vegetation and Vascular Flora of Doi Sutep-Pui National Park, Northern Thailand**" in 2001 (https://www.forru.org/library/0000109).

TREE DIVERSITY AROUND YOUR SCHOOL

Tree maps are great way to combine plant identification skills with GIS mapping skills. Plotting them provides students with a sense of "stewardship" of their immediate environment, since the process of examining trees for identifying characteristics and recording their location develops a feeling of closeness between the observers and the trees. Students learn where dying trees should be removed to prevent accidents and where new trees should be planted to replace them. Performing the activity annually allows students to see changes in tree cover around the school over time.

Objective

1. To promote awareness of significant living organisms in the immediate surroundings

2 hours operating time

Media materials & equipment

Equipment	Amount for 1 group (5 students)
Measuring tape 1.5 meters and 50 meters	1 piece each
Camera	1
Proof paper	1 sheet
School map	1 sheet
Notebook	1

Implementation

1. After teaching about biodiversity, the teacher raises questions such as: how many trees are there around the school campus, how many species and what are the commonest or rarest species. How can we find out if more or fewer trees are needed?

2. Divide students into groups of 4-5. Divide the school campus map into the same number of segments as there are groups and assign one group to each segment.

3. Students locate all trees within their assigned segment. Only count trees with a stem circumference of 16 cm (diameter 5 cm) 130 cm above the ground.

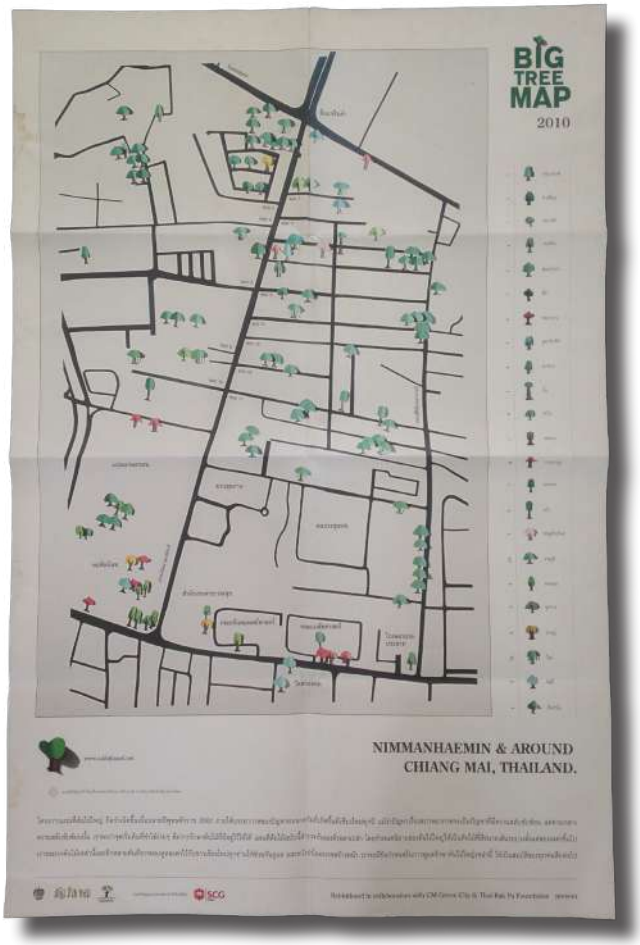
4. Mark each tree on the map and record GPS co-ordinates using a phone app (e.g. GPS Test).

Flame tree (Butea monosperma) - a common native tree, often planted as an ornamental

5. For each tree, record: girth 130 cm above the ground, height (estimate or use measuring pole), presence of flowers, fruits and leaves (young (light green), mature (darker green) or senescent (brown/yellow/orange etc.).

6. Take a photo of the tree and try to identify it. Use "**The Forest Trees of Northern Thailand**" (https://www.forru.org/library/0000227) or experiment with various plant-identification phone apps (e.g. **PlantSnap**).

7. Back in the class room, all groups add their trees to the master map and the total number of trees and tree species is calculated. Discuss whether it would be worthwhile to plant more trees around the campus and where would be the best places to plant them. How to select which species to plant?



The BIG TREE MAP project surveyed trees around Chiang Mai city in 2010

The talipot palm grows for 30-60 years, flowers once and then dies. It has the largest inflorescence of any plant, 6–8 m long bearing several million flowers.

Follow-up

This activity provides an entry point to start discussions about planning a tree nursery on the school grounds, using the existing trees as seed sources. To collect seeds from the campus trees, organise students to systematically observe the trees monthly, using the map to tick off the trees one by one, as they are observed. Record flowering and fruiting as they occur, and note when the fruits begin to fall from the trees. That's the best time to collect them, and prepare them for germination. See part 6 of https://www.forru.org/library/0000153.

The Diversity of Birds

Greentailed Sunbird - unique to Doi Inthanon, feeds on nectar and pollinates flowers

The most resilient of the hornbills—the Oriental Pied Hornbill could be found on Doi Suthep until the 1980's

Birds are easy to see and identify and are found in all habitats. Different species represent different trophic levels and they perform essential ecological functions, such as pollination and seed dispersal. Thus, they are an ideal group of organisms for introducing students to the topic of diversity in ecosystems.

- Some birds feed on nectar (**nectarivores**) and pollinate flowers, e.g. sunbirds.
- Some feed on fruits (**frugivores**) and help disperse seeds e.g., hornbills, fruit pigeons, barbets etc.
- Some eat insects (**insectivores**) and can help to control agricultural pests, e.g., swifts and swallows.
- Raptors or birds of prey, feed on live vertebrates (**carnivores**), e.g. eagles and hawks.
- Some birds feed on animal carcasses (**scavengers**), e.g. crows and vultures. Until the 1960's, there was a vulture colony on Doi Suthep (where the zoo is today). It disappeared in the 1960's as the city expanded and animal carcasses became scarce. All over Asia, most vulture species are now endangered with extinction.

Resident birds: forage, nest, and live here all year round.

Migratory birds: move between feeding to breeding areas seasonally. In the northern hemisphere many bird species fly south in the winter, where it is warmer and suitable for breeding. So Chiang Mai welcomes many winter visitors e.g. many raptors, water birds and thrushes.

Ashy Woodswallows—the farmers friend. They feed on insects over agrocultural fields.

Birds Around Chiang Mai Town

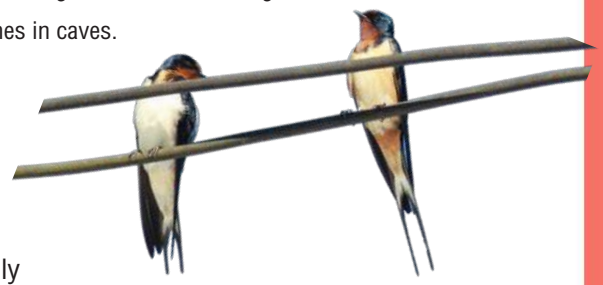
Barn Swallow

Scientific name: *Hirundo rustica*

Order: Passeriformes Hirundinidae family

Small thin body with and long, pointed wings. Catches insects whilst gliding above agricultural fields and gardens. Builds its nest from mud mixed with dried grass attached to walls and sometimes in caves.

Status: Resident



Spotted Dove

Scientific name: *Streptopelia chinensis*

Order: Columbiformes Columbidae family

Usually seen on the ground in gardens searching for grass seeds. Plump body and small beak with spots on the neck. They eat seeds and fruits and build their nests in trees from small twigs.

Status : Resident

Weerachat Sriwiset

Coppersmith Barbet

Scientific name: *Megalaima haema-cephala*

Order: Piciformes Megalaimidae family

Mostly green body with bright red forehead and yellow patches around the eyes. They eat fruit and disperse the seeds of forest trees. They nest in rotten trees by hollowing out a nest cavity.

Status: Resident

Oriental Magpie Robin

Scientific name: *Copsychus saularis*

Order: Passeriformes Muscicapidae family

Black and white. Usually seen on the ground or in small trees searching for insects. They also eat fruit and nectar.

Status: Resident

Chathupoom Meesena

Greater Racket-tailed Drongo

Scientific name: *Dicrurus paradiseus*

Order: Passeriformes Corvidae family

Black all over, with unmistakable long plumed tailed, when seen in flight. Aggressive when defending its territory. Mostly feeds on insects. Cup-shaped nest made of twigs and leaves.

Status: Resident

Sooty-headed Bulbul

Scientific name: *Pycnonotus aurigaster*

Order: Passeriformes Pycnonotidae family

Several bulbul species live around Chiang Mai. They eat fruit and are important seed dispersers, but they also take insects. The sooty-headed bulbul is recognized by its crested black head without red on the face. Upper body, greyish brown; lower body grey with red/ orange patch at base of tail. Builds a cup-shaped nest on tree branches.

Status: Resident

Kwanpirom Naruengsri

White-vented Myna

Scientific name: *Acridotheres grandis*

Order: Passeriformes Sturnidae family

Beak, yellow and straight, relatively small, pointed tip. Body black. It eats insects, fruits, grains and feeds mostly on the ground. It nests on branches and uses natural hollows or old burrows.

Status: Resident

Birds around Doi Suthep-Pui National Park Accommodation centre

From Chiang Mai town, drive up Doi Suthep, about 500 m past the Wat Prathat Doi Suthep, sharp turn on the right (Lat. 18.806824, Lon. 98.916358).

Golden-fronted Leafbird

Scientific name: *Chloropsis aurifrons*

Order: Passeriformes Chloropseidae family

Body, green. Orange/yellow spot on forehead. They eat fruits, nectar and insects, particularly caterpillars on leaves (hence the name). They build nests, made of twigs and leaves, on tree branches **Status: Resident**

Chathupoom Meesena

Verditer Flycatcher

Scientific name: *Eumyias thalassinus*

Order: Passeriformes Muscicapidae family

Short beak. Males have a short black eye stripe and dark green-ish-blue body. The eye stripe of the female is less distinct and the female body is lighter blue-grey. They eat reptiles, insects and fruit and nest in tree forks.

Status: Resident

Blue Rock-Thrush

Scientific name: *Monticola solitaries*

Order: Passeriformes Muscicapidae family

The male has a greyish-blue body with black and white scales scattered all over the body. The female body is greyish-brown. They eat insects, reptiles and fruits and build cup-shaped nests in branch forks in tree crowns.

Status: Winter visitor

Jose Maria Carretero Palacios

Thawat Tanhai

Male Scarlet Minivet

Hafisz Issadeen

Female Scarlet Minivet

Scarlet Minivet

Scientific name: *Pericrocotus flammeus*

Order: Passeriformes Campephagidae family

Brilliantly coloured orange and black males, yellow and black females, long tails, strong beaks. They feed on insects in the forest canopy in flocks, working their way down the mounting in the mornings and back up the mountain in the evenings. They build cup-shaped nests in branch forks in tree crowns.

Status: Resident

Jason Thompson

Black-crested Bulbul

Scientific name: *Pycnonotus flaviventris*

Order: Passeriformes Pycnonotidae family

Yellow greenish bird with black head and prominent black crest. Melodious song. They eat insects, nectar and fruits and are important seed dispersers. They build cup-shaped nests in tree crowns and bushes.

Status: Resident

Velvet-fronted Nuthatch

Scientific name: *Sitta frontalis*

Order: Passeriformes Sittidae family

Blue upperparts, black forehead and dull grey underparts, yellow eye ring, red bill. The male has a black eye stripe and the female does not. It feeds on insects in the crevices of tree bark, adopting a very characteristic head-down stance.

Status: Resident bird

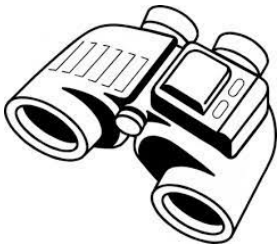
Vimal Rajaguru

Female Velvet-fronted Nuthatch

Doi Suthep Accommodation centre

BIRD WATCHING

Bird watching is a great way to introduce school children to biodiversity in a natural environment. The activity can be performed around the school campus or by travelling out to one of several bird-watching hot spots around Chiang Mai.



Objectives

1. To learn how to identify common bird species
2. To estimate the diversity of bird species and compare between habitats.

3 hour operating time

Media, materials & equipment

Equipment	Amount for 1 student pair
Binoculars	1
Birds of Thailand guide book	1
Notebook and pencil	1

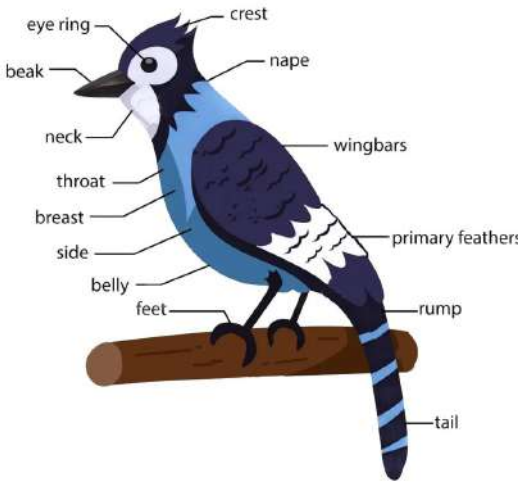
Preparation

1. Teachers first select a convenient location and check out the area in advance, particularly to familiarize themselves with the common bird species there. If the school campus is green or rural, this activity may be run on campus. Along the canal road, north past the 700 Year Stadium, on the left, Huay Thung Tao is a famous bird-watching location (entrance fee). Any trail in Doi Suthep-Pui National Park will also provide a rewarding experience. Further afield Doi Inthanon, Doi Luang Chiang Dao, Doi Ang Khang and Doi Pha Hom Pok are well known for high bird diversity.

2. Prepare students how to interpret bird descriptions by teaching the names of bird body parts and the colours of distribution maps, from instructions in the first few pages of any bird guide book.

3. Prepare students for field work. Make sure they are dressed appropriately: long trousers and long-sleeved shirt (no bright colours), hat, water bottle, mosquito repellent etc.

Bird watching guide book



Implementation

1. Run the activity early in the morning or late in the afternoon

2. Organize the students to work in pairs and assign an equal number of student pairs to each of 2-3 different habitats in the area, recognized during the preparatory excursion.

3. First both students scan the area for birds. Once a bird is seen, one student (the viewer) gets a closer look, using the binoculars and, in a low voice, describes the bird and its behaviour. The other student (the recorder) notes down the **time** and records the description. Both students then consult the bird book, to identify the species. The recorder records the species name. These roles can be alternated between the partnered students every 30 minutes or so.

4. Instead of a conventional bird guide book, you may like to try an online bird-identification app such as Merlin (https://merlin.allaboutbirds.org/), provided students have well-charged mobile phones with them. During the preparatory excursion, check that signal reception in the area is good enough.

5. Students are instructed to be as quiet as possible and not to bunch together, so a wide area is covered on each of the habitats and different pairs are not seeing the same birds.

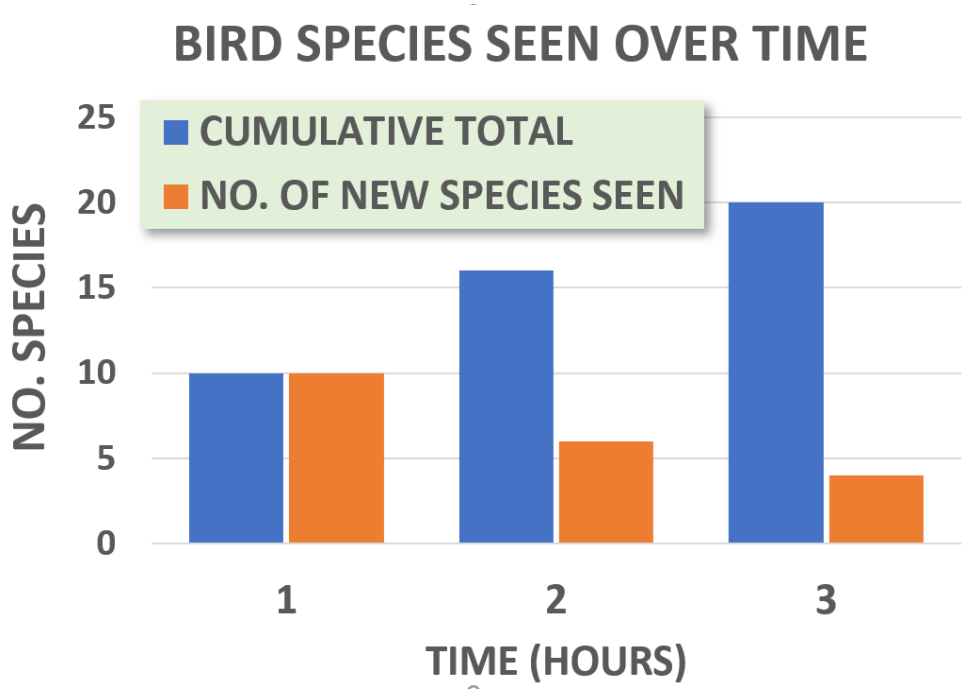
6. In case students need teacher assistance and have wandered, they are instructed to use mobile phone or messaging app (with location indicator) to call the teacher.

7. Students are instructed to return to the assembly point at a specified time. Three hours is recommended, but shorter times may be more appropriate for younger students.

Follow up

1.Students present their favourite bird species to the class.

2. For each habitat, pool the bird species records from all students pairs. Count the total number of **different** bird species recorded in the first hour for all student pairs. How many ***additional different*** bird species were seen in the second hour? Add that number to the number seen in the first hour, to arrive at the **cumulative** total number of different species seen in 2 hrs. Repeat for the third hour (if the activity was run for less than 3 h, use smaller time intervals). Plot the data as a bar chart like this …



3. Students observe that the number of new species discovered declines with time. They should deduce that if they had continued to watch birds for longer, the orange bars would decline to zero, at which point the blue bars would reach an upper maximum: an estimate of the total number of observable bird species in the habitat. The graph can also be used to estimate the number of hours that would be needed to see all the species.

4. This is the simplest measure of species richness in an ecosystem, which relates the number of species recorded with the effort expended to record them. In this case, "effort" is quantified as the time spent bird watching in each habitat by all students. The result is a species-effort curve, which predicts the total number of observable species likely to occur in the ecosystem.

5. Students compare the graphs among the habitats surveyed and conclude which habitat has the highest or lowest bird species richness.

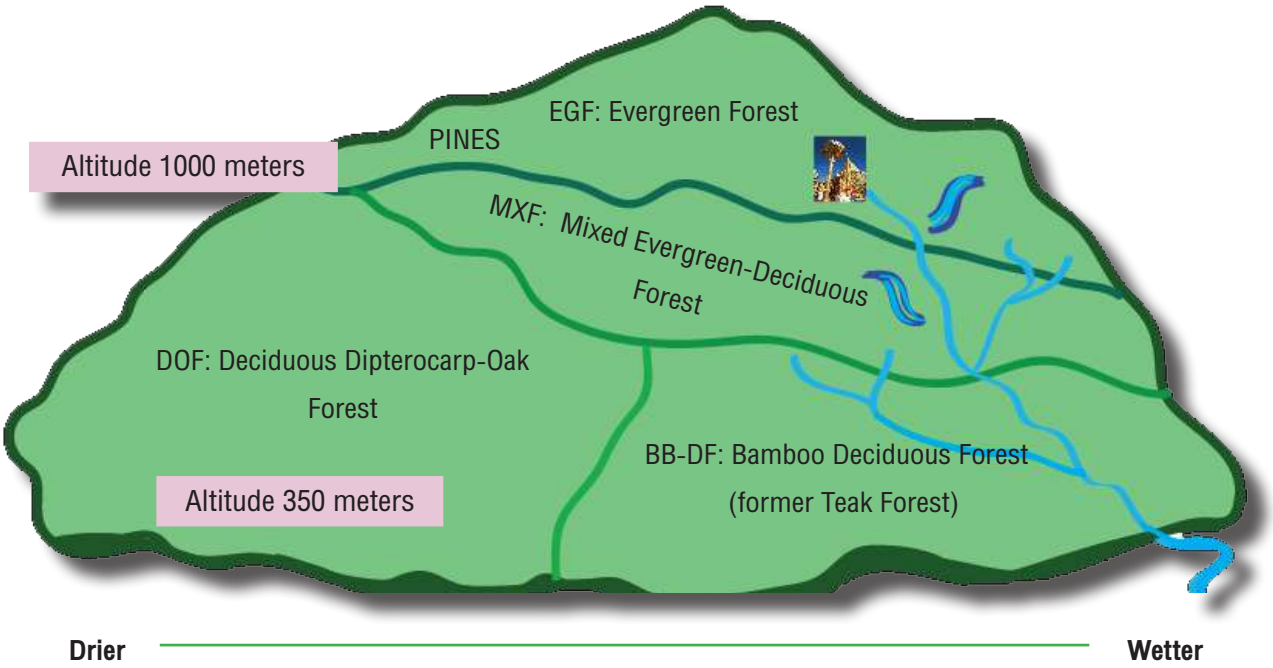
6. Discuss what may account for the differences in bird species richness among the habitats, both natural factors and human factors that may affect the efficiency of seeing bird species.

ECOSYSTEM DIVERSITY

Ecosystem diversity is the variety of different distinguishable ecosystem types within a defined area, e.g., a mountain range, river basin, etc. including both terrestrial and aquatic ecosystems (fresh and salt water). Where ecosystem diversity is high, species diversity is also high, since some species are restricted to live In particular ecosystems.

FOREST ECOSYSTEMS OF DOI SUTHEP AND THEIR BOTANICAL DIVERSITY

Due to its mountainous landscape and the seasonal climate, several different forest ecosystem types occur around Chiang Mai, in close proximity to each other. Local forest ecosystems can be divided into two main groups: evergreen forests near mountain tops and deciduous forests in the foothills. Very few of the species characteristic of evergreen forest also live in deciduous forests. So, species diversity for the region is exceptionally high, thanks to high ecosystem diversity.



The distribution of forest types in Doi Suthep-Pui National Park (www.forru.org/library/0000153, PART 2).

Evergreen forest (EGF) grows above roughly 1,000 m elevation and sometimes along streams lower down, where annual rainfall exceeds evapo-transpiration (see Chapter 1). Pines sometimes grow mixed in with the broadleaved evergreen forest trees (EGF-Pine). At the foot of the mountain, where annual evapo-transpiration exceeds rainfall, open deciduous dipterocarp-oak forest (DOF) grows in the driest areas (particularly ridge tops), whilst bamboo-deciduous forest (BB-DF), with a denser canopy, grows in more moist locations (in gulleys). The trees drop their leaves in the dry season, becoming dormant, to prevent moisture loss. In between EGF and DOF/BB-DF, mixed evergreen-deciduous forest (MXF) grows in a narrow band, with more or less equal numbers of deciduous and evergreen tree species.

EVERGREEN FOREST (EGF)

Evergreen forest along the Huay Kog Ma trail

Evergreen forest (EGF) is distinct from deciduous forest ecosystems. The main canopy is dense, often exceeding 30 m in height. More tree species grow in EGF than any other forest type in northern Thailand; 250 have been recorded. Although no species dominates, several plant families tend to be better represented there than in deciduous forest types e.g., oaks, chestnuts and magnolias. Rattan palms are a distinguishing feature. Despite the name of this forest type, about 27 % of EGF tree species are in fact deciduous (leafless in the dry season). Most of the rest shed a few leaves and grow new ones year round. The seeds of most tree species are dispersed by animals. Beneath the main canopy is a dense understorey comprised of small trees and shrubs. Woody climbers are a notable feature of EGF; 78 species have been recorded.

A high abundance of epiphytes is also distinctive, including ferns and orchids, mosses, liverworts and lichens, often encrusting tree trunks and branches; 82 species have been recorded. Tall bamboos are scarce. The ground flora is often dense, with many species of ferns, gingers and banana (321 recorded species) as well as small tree seedlings. The parasitic plants *Balanophora* species and *Sapria himalayana* mentioned in Chapter 4 can be found growing in EGF.

Typical plants of EGF: left to right: Phlogacanthus curviflorus (understorey shrub), Impatiens violaeflora (ground flora) and Magnolia garrettii (canopy tree)

MIXED EVERGREEN-DECIDUOUS FOREST (MXF)

Mixed evergreen-deciduous (MXF) forest grows in a narrow band at about 800-1,000 m elevation on northern Thailand's mountains. It is transitional between evergreen and deciduous forest types. Although many of its plant species are shared with the other forest types, about half are unique to MXF, making it a diverse and distinctive forest ecosystem type. Canopy height varies from 20 to 30 m, but scattered emergent trees often exceed 30 m in height. They are mostly evergreen dipterocarps, the most characteristic trees of this forest type: e.g., *Dipterocarpus costatus* and *D. turbinatus.* With their massive grey trunks, small leaves and dense, broad crowns, they sometimes resemble giant sticks of broccoli. Canopy cover is usually dense, though less so than in evergreen forest.

Emergent giant diptercarp trees the most distinctive feature of MXF

A total of 217 tree species have been recorded in MXF on Doi Suthep, of which about 43 % are deciduous. Woody climbers are a major feature, with more than 60 species having been recorded. Epiphytes are common, including 57 species of mostly ferns, orchids and Gesnerids. Mistletoes also grow high in the trees as hemiparasites (parasitic plants that can also perform photosynthesis). Bamboos are present, though less prevalent than in BB-DF. A ground layer of herbs (at least 278 species) and tree seedlings is usually dense. Grasses rarely dominate except in burnt areas. Abundant gingers and ferns are characteristic.

Distinctive plants of MXF: Gomphostemma strobilinum (left), with striking variegated leaves in the ground flora and the flowers of Bauhinia variegata (right) the so-called orchid tree, which blossoms when leafless in February and March—often planted along roadsides.

BAMBOO-DECIDUOUS FOREST (BB-DF)

Bamboo-deciduous forest (BB-DF) with a remnant teak tree

Until the 1890's, vast teak forests covered northern Thailand's lowlands (up to 900 m elevation). But exploitation of this valuable timber tree, has changed these forests. Other trees and especially bamboo have largely replaced teak. So these forests are now called bamboo-deciduous forest (BB-DF). The main canopy is up to 20-30 m tall but patchy. Canopy cover in the dry season is sparse, when most trees drop their leaves. At least 180 tree species grow in BB-DF, of which more than 70 % are deciduous. None approach the former dominance of teak, although remnant teak trees can still be found. An understorey, dominated by dense thickets of bamboos and shrubs is indicative. Bamboos (in the grass family) are abundant, especially in disturbed areas (mostly *Bambusa* and *Dendrocalamus* species). There are 30 shrub species, of which 63 % are deciduous. Woody climbers are common and large ones are a notable feature of this forest type.

A total of 55 species have been recorded, of which 65% are deciduous. Epiphytic orchids and ferns grow frequently on the trunks or main branches of the larger trees (38 species recorded). The ground layer consists mostly of mixed herbs and grasses. In the dry season the ground is mostly bare, with gingers and orchids first emerging in April. During the rainy season the ground flora is dense and diverse with many ferns, but starts to die back in November and often burns in the dry season.

Distinctive plants of BB-DF: one of many ginger species (left), Boesenbergia longiflora flowers in the dry season when leafless; the flowers of Afzelia xylocarpa (centre), a valuable rosewood timber tree and (right) bamboo flowering occurs only once every 7 years

DECIDUOUS DIPTEROCARP-OAK FOREST (DOF)

Deciduous dipterocarp-oak forest (DOF) replaces bamboo-deciduous forest in dry or degraded areas, from the lowlands up to about 800-900 m elevation. It occurs along dry ridges with little top soil. The trees rarely grow taller than 20 m and form an open or irregular canopy. More than 80% of them shed their leaves in the dry season, flushing green again, shortly before the first rains. DOF has lower tree species richness (around 100 species) than the other forest types. With their huge leaves and massive winged fruits, the dipterocarps are undoubtedly the most characteristic tree species in this forest type. The next most easily recognised tree group are oaks and chestnuts (Fagaceae), recognised by their serrated leaves and characteristic nuts. The very rare pine *Pinus merkusii* can sometimes be found in DOF. Woody climbers (only 14 species) are rare, whilst shrubs (29 species) are more common in the understorey.

Deciduous dipterocarp-oak forest changes colour in the dry season

Large bamboos are absent. Of the 47 epiphytic vascular plant species, recorded in DOF, the most characteristic is the ant plant *Dischidia major* (see Chapter 4). Several orchid species also grow as epiphytes. Two epiphytic ferns, with distinct growth forms, are also fairly common in DOF; *Drynaria rigidula* and *Platycerium wallichii*. The ground layer is characteristically dominated by grasses and sedges, providing highly combustible fuel for fires, which are frequent in the dry season. A few gingers, orchids and the indicative phoenix palm grow amongst the grasses.

Distinctive plants of DOF: fallen flowers and dried leaves of Dipterocarpus obtusifolius in January (left); rising from the ashes, the Phoenix palm survives (centre) and attractive orchid with grass-like leaves Arundina graminifolia (right)

NATURE TRAILS ON DOI SUTHEP

The best way for students to appreciate the variety of forest ecosystems on Doi Suthep and the diversity of their plant species is to explore the national park's many nature trails. The fig trail near the park accommodation centre provides an excellent introduction to evergreen forest, whilst the Wang Bua Ban trail does the same for deciduous forests. Whilst organizing field trips involves teachers in extra work, they are immensely rewarding to students, and FORRU-CMU staff are always willing to help out with guides, information and other technical support.

Students exploring the Fig Tree Trail

Objective

1. To explore the forest types of Doi Suthep and their botanical diversity

2-3 hours operating time

Media materials & equipment

Equipment	Amount for 1 student
Trekking worksheet	1 set
Magnifying glass	1 piece

Implementation

1. Having presented the forest types and floral diversity of Doi Suthep, organise a field trip to explore walking trails on Doi Suthep— one in lowland deciduous forest and one in upland evergreen forest. FORRU-CMU has prepared several trail guides, to highlight notable features:

- **Deciduous forest** - Wang Bua Ban trail & Huay Kaew Waterfall trail
- **Evergreen forest** - Giant fig tree trail & Tum Reusi trail (see Chapter 4)
- **Evergreen forest mixed with pine** - Doi Pui Summit trail

Download nature trail leaflets from **www.forru.org/outreach/education-materials**

It is recommended that teachers prepare by walking the trails in advance, to identify prominent plant species and check out any hazards.

2. Recommended materials to identify species include "The Forest Trees of Northern Thailand" (www.forru.org/library/0000227) and the phone app PlantSnap (www.plantsnap.com/)

Caution:
- During the rainy season, all nature trails are dense with ground plants such as grasses, small herbaceous plants, and the path may be slippery.
- Do not walk outside the specified route because it can be dangerous.
- Dress appropriately: long trousers, long-sleeved shirts, strong shoes, water and insect repellent.

Alien Species

Alien (or exotic) species are those which have come in from other countries. In their ecosystem of origin, they evolved to adapt to the species around them; in particular the predators which keep their populations in check. But when they are transferred into foreign ecosystems, without those predators, their populations can increase uncontrollably i.e. they become **invasive** and displace native species. Invasive alien species are the second highest cause of biodiversity loss after habitat destruction.

Non-invasive Alien Species

Mostly cultivated species unable to reproduce well and spread unless helped by farmers

Coffee

Chilli

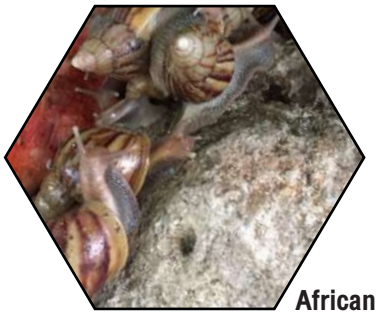
Corn

Dates Palm

Invasive Alien Species

Highly suited to the climate of the destination country, arriving without natural predators and able to spread and suppress local native species

Mexican Sunflower



African giant snail

Water hyacinth

Siam weed

RECOGNISING ALIEN SPECIES

This activity is to encourage students to learn how to identify alien plant species, so that they can help to control them and reduce their impact on natural ecosystems.

Objectives

1. To increase awareness among students of the most prevalent invasive alien plant species in northern Thailand.

1 hour operating time

Media material equipment

Equipment	Amount for 1 group (3 students)
Computer or mobile phone	1
Notebook	1

Implementation

1. The teacher describes the origin of invasive alien species and divides students into groups of 3.

2. Students are provided with the list (below) of the scientific names of invasive alien plant species. For additional species try: **www.inaturalist.org/projects/invasive-species-of-thailand?tab=species.** Assign 1-2 species to each group.

3. Students perform an online search to find pictures and information about each species, particularly: local names in Thai and English, country of origin, impact on vegetation and plant species in Thailand (both negative and positive) and local uses.

4. Print out pictures of the plants and take them along when walking nature trails (previous activity), so students can recognize them in the field.

5. Each group presents information they have found about their assigned plants.

6. The teacher leads a discussion on the overall impact of invasive alien plants and how their introduction and spread might be controlled. **Follow up activity** - find and remove invasive exotic plant species from the school grounds.

Chromolaena odorata	*Mimosa pigra*	*Eichhornia crassipes*
Lantana camara	*Mikania scandens*	*Leucaena leucocephala*
Tithonia diversifolia		

THREATS TO BIODIVERSITY AND HOW YOU CAN HELP

Habitat Loss: Tropical forests support more biodiversity than any other ecosystems. But they are fast being destroyed. First, they are logged to provide timber and then further cleared to provide land for agriculture. In Chiang Mai there is no commercial legal logging, so most of the forest lost has been due to conversion to agriculture. From 2001 to 2020, Chiang Mai lost 102,000 ha of tree cover. The current rate of forest loss is about 0.5% per year. The problem is that whereas agriculture, to provide food for a growing human population, has clear economic value, it is difficult to put an economic value on biodiversity.

Support Ecotourism

True ecotourism does put a direct economic value on biodiversity if ecotourists pay to see wild plants and animals in their natural habitats. So, ecotourism can provide an alternative source of income to local people who might otherwise log the forest or clear it for agriculture. However, when you book "eco-tours" make sure that it is true ecotourism:

- provides income to local people who might otherwise clear forest to earn a living;
- has minimum impact on the natural environment e.g., renewable energy sources, tents or other low impact accommodation etc.;
- involves ecotourists in conservation activities such as wildlife surveys or planting trees and
- provides an educational experience.

Plant trees or get involved in forest restoration

Even a single tree provides habitat for numerous insects and birds, so planting trees around your school is a great way to help conserve biodiversity. There are also many opportunities to get involved in tree planting on a much larger scale to restore forest ecosystems around Chiang Mai. Join FORRU-CMU on Facebook for notification of such opportunities **(https://www.facebook.com/forru.cmu.th/).**

If habitat destruction is the greatest threat to biodiversity - forest restoration is the obvious solution

Invasive Alien Species: As already explained, some alien species can outcompete local flora and fauna and seriously reduce native biodiversity. **Learn how to recognize them and remove them** from your gardens and school grounds.

Hunting or Capturing Wildlife or Collecting Wild Plants: Very few people rely on wildlife as a primary source of meat, these days. So, hunting is mainly done for sport and to supply the lucrative market in wildlife products such as skins and horns etc. Sometimes animals are capture as pets or for zoos. Many plants are also harvested from the forest to plant in gardens, particularly orchids, ferns and cycads.

Do not buy wild animals as pets or wildlife products

Dogs and cats are easy to keep as pets, whereas wild animals, although cute when young, become difficult to manage or aggressive as adults. So, never buy wild animals as pets. They belong in the forest to breed and maintain their populations. Also don't buy birds to release for merit in front of temples. Wildlife meat (snake, monitor lizard, turtle, deer) can still be found in some restaurants around Chiang Mai. Consumption of such meat can be dangerous to your health as well as impacting biodiversity. Wildlife products can still be found around Chiang Mai, although much less these days. Never buy animal skins, antlers, horns teeth etc. or animal products with claimed medicinal properties, such as bear gall bladder. Many such products are fake and can be dangerous.

Do not buy wild orchids

Wild orchids have imperfect leaves, usually showing insect damage—do not buy them. Instead look for orchids with perfect leaves grown in a nursery.

Leopard skins and deer antlers for sale at Mae Sai.
If you care about biodiversity, never buy such things

THIS LESSON IS ABOUT RELATIONSHIPS—THOSE AMONG PLANTS AND ANIMALS, WHICH ENABLE REPRODUCTION AND SURVIVAL OF SPECIES, AND THOSE BETWEEN LIVING ORGANISMS AND NON-LIVING ECOSYSTEM COMPONENTS, WHICH MAINTAIN ESSENTIAL PROCESSES, SUCH AS ENERGY FLOW AND THE NUTRIENT CYCLES.

AN **ECOSYSTEM** IS A DISTINCTIVE COMMUNITY OF PLANTS AND ANIMALS, INTERACTING WITH EACH OTHER AND WITH THE ABIOTIC ENVIRONMENT, SUCH THAT MATERIALS CYCLE BETWEEN LIVING AND NON-LIVING COMPONENTS AND ENERGY FLOWS THROUGH THE SYSTEM.

CHAPTER 4

INTERACTIONS

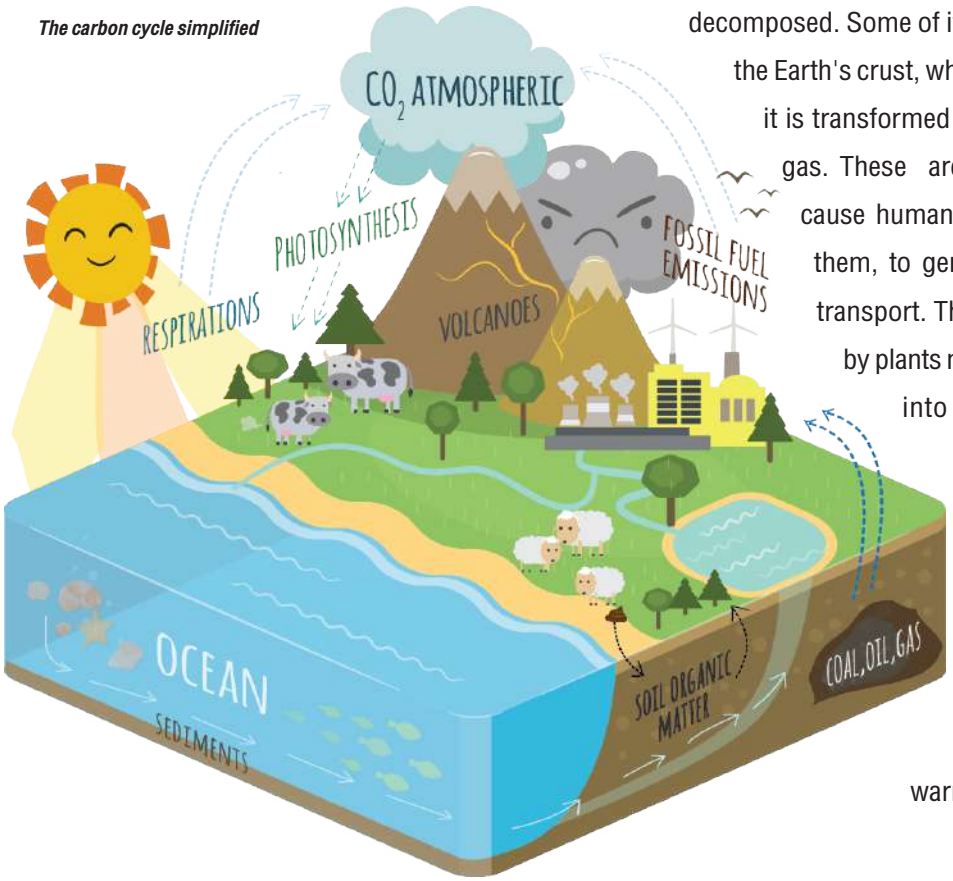
NON-LIVING ECOSYSTEM COMPONENTS

Energy and chemicals are the most important non-living or **abiotic** ecosystem components. Energy **flows through** ecosystems, but chemical elements **cycle around**—from the environment into living organisms and back into the environment. Such cycles are essential for life; plants and animals cannot survive without nitrogen (for proteins) phosphorus (for lipids) and carbon (for energy and structure). Some of tiniest organisms play critical roles in these cycles. For example, although the atmosphere is 75% nitrogen, plants and animals cannot use it as a gas; but **nitrogen-fixing bacteria** *can*. The nitrogen in proteins of most plants and animals therefore owes its origin to these bacteria, which convert nitrogen gas into nitrates, which plant roots can absorb and use to make proteins. Though biogeochemical cycles, living things regulate the amounts of substances in the environment. For example plants absorb carbon (in carbon dioxide) from the atmosphere which helps to regulate the greenhouse effect.

CARBON CYCLE

Plants absorb carbon dioxide (CO_2) from the atmosphere by **photosynthesis**, combining it with water, to make carbohydrates for energy and structure (cellulose, wood etc.) and releasing the oxygen (O_2) back into the atmosphere. Both plants and animals perform **respiration**, breathing in oxygen and breathing out CO_2 when energy is released from carbohydrates. Carbon passes from plants to animals when animals eat plants. When plants and animals die, they fall into the soil and become **dead organic matter (DOM).** Soil invertebrates and micro-organisms decompose DOM, releasing much of its carbon into the atmosphere as CO_2. But not all DOM carbon is decomposed. Some of it becomes buried deep in the Earth's crust, where over millions of years it is transformed into coal, oil or methane gas. These are called **fossil fuels**, because humans dig them up and burn them, to generate electricity and for transport. This releases carbon, fixed by plants millions of years ago, back into the atmosphere—more than plants today can adsorb. It creates imbalance in the carbon cycle, accumulating CO_2 in the atmosphere, which contributes to global warming (see Chapter 1).

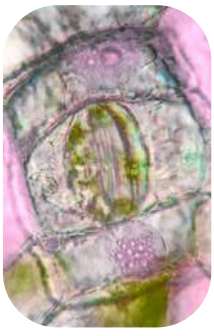
The carbon cycle simplified



Near the surface of oceans, micro-algae (diatoms) convert dissolved CO_2, into carbonates. When they (or the animals that eat them) die, the carbon falls to the ocean bed, where it accumulates and, over millions of years, it eventually becomes limestone. Corals do a similar job, since their polyps live symbiotically with algae, which can also absorb dissolved carbon dioxide, converting it into aragonite, a form of calcium carbonate. For example, the limestone of Doi Chiang Dhao is an ancient coral reef and other marine deposits, laid down during Permian period 230-250 million years ago. As such, the mountain is a massive store of terrestrial carbon in solid form—a product of the **oceanic carbon pump.**

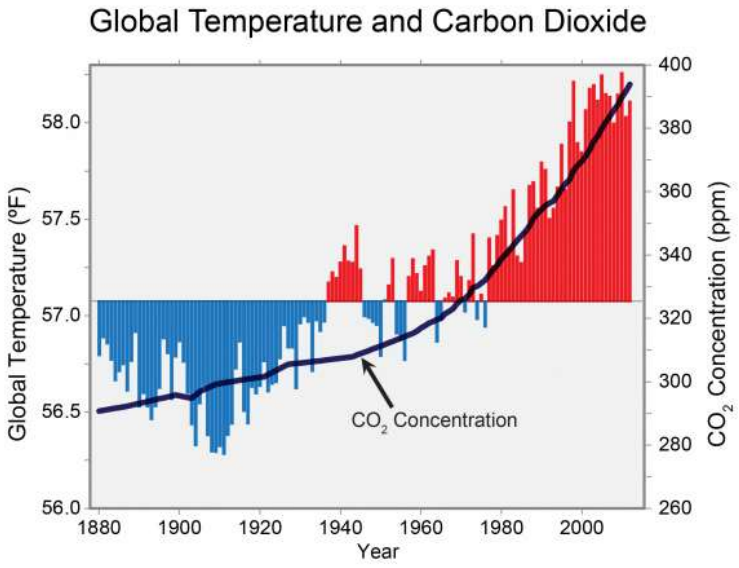
Photosynthesis

Green plants fix carbon and energy in ecosystems by photosynthesis. The energy is sunlight and the carbon comes from CO_2 gas, diffused into leaves from the atmosphere through tiny pores called **stomata.** Inside leaves, a complex chemical reaction combines CO_2 with water to make glucose, using sunlight energy, captured by chlorophyll. Some of the glucose is used to provide energy for plant life, some is converted to starch (as an energy store) or combined with other elements to make proteins and lipids etc. Much of it is transformed into complex structural molecules for plant growth e.g. cellulose to build plant cells walls, lignin to make wood etc. In this way, sunlight energy is converted into chemical energy, stored in the bonds between atoms in complex organic molecules. When those molecules are broken down (during respiration) the chemical energy is released as heat and carbon returns to the atmosphere as CO_2 .



Stomata are microscopic pores in leaf surfaces, through which carbon enters ecosystems.

How photosynthesis works



How humans disrupt the carbon cycle

Each year the burning of fossil fuels and deforestation emits about 9 gigatonnes of carbon ((GtC) into the atmosphere as CO_2. One GtC is one thousand million tonnes. The vegetation on land and algae in the oceans absorb only about 5 GtC each year—these are called carbon sinks. So, human activities are adding 4 GtC to the atmosphere annually. Consequently, the concentration of CO_2 in the atmosphere is rising.

Since CO_2 is a greenhouse gas, which absorbs thermal radiation, rising CO_2concentrations cause global temperatures to rise. To halt the increase we must reduce emissions of CO_2 by human activities by about 4 GtC per year, without delay. In addition we must also maintain healthy forest and ocean ecosystems, to maintain or even increase their capacity to absorb carbon through photosynthesis and act as carbon sinks.

LIVING ECOSYSTEM COMPONENTS

The living or **biotic** components of ecosystems include micro-organisms, plants and animals (including humans). Ecologists like to categorize plants and animals according to their functions within ecosystems as primary producers (green plants), primary consumers (herbivores), secondary consumers (carnivores) and decomposers.

PRIMARY PRODUCERS

Green plants are called primary producers, because they are the only entry point for both energy and carbon into living systems. Since they produce their own food by photosynthesis, they are also called **autotrophs**. They are the foundation of ecosystems on land in fresh water and in the oceans. They range in size from microscopic algae and tiny mosses, to gigantic trees. These days, 25% of global primary production is crop plants, used to feed humans.

Moss - tiny primary producer

Rice - primary production for humans

Massive fig tree

CONSUMERS

Organisms that cannot produce their own food, must obtain energy and carbon from eating other organisms. They are called **heterotrophs** or **consumers**. There are two main classes of consumer:

Primary consumer - wild cattle "banteng" at Wat Umong

Primary consumers eat plants. They are called **herbivores.** Most herbivores are insects (in terms numbers of species). Look at the leaves of almost any plant and you will see holes made by insects. The largest herbivorous animals are **ungulates** (hoofed mammals)—deer, sheep, cattle, goats, elephants etc. Those specialized to eat fruit are called **frugivores** e.g. gibbons, hornbills etc.

Phachara Phromnophawong

The magpie robin, a common bird in gardens around Chiang Mai, is mostly carnivorous

Secondary consumers eat other animals, usually herbivores. They are called **carnivores** or **predators**. Examples include tigers, eagles and sharks. Animals that feed on recently dead animals are termed **scavengers**, for example vultures.

Some animals are both primary and secondary consumers, eating *both* plants and animals. They are called **omnivores**, for example most civet species.

DECOMPOSERS

Decomposers feed on dead organic matter (DOM)—the dead bodies of producers and consumers. They break down energy-rich complex organic molecules into simpler inorganic nutrients, using enzymes, releasing energy as heat and carbon as CO_2. Insects and worms break up the DOM into smaller pieces, whilst fungi and bacteria break down the organic molecules and release nutrients back into the soil for further plant growth—and so the cycle of life continues.

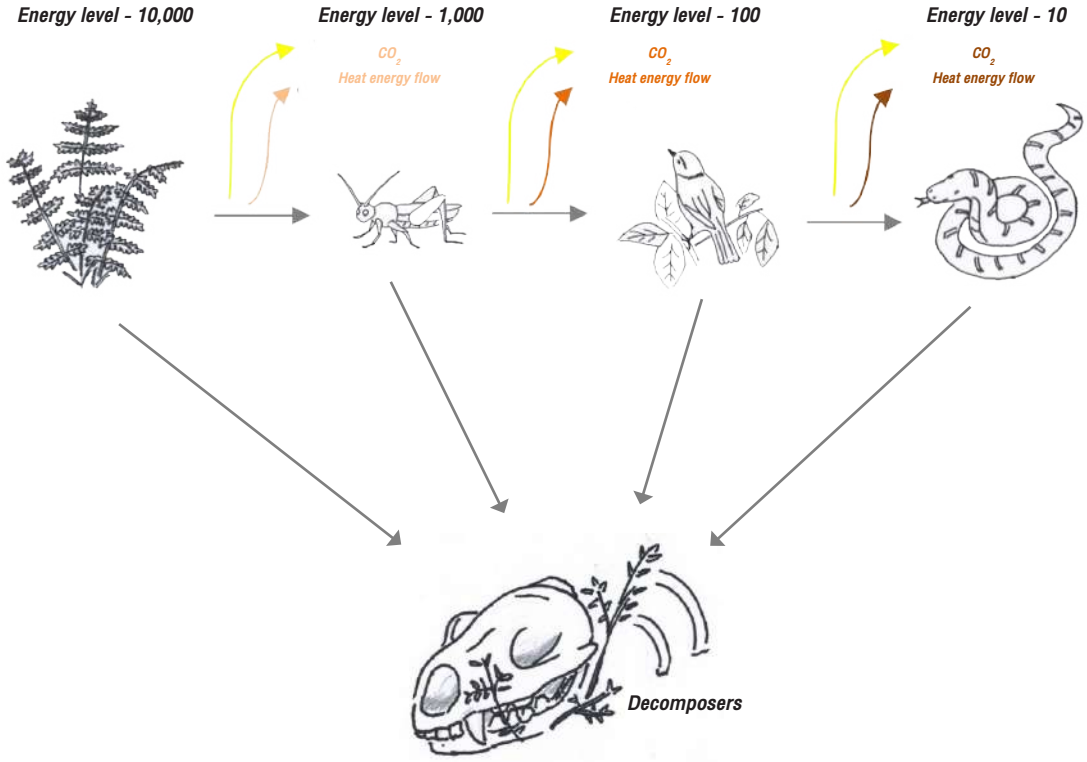
Fungi on dead wood. Inside the log, fine strands of fungi, called "hyphae" feed on the dead wood by secreting enzymes which digest it. The visible orange mushrooms release spores. They are the reproductive organs of the fungus.

REPRESENTING ENERGY FLOW THROUGH ECOSYSTEMS

FOOD CHAINS

A food chain is a simplified representation of how energy is transferred from producers to consumers in an ecosystem through the consumption of food. During each transfer step, some food is wasted and is left for the decomposers. Also some energy is released as heat. So carbon and energy decrease as we move along the chain.

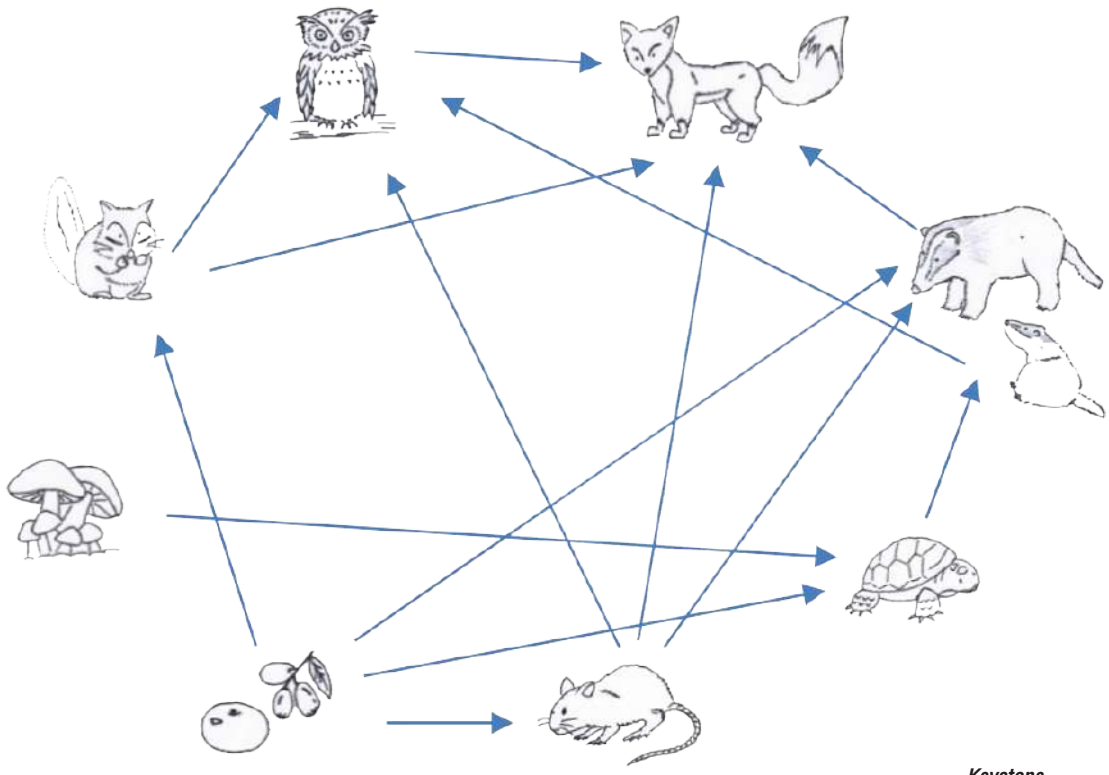
In fact it decreases a lot. Only about 10% of the energy in one organism is passed along to the next, in the chain as food. About 90% of the energy is lost due to inefficient transfer or it used up for bodily processes such as digestion, excretion and respiration.



A simple food chain

FOOD WEBS

Unfortunately ecosystems are a lot more complicated than simple food chains. Most consumer species feed on many different plant and/or animal species. So a more realistic way to represent the flow of energy through ecosystems is by food webs which show links between many species, based on which species eat or are eaten by others. These links are called **trophic relationships**. So a food web is a representation of a ***network of trophic relationships*** within an ecosystem.



Food web

Keystone species

A keystone is the brick at the top and in the middle of a Roman arch. It does not bear any weight, but if it is pulled out, the arch collapses. So a keystone species is vital for the survival of the entire ecosystem. If a keystone species disappears from the ecosystem, then the whole ecosystem may collapse, due to the interdependency of species on each other in food webs and other non-trophic relationships.

Keystone - Roman arch

Fig fruits—a vital source of food for a whole network of animals and their predators, when other foods are seasonally scarce.

In the forests of northern Thailand, fig trees (*Ficus* species) are keystone species. Many animals depend on figs as food, particularly during the dry season, when other food are in short supply. These include, many species of birds, squirrels, monkeys, deer, etc. So, if fig trees disappeared, many animal species would die out, due to starvation, along with the predators that feed upon them. Thus fig trees are therefore keystone species.

FOOD CHAINS

This activity introduces students to simplified trophic relationships in the form of food chains, before expanding the concept into food webs.

Objective

1. To introduce the concept of the energy transfer from producers to consumers in ecosystems.

1 hour operating time

Media, materials & equipment

Equipment	1 group (6 students)
Small pieces of paper about 2 x 3 inches or post-its	20 sheets
Paper clip	6
Plasticine	About 300 gm

Implementation

1. Start with a discussion about the plants and animals commonly seen around the school or during a walk in the forest. Include both plants and animals and guide the students to consider both large and small organisms—producers, consumers and decomposers.

2. Divide students into groups of 6, and provide each group with 20 sheets of paper.

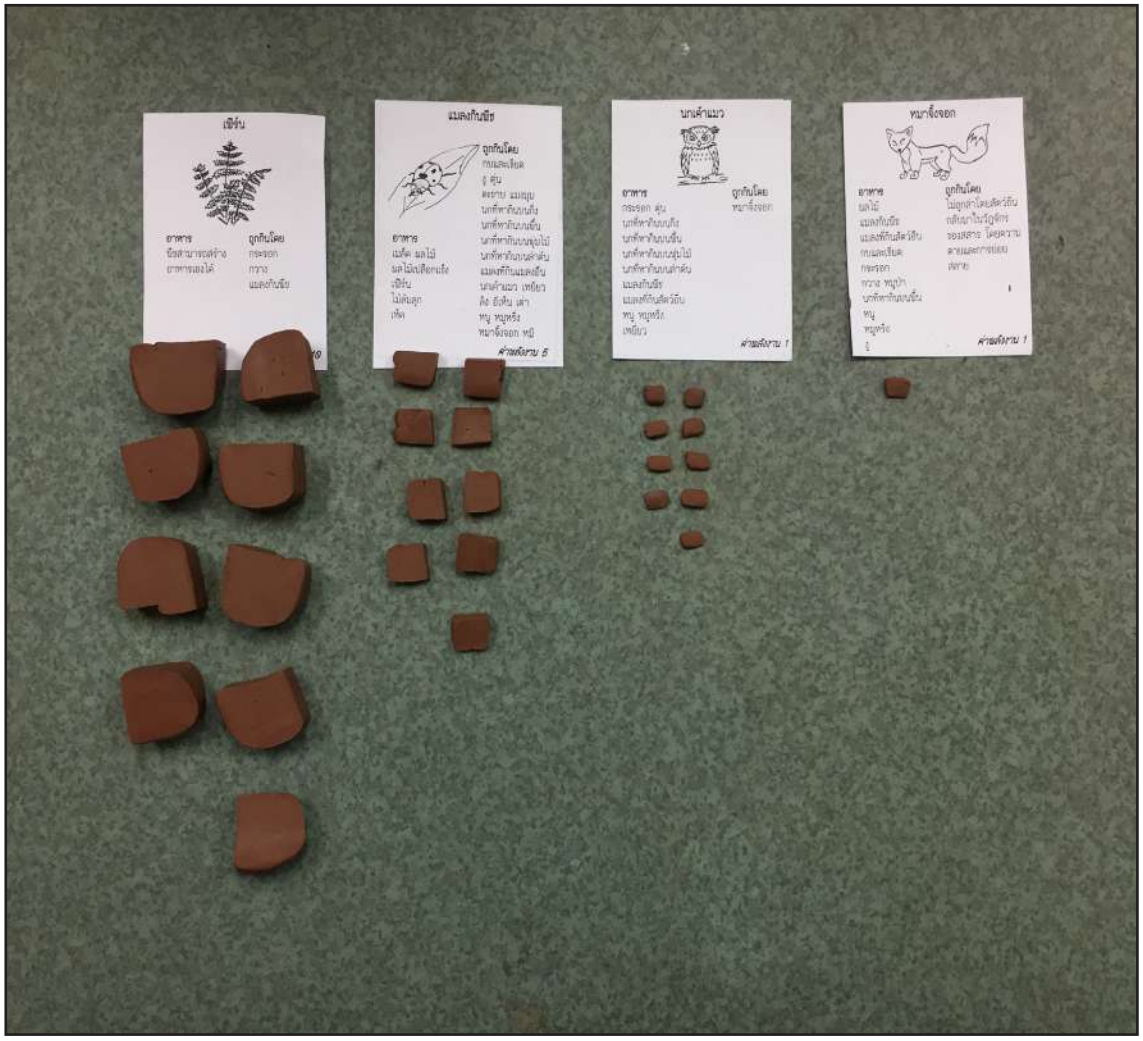
3. Ask each group design their own food chain by drawing pictures of the local organisms on their given papers. Groups present their food chains to the class for feedback.

Example of organism drawing

4. Teacher explains the 10% rule. If a producer generates 100 units of the energy, primary consumers will consume no more than 10 units and secondary consumers would consume no more than 1 unit etc.

5. From all the food chains, compile lists of primary producers, primary and secondary consumers etc. Distribute the plasticine to the groups and ask students to divide it into 10 equal pieces and place all pieces under the list of primary consumers. The 10 pieces represent 100% of the energy fixed in the ecosystem by photosynthesis. Ask students to transfer 1 piece to the primary consumer list, representing 10% transfer. Ask students to divide that piece into 10 equal parts and transfer 1 piece to the secondary consumer list and so on down the chain. Students understand that chains have limited length and that the mass of secondary consumers in ecosystems must be very small.

6. Ask the students to consider where does the rest of the energy go and what happens to the energy when plants and animals die. When students raise the question of how to represent an animal that eats more than one food species, the class is ready to expand the concept into food webs.



Using plasticine represent 10% law energy flow

FOOD WEBS

Food webs are a more realistic representation of energy flow through ecosystems. Showing how producers and consumers interact in a network of trophic relationships (rather than linear chains). They also reveal the need for biodiversity in ecosystems not only to meet the varied nutritional needs of different species but also to maintain ecosystem stability.

Objectives

1. To represent the complexity of energy transfer in ecosystems as networks of trophic relationships.

2. To identify keystone species and learn how food-web complexity contributes to ecosystem stability.

1 hour operating time

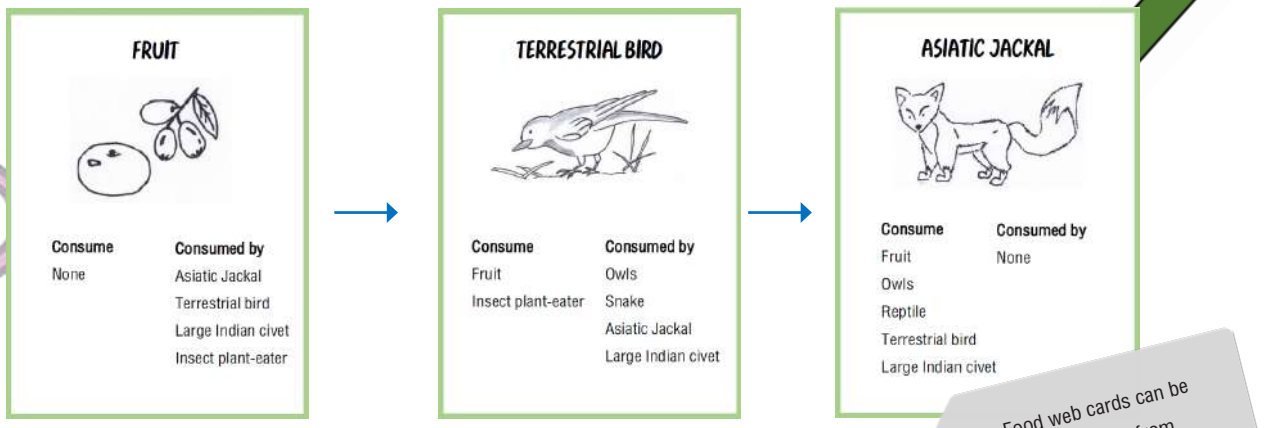
Media, materials & equipment

Equipment	1 group (5 students)
Food web card (2 Set)	8 or 12 sheets
Proof paper	1 sheet
Pen	3

Implementation

1. Divide students into groups of 5. Review the concepts and principles of energy transfer in ecosystems and the conclusions from the food-chain activity.

2. Distribute the food-web cards, which represent producers, consumers, and decomposers. Students create a food webs by placing the cards on the proof paper. Start with a producer and then ask the next student to place another card, a consumer, next to the producer, with an arrow pointing towards the consumer. Repeat until the group is out of cards.

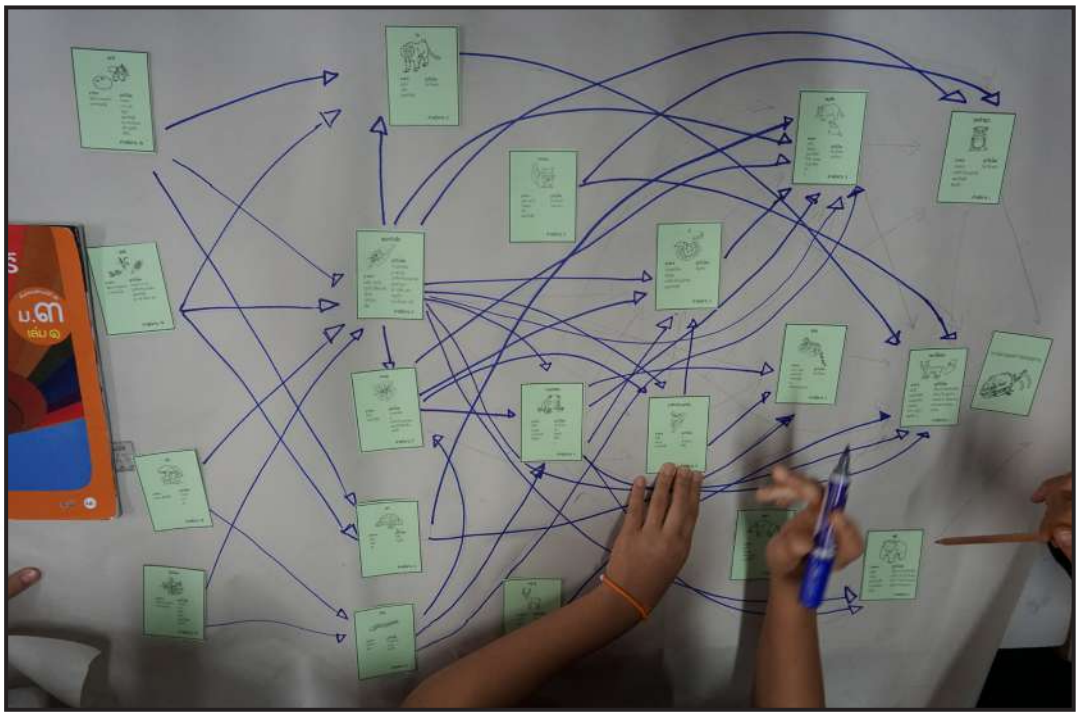


An example of an ecological creature card.

Food web cards can be downloaded from https://www.forru.org/

3. Once the network has been established, ask students to remove one species card from the food web and consider i) what might cause the species to disappear from the ecosystem and ii) what effects would removal of the species have on other species in the web.

4. Ask students to consider each species individually and identify which one, if removed, would have the greatest effect on the ecosystem as a whole. This is the keystone species.



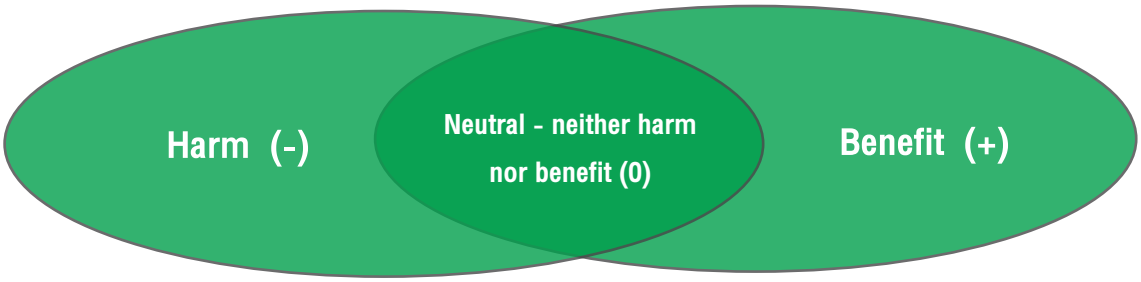
Constructing food webs and finding keystone species

Follow up Activity

Consider the human food web. Examine the items available for lunch in the school canteen. Are humans primary consumers, secondary consumers or both? Considering energy loss along food chains, and the need for large areas for agriculture, how could humans decrease the impact of food production on global ecology? Are humans really the final "top" consumers in food chains? Do any organisms get their carbon and energy from us?

RELATIONSHIPS AMONG FOREST ORGANISMS

Ecosystems include many different plant and animal species. Food webs show just the trophic relationships between species, but there are many other kinds of relationship. Some benefit one species whilst harming another, some benefit both species and some have neither beneficial nor harmful effects. Tropical forests are well known not only for high numbers of species but also for the complexity of the network of interactions among them.



PREDATION; +/-

Predation is the most obvious example of a +/- relationship one animal gains food (**predator** or **carnivore**) and the other is killed (**prey**). Predator/prey relationships exist between both large animals (e.g. tiger/deer) and smaller ones (e.g. spider/insects). These days, the term "predator" is also used to describe animals eating plants (**herbivory**). For example monkeys are considered to be **seed predators**, since, by eating fruit and the seeds contained within them, they reduce reproduction and dispersal of plant species.

A spider eating a butterfly

Seed predator - macaque monkey

A snake eating a gecko

Weerachat Sriwiset

PROTO-CO-OPERATION; +/+

Proto-co-operation is when both organisms benefit from a relationship, but they are not solely dependent upon each other; they *can* survive apart. This is called a **facultative** relationship; mutually beneficial but not obligatory for survival e.g. bees and flowers. Bees pollinate flowers, enabling plants to reproduce. Flowers reward bees with nectar and pollen as food. However, most flowers can be pollinated by several insect species, so they are not solely dependent on bees. And most bees can obtain nectar from many plant species, so are not solely dependent on any single plant species.

Bees and flowers - an example of proto-co-operation

Dischidia major provides luxury accommodation for ants in exchange of multiple services

Dischidia major on plant

D. major is a vine. Its stems curl around tree branches in lowland deciduous forest. Its specialized hollow leaves look like green bananas

Ants nest inside the leaves. The plant grows roots into the nests to extract nutrients.

Look up into the trees in deciduous forest, on the lower slopes of Doi Suthep (near CMU observatory is a good place) and you may find an extraordinary example of proto-co-operation: *Dischidia major* (Asclepiadaceae). It looks like a bunch of green bananas, curled around tree branches. It is an **epiphyte**—a plants which grows *on* (but *not in*) another plant. Since they are not rooted in soil, epiphytes face a major problem—how to get nutrients? *D. major* solves this problem by co-operating with ants. Some of its leaves are swollen and hollow, providing perfect accommodation for ants' nests. The nest debris is rich in plant nutrients, which *D. major* absorbs through roots, which it grows *inside its own leaves!* No other plants do this. Ants also increase the concentration of carbon dioxide inside the leaf cavity. By having its stomata only on the inside of the leaf, the plant can easily absorb carbon dioxide without losing a lot of moisture. The ants also defend the plant against herbivores and may pollinate its flowers.

COMMENSALISM; +/0

Epiphytic fern—funnel type structure

Epiphytes are an example of commensalism, whereby one organism benefits, whilst the other is neither harmed nor helped. In a forest, the trees grab most of the light, shading out the smaller plants beneath. Epiphytes solve this problem by growing high up on tree branches. Their roots do not penetrate the trees, so the trees are not harmed. The epiphytes receive more light up there, and they can escape ground fires, but they lack soil moisture and nutrients. So, most have evolved various structures to capture water and nutrients, such as growing in a funnel shape, to catch rainwater and falling leaves.

Epiphytic orchid with aerial roots

Aeschynanthus hosseusii

COMPETITION; -/-

Competition refers to mutually harmful relationships, whereby two organisms fight for the same resources. The winner is the one that can capture the most resources. But competition reduces resource availability to *both* organisms and therefore both are harmed. Competition can occur between organisms of the same species (**intraspecific competition**) or between those of different species (**interspecific competition**).

In deforested sites, competition between regenerating tree seedlings and herbaceous weeds is intense. The weeds often kill the trees and prevent forest recovery. So, weed control is often necessary to restore forest ecosystems.

MUTUALISM; +/+

Mutualism is a mutually beneficial partnership between organisms, which have become so interdependent upon one another that they cannot live apart. In tropical forests, lichens are good examples. They consist of two organisms, growing as a single body—an alga and a fungus. The algal partner captures carbon and energy by photosynthesis, whilst the fungal partner absorbs water and inorganic nutrients from the surrounding environment. Lichens grow very slowly on rocks and tree bark. Next time you walk in a forest, take a hand lens to look at lichens on tree trunks. You will be amazed by the intricate structures and patterns of lichens up close. For an even better view, use a binocular microscope to look at small samples back in the classroom. Lichens help scientists to monitor air pollution since some species are very sensitive to pollutants and die back, whilst a few others are less affected and proliferate. The highest abundance and diversity of lichens are therefore found on high mountains, where the air is clean.

Three main groups of lichens based on their form

Crustose

Thin blue-green crusts growing as irregular patches, firmly attached to tree bark or rocks

Foliose

Papery or leathery, leaf-like, lobed patches, easily removed from substrates

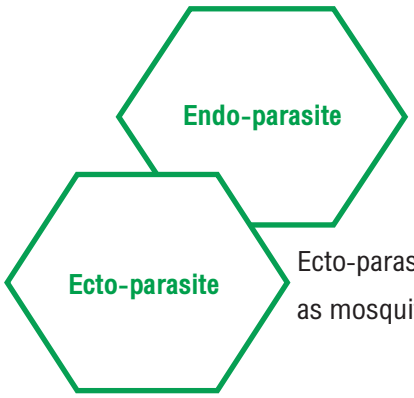
Fruticose

Densely branching lichens, often found on small twigs and branches on high mountains and in the oldest forests.

PARASITISM; +/–

Parasitism is when a small organism (**parasite**) feeds on a much larger organism (**host**), whilst the larger organism is still alive. The parasite benefits by receiving food from the host, whilst the host may suffer illness or even death due to the parasitic infection. Both plants and animals may be parasites. Parasites, which may feed on humans during a walk on Doi Suthep, include mosquitoes, ticks and leeches.

There are two main groups of parasites depending on where they attack the host



Endo-parasites feed on hosts' internal organs, e.g. various parasitic worms.


Liver fluke

Ecto-parasites live on the skin of their hosts, e.g. various arthropods such as mosquitoes, lice and fleas. They feed on blood or skin cells.

Ticks are ecto-parasites that feed on blood. They are found in many places including houses and forests. They feed on wild mammals and on pets, particularly dogs, from which they can transfer to humans. They can transmit diseases such as typhus and meningitis, so seek medical advice if you find one feeding on you.


Tick

Parasitic plants on Doi Suthep

A major challenge for any plant, growing on the floor of a dense evergreen tropical forest, is to obtain enough light for photosynthesis. One way to solve this problem is to extract food from other plants and live as a parasite. Parasitic plants have no green leaves and cannot carry out photosynthesis themselves. They exist as microscopic filaments inside the host, from which they absorb water, nutrients and the products of photosynthesis. Only their flowers are visible outside the host. Parasitic plants undoubtedly harm, and may even kill, their hosts, but not before the parasite has had time to flower and disperse its seeds to new hosts. Parasitism is not a very common mode of life amongst vascular plants. On Doi Suthep there are only 24 parasitic vascular plant species (1.16% of the mountain's flora).

Sapria himalayana

The plant family Rafflesiaceae contains the world's largest flower—*Rafflesia arnoldii,* which grows to more than a metre in diameter, in the rain forests of Indonesia. On Doi Suthep, a smaller member of the family grows—*Sapria himalayana,* with flowers about 20 cm across. It grows inside the roots and stems of several species of *Tetrastiga* lianas (in the same family as grape vines (Vitaceae)) in dense evergreen forest. It flowers only in the cool season (November to January). The flower stinks like rotting meat. This attracts carrion flies which perform pollination. Rats are thought to disperse its seeds.

Natcha Chaisoong

Natcha Chaisoong

Stephen Elliott

Leaves and stems (left) of Tetrastiga laoticum, the host of Doi Suthep's most spectacular flower, Sapria himalayana (right)

Balanophora species

Also on Doi Suthep in high evergreen forest, several species of *Balanophora* grow amongst the leaf litter. When first discovered in the early 1800's, *Balanophora* spp. were thought to be fungi. The above-ground parts are fleshy, club-shaped, dense clusters of the smallest flowers in the world. They emerge mostly in the cool season. The parasite is attached to its host by a tuberous growth, consisting of a mix of host and parasite tissue. On Doi Suthep, *Balanophora* usually feeds on oak or chestnut tree roots, but more than 70 plant species can host these parasites. Insects probably pollinate their flowers. Their fruits are amongst the smallest in the world, weighing less than 0.01 mg, probably dispersed on air currents.

Stephen Elliott

***Balanophora fungosa*, parasitic on tree roots. Male and female flowers occur on separate plants. These are males.**

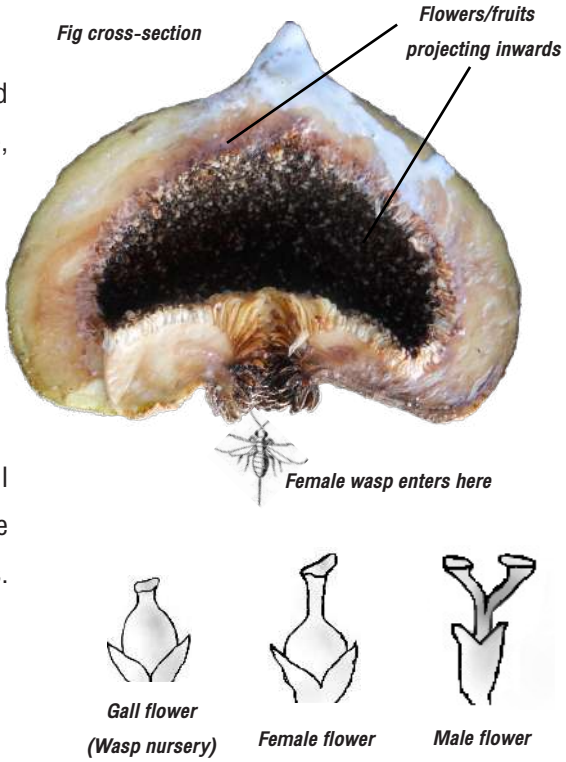
THE EXTRAORDINARY LIVES OF "STRANGLING" FIG TREES
EPIPHYTES, COMPETITORS AND KEYSTONE SPECIES

"Strangling" fig trees (*Ficus* spp., Moraceae), do not actually strangle their support trees; they out-compete them. They are not parasites; they begin life as epiphytes, growing from tiny seeds, in the faeces of birds or squirrels, deposited into bark crevices on branches or tree trunks (**support trees**). *Ficus* seedlings start small, but after growing a few leaves, they grow long roots down the trunks of support trees. Once these roots reach soil, *Ficus* trees are relieved of the problems faced by epiphytes (water and nutrient shortages), whilst still taking advantage of the high light intensity of the upper canopy, so growth accelerates. At this point, *Ficus* trees start competing with the support trees for light water and nutrients. Fig tree crowns smother their support trees, whilst their dense root systems drain the soil of water and nutrients.

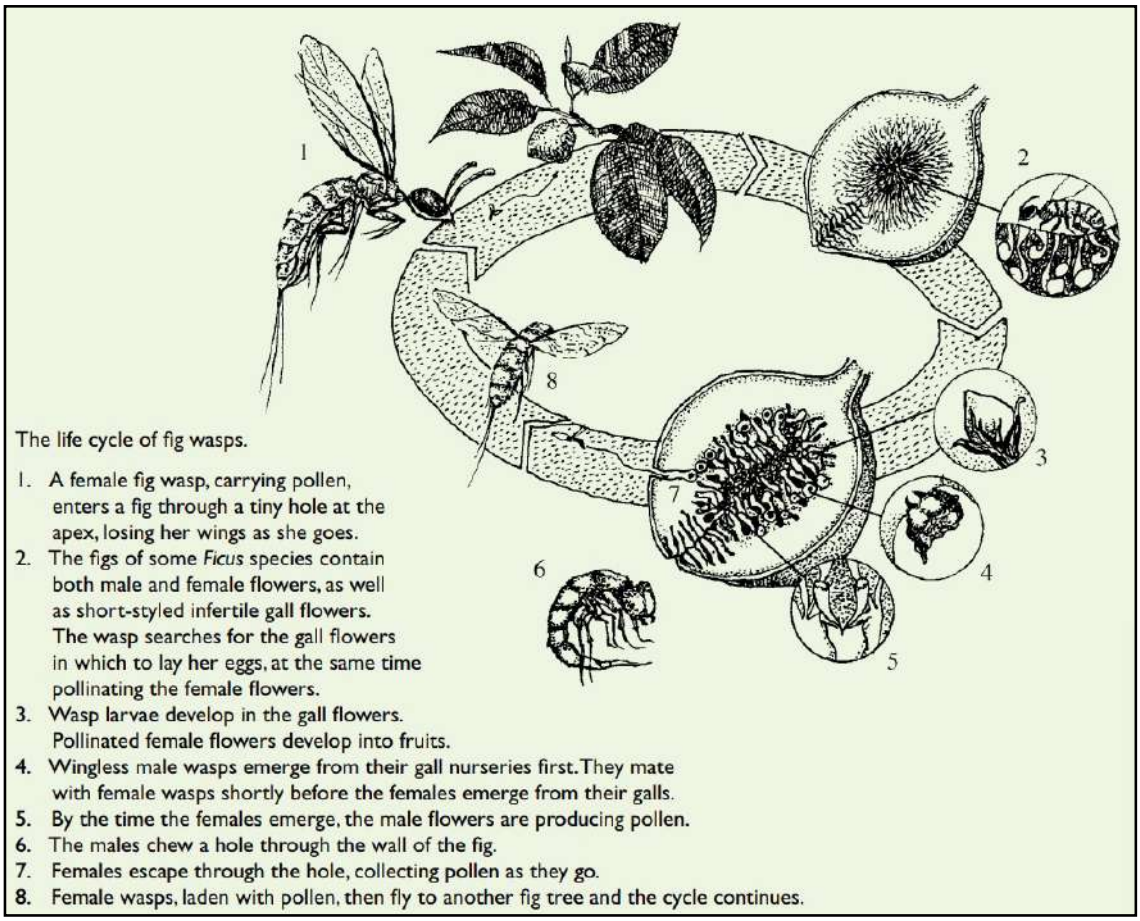
"Strangling" fig trees start life as harmless epiphytes. Later, they kill their support trees through competition.

Ficus trees usually win, because the support trees must use most of their energy to maintain their existing massive trunks, branches and roots, whereas *Ficus* trees an channel their energy into growth. As support trees die, *Ficus* trees growing basket-like networks of roots around support-tree trunks (see page 95). So, by the time support trees rot away, *Ficus* trees can support themselves.

Fig tree flowers and fruits are tiny and are contained within figs (called **syconia**). Inside the figs, are male, female and **gall** flowers. The pollinators are tiny **fig wasps** (*Blastophaga*). Female wasps, carrying pollen from the figs in which they hatched, push their way into figs on another tree through a tiny orifice, losing their wings in the process. They lay their eggs in gall flowers, whilst also transferring pollen to female flowers; then die. Wasp larvae develop inside the gall flowers. Wingless males emerge first and mate with the females, whilst they are pupating inside the gall flowers. The males then tunnel through the fig wall and die.



Fresh air, entering the fig through the hole, stimulates male flowers to produce pollen and winged females wasps to emerge. The females become covered in pollen, as they exist the fig through the hole, made by the males and fly off to find figs on another tree, in which to lay their eggs. The fig tree, therefore, grows infertile gall flowers to maintain populations of its pollinators. By helping fig trees to reproduce, the wasps maintain a supply of figs, within which future generations can breed. Fig trees are totally dependent on the wasps for their reproduction and vice versa.



The ife cycle of fig wasps diagram

Because the life cycle of the wasps is only 6 weeks, there must be some figs in the forest all year round to maintain wasp populations. Figs are therefore a reliable all-year-round food supply for many animals, even when other foods are scarce. Without figs, many forest animals would not survive. So, *Ficus* trees are 'keystone" species. Many different animal species feed in *Ficus* trees when the figs are ripe: birds, monkeys, squirrels etc. whilst underneath, wild pigs, deer and rodents feast on fallen figs.

Figs are a vital food resource for monkeys

EYE-SPY ECOLOGICAL RELATIONSHIPS ON DOI SUTHEP

The best way to re-enforce the lessons in this module is for students to discover for themselves the plant and animal types described and the relationships among them in a forest ecosystem. One of the best places to do that is along the Hermit Monk's Cave Trail. (Tum Reusi) on Doi Suthep.

Objectives

1. To discover the diversity of plant and animal species, the different roles they play in forest ecosystems and relationships among them.

Operating time - 1/2-day including travel from Chiang Mai city

Media materials & equipment

Equipment	Amount for 1 group (2-3 students)
Hand lens and binoculars	1
Eye-spy sheets	1 sheet

Preparation

The teachers walk the trail in advance to check the route and items likely to be seen along the way. Bear in mind that some items are seasonal. Make sure students are well prepared: long sleeved shirts and long trousers, strong shoes, hat, water bottle.

The trail

Access the trail from highway 1004, 1 km past Doi Suthep Temple, on the left (Google Maps-"Phraruesi Cave"). Alight from vehicles in the open area at the top of the trail. Ask drivers to park vehicles at the medicinal plants garden (500 m back towards the temple). The trail is about 0.8 km long. Tell students to walk slowly and quietly to see more wildlife. The trail starts with a short but steep descent down steps. A small waterfall and cave with shrines are at the bottom. Continue past cave, bearing left at the fig tree and rocks. Follow path sloping gently down, past a tangle of large woody lianas overhead. At the stream, turn right for a few metres, before crossing and ascending a path into the medicinal plants garden.

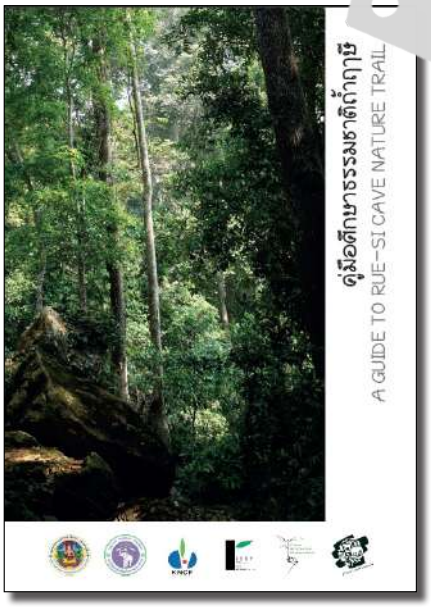
A tangled mass of lianas marks the half way point along the trail

Implementation

At the cave, ask students to sit down (a mat may be useful at this point). The cave is believed to be where the hermit monk Warsuthep meditated. So, it is a good place to tell the tales of Pu Sae Ya Sae and Queen Chamadevi (from Chapter 2). Distribute the Eye-Spy target list. The students' mission is to find an example of everything on the list. Plan stops along the way, to focus on particular organisms—one to look at lichens and other epiphytes growing on trees, one to observe soil organisms, one to spot birds or squirrels in the trees with binoculars. The students take photos of items they can

see up close, or sketch those they view with binoculars. In the medicinal plants garden discuss how plants from the forest are useful to humans. The garden was established to grow *Cinchona* trees from S. America for pharmacology experiments. *Cinchona* bark is a source of quinine, used to treat malaria. In one of the salas in the garden (or back in the classroom), students present their pictures to the class. Classmates discuss if the plants or animals presented match the items on the sheet. Extra credit can be given for finding species names

The Tum Reusi Trail booklet can be downloaded from **https://www.forru.org/**



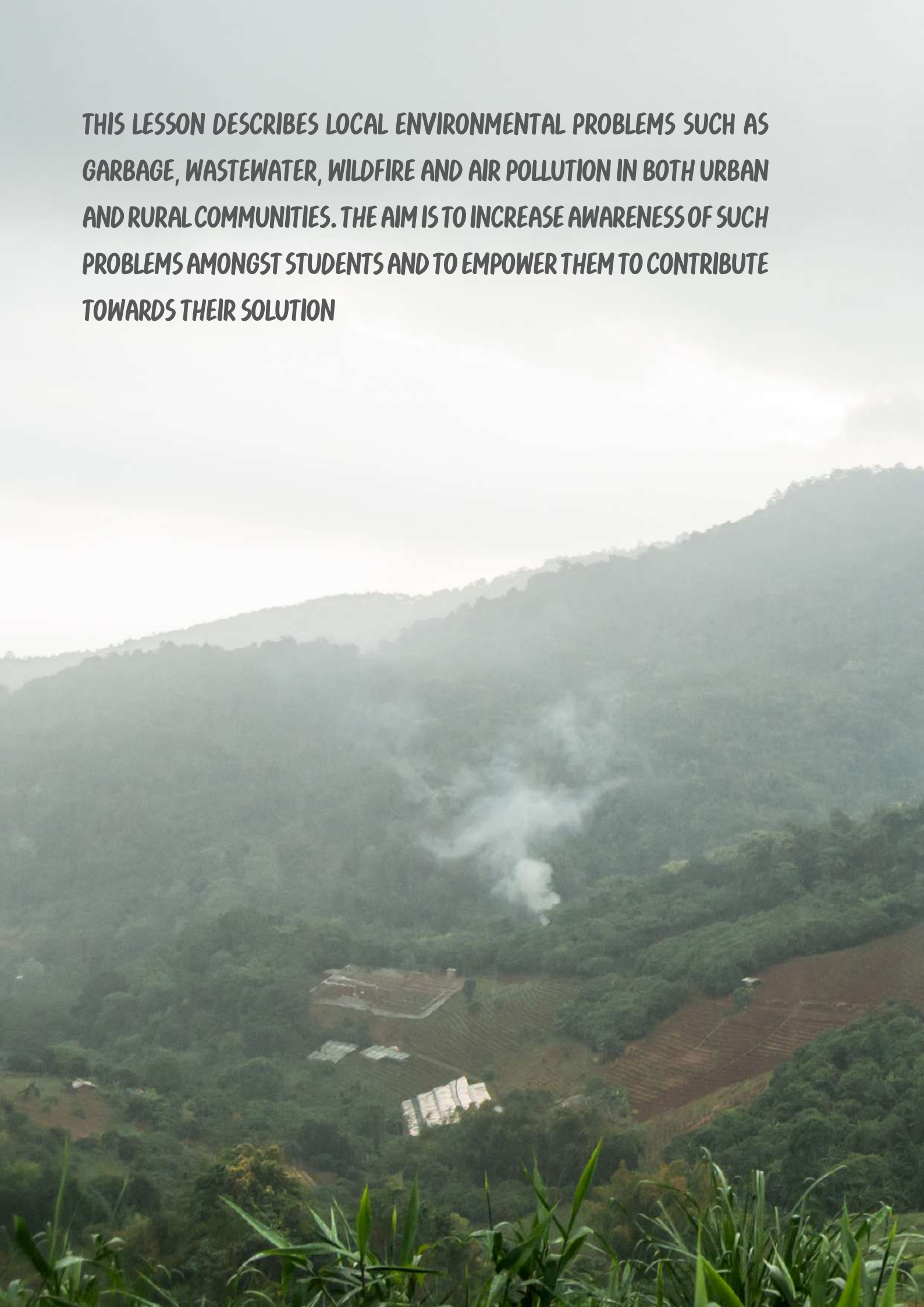
Eye-Spy Target List

- A primary producer
- A primary consumer
- A secondary consumer (predator)
- A decomposer
- An epiphyte
- A lichen (example of mutualism)
- A key stone species
- A parasitic plant*

Nature detectives prepare to investigate at Reusi Cave

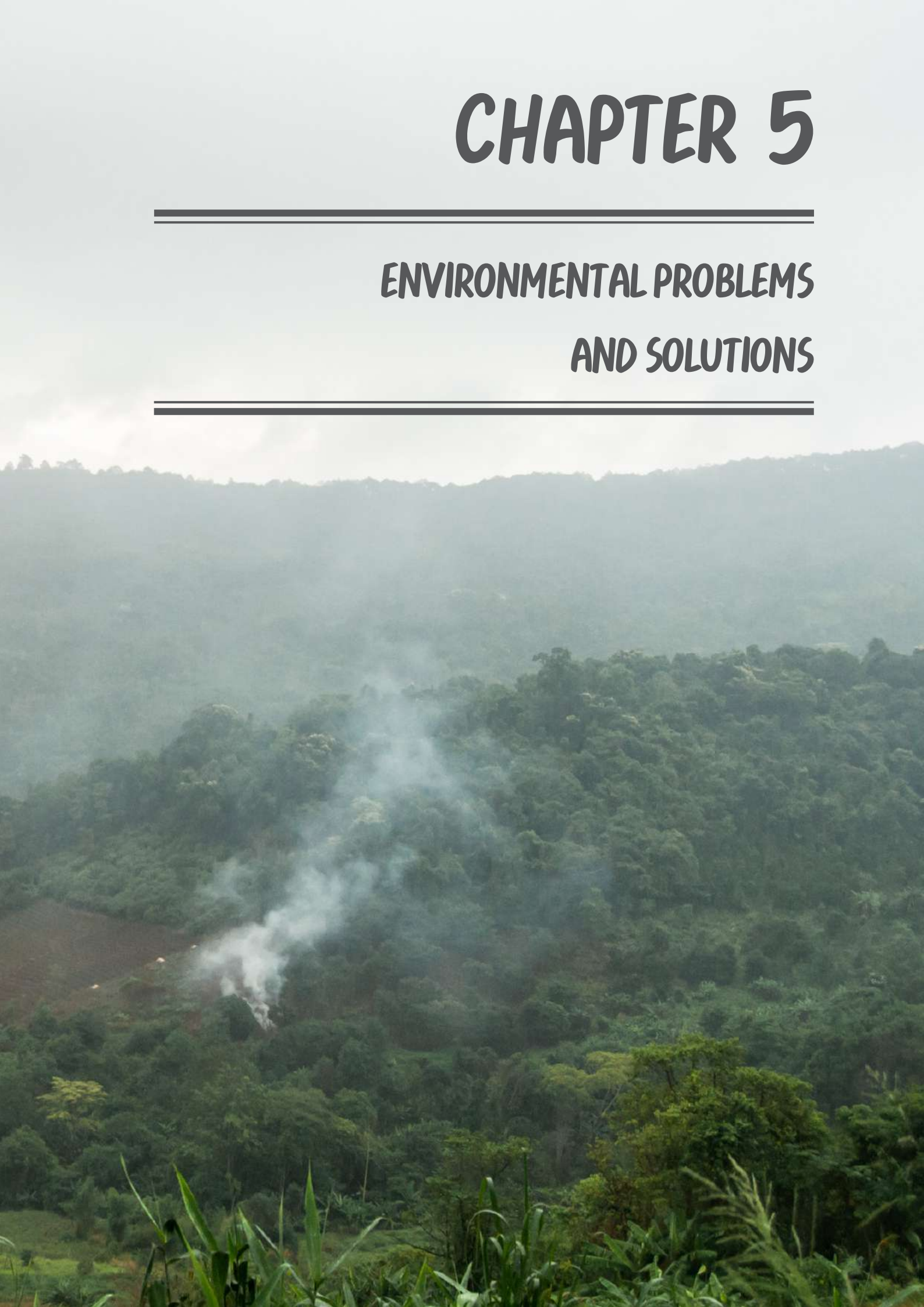
**Both Balanophora and Sapria grow in this area but are difficult to spot - so offer extra credit for spotting one*

THIS LESSON DESCRIBES LOCAL ENVIRONMENTAL PROBLEMS SUCH AS GARBAGE, WASTEWATER, WILDFIRE AND AIR POLLUTION IN BOTH URBAN AND RURAL COMMUNITIES. THE AIM IS TO INCREASE AWARENESS OF SUCH PROBLEMS AMONGST STUDENTS AND TO EMPOWER THEM TO CONTRIBUTE TOWARDS THEIR SOLUTION



CHAPTER 5

ENVIRONMENTAL PROBLEMS AND SOLUTIONS



GARBAGE

One of Chiang Mai's longest running environmental problems is solid waste disposal. Accumulated waste can be found at various points around the city and there are many illegal dumps by roadsides throughout the province. The problem has grown as Chiang Mai's human population has grown and the accessible landfill sites have been used up. Financial and political problems have contributed to mis-management of waste collection, handling and disposal resulting in environmental pollution.

GARBAGE SITUATION IN CHIANG MAI

In 2016, Chiang Mai Province generated 605,351.2 tons of waste per year, up from 522,846 tons per year in 2013. This increase was partly due to an increase in the number of households in Chiang Mai (now about of 768,855), resulting in an average of 1,658.5 tons of solid waste produced per day—that's about 2.2 kg per household per day (Pollution Control Department, 2016). Although it's easy to blame politicians for mismanagement of wast disposal, solving the waste problem must start with changing human behaviour at the household level, such as encouraging waste separation and recycling.

Garbage dump in the middle of the forest.

Source: http://www.thairath.co.th/content/297009

A large dumping pit hidden in the middle of a mountain in Mae Ram, Chiang Mai Province. More than 10,000 tons of waste on an area of 27 rai. Wastewater also seeps into the water source, making it unusable for consumption and affects the water resources of the community.

CASE STUDY

Garbage problem on Doi Suthep

It is traditional to walk up the mountain on Visakha Bucha day each year, to pay respects to Phra That Doi Suthep at night. Unfortunately the event usually leaves a trail of trash to clean up afterwards.

Leaving trash in the forest not only creates eyesores, it also affects wildlife including some rare or endangered species. Animals can die from eating plastic and toxic waste and it can cause behavioural changes in animals as well.

In the morning after Visakha Bucha, there is often a lot of trash left on both sides of the road, including foam, plastic bottles, cans and food scraps. Although garbage bags are placed along the way, there are still many people who throw garbage on the ground. The solution is to organize volunteers to help clean up, although everyone should be conscious of their impact and throw garbage into the bins provided or take it home with them.

The first step in addressing any environmental problem is to recognize the problem and acknowledge the consequences of individuals' behaviour. Only then can collective actions be harnessed to create solutions.

SOLID WASTE PROBLEMS

Human activities create many different kinds of solid waste. Some decompose rapidly, such as food waste, and can be turned into compost. Others are persistent, such as plastics and metals, which can be recycled. And some can be hazardous, such as old batteries, which must be buried in a safe place. Residential, industrial and agricultural areas all produce different types of waste.

DRY GARBAGE : DIFFICULT TO DECOMPOSE, REUSABLE
(PAPER, PLASTIC, GLASS, METAL)

WET GARBAGE : BIODEGRADABLE , MAKE BIO-FERTILIZER
(FRUIT PEELS, FOOD SCRAPS)

Different types of municipal solid waste can be separated according to the colour of waste bins, as follows, so that each waste type is dealt with in the appropriate way.

Organic waste is biodegradable waste from food discarded by humans. It makes up about 64% of all solid waste generated and has the largest volume of all solid waste. Green bins are for rotten and decomposing organic waste.

Recycling waste is solid waste from waste materials that can be reused. This is the easiest to manage and accounts for 30% of all solid waste generated. Yellow bins are for waste that can be recycled or resold.

General waste is solid waste that accounts for 3% of all solid waste generated and is difficult to decompose without emitting toxins into the environment. Blue bins are for hard-to-decompose waste.

Hazardous waste contains hazardous substances or contaminants that cause toxic harm to living things and the environment. It accounts for 3% of all solid waste generated. Red bins are for hazardous waste that often decomposes slowly and accumulates, causing pollution.

SOLID WASTE MANAGEMENT GUIDELINES

Effective solid waste management starts with reducing, sorting, collecting, disposing and reusing materials to minimize waste. The guidelines are as follows:

Reducing garbage production: Choose products that have minimal packaging and emission-free products. Reduce the use of hard-to-dispose of materials to reduce the amount of solid waste and toxins that go into their destruction processes.

Garbage sorting : Separate waste by arranging bins that are clearly classified as organic waste, recyclable waste, general wast and hazardous waste. Waste separation efforts at the source enable systematic waste management.

Garbage collection : Organize a collection service system by the local government organization. Set up collection points to support each type of waste at different points and develop transportation to transfer waste properly.

Garbage Disposal : Develop a waste-disposal system that helps preserve the environment. Disposal systems such as land-filling, or incineration should be selected by involving all stakeholders in discussions.

Recycling system arrangement : If the area has a large amount of daily solid waste, a solid waste sorting and recycling centre may be established.

Solid waste management			
Organic waste	**Recycle waste**	**General waste**	**Hazardous waste**
- The decomposition of organic matter relies on availability of water, air, and minerals suitable for the growth of micro-organisms. - Dispose in a landfill but sort materials for impact before going to the landfill. - Use leftover garbage such as food scraps to feed the animals. -Generate bio-gas from the landfill as saleable by-product	-Sort, clean and sell as raw materials - Or explore ways to convert such materials into new value-added products to preserve stocks of non-renewable natural resources and save energy.	- Convert to alternative fuels for primary energy such as thermal energy or bio-gas in industry. - Some types of solid waste that are still useful can be recycled or modified to add value to the products.	- Treat and dispose in ways that prevent chemical contamination of water sources. Incineration in a kiln must be at proper temperature for the most complete sintering, but there must be measures to control air pollution from the furnace. - Some can be recycled but processes to do so can be complicated and costly

Waste management at Montathan Waterfall, Doi Suthep-Pui

THE IMPACT OF SOLID WASTE ON HUMANS AND THE ENVIRONMENT

Air pollution

Waste disposal by incineration creates smoke containing small particulate matter and some toxic gases which are a health hazard.

Toxic contamination of the water sources

Contamination of water by heavy metals, usually from industrial waste is a major health concern. Water seeping through landfills can also contaminate water and change aquatic ecosystems, leading to proliferation of toxic algae. To prevent this, landfills must be lined with an impervious material.

Insect breeding sites and pathogens

Organic waste is a breeding ground for flies and a habitat for disease-carrying animals such as rats and cockroaches.

Disease from garbage

Solid waste, not properly disposed of, can be a source of germs and toxins that can contaminate agricultural land, water sources or even spread in the air. Burning trash, without proper incineration, can also cause gastrointestinal diseases, allergies and cancer.

Garbage, mostly plastic waste, collected from the streets of Chiang Mai

WASTE MANAGEMENT

The purpose of this activity is to raise awareness amongst students of the rates at which different waste materials decompose naturally and to start to explore how to reduce waste at the household level and in school.

Objectives

1. To raise awareness of the problems of waste and how to manage its disposal.
2. To learn how to separate waste materials according to their decomposition period.

Operating time 1 hour

Media and equipment

Equipment	Amount for 1 student
Waste decomposition table	1 sheet

Event guidelines

1. Ask students how waste is generated. For example, if you buy a single product, how many pieces of waste does it have? What does it take to make the product?

2. Use the waste decomposition table to calculate the number of decomposable and non-decomposable materials the students have used and see how long it takes to decompose. When disposing of this garbage, what colour container would they select?

3. Run a discussion session about what other steps can be taken at home and around the school to further reduce and manage wast disposal.

Garbage type	Duration
Vegetable	5 days – 1 month
Cotton clothes	5 days – 1 month
Orange peel	6 months
Plastic coated milk carton	5 years
Food packaging metal can	50-100 years
Plastic	450 years
Paper	2-5 months
Leaf	3 months
Leather shoes	25-40 years
Beverage cans (aluminium)	80-100 years
Foam box	1000 years - does not decompose
Wood	13 years
Plastic bottle	450 years
Wool	1 year
Coated paper cup	5 years
Metal can	100 years
Jute rope	3-14 months

Source: Discipline Building Manual towards sustainable waste management

DROUGHTS, FLOODS, AND WASTEWATER

Chiang Mai Province is located in the Ping River catchment area. Our water originates from natural water sources from the mountains, mostly from Chiang Dao district. The water demand in rural areas averages about 100 litres/person/day, whilst in the cities it is higher— averaging 120-300 litres/person/day. In addition to household there is also higher demand for water for agriculture and industry and various tourism related facilities (hotels etc.). Lastly, we must leave water in the rivers for downstream use.

Ping River at Chiang Dao District

In Chiang Mai City it is rare, these days, for taps to run dry even in the dry season, although water pressure does drop to very low levels in some places. In addition, many properties have wells, which help when the public supply runs low. However, maintaining a constant supply of clean water is a challenge as the population grows, along with sources of pollution.

Municipality's wastewater

https://www.chiangmaicitylife.com/citynews/local/more-water-released-to-mitigate-drought-problems/

DROUGHTS

Droughts are caused by low rainfall, leading to low water levels in reservoirs and subsequently water shortages for consumption and agriculture. Causes include:

Drought casues shortages of both water and food

- Summer season being longer than usual.
- Irregularity of monsoons, causing intermittent rain.
- Irregularity of sub-tropical cyclones moving through northern Thailand.
- Global climate change.

The immediate effects of drought include low water pressure in the taps and sometimes a cut in water supply altogether or water rationing. During droughts, reduce watering of gardens, and save water for domestic use. During the rainy season, harvest rainwater from rooves and store in large containers outside, to be used for washing (not drinking) during droughts. Long droughts can affect agriculture and food supplies, as farmers are instructed by the government to reduce the number of crop rotations. This is indicated by a rise in food prices. Droughts are more likely and more severe during a dry season following an El Niño event (see Chapter 1).

FLOODS

Floods are mostly caused by prolonged heavy and continuous rain. They usually occur when low pressure systems linger over northern Thailand, tropical cyclones come in from the east or, more rarely when a dam collapses. There are three types of flood:

Flash floods : are common around Chiang Mai especially near waterfalls. They can be caused by a single rainstorm in steep areas, leading to instantly rising streams in narrow valleys. Since waterfalls are tourist hot spots, flash floods frequently kill. If you are ever near a waterfall and the water starts to rise, move to higher ground immediately.

Groundwater flooding: occurs when ground water levels rise to the surface, caused by prolonged periods of rainfall, usually towards the end of the rainy season. Such floods can last for weeks or months.

River flooding: is when a river bursts its banks and floods the areas around it, caused by heavy rain upstream. Such floods are worsened by river blockages, such as fallen trees or garbage. Land owners near rivers are therefore obliged to make sure that they do not block river flow.

The Big Flood of 2005 in Chiang Mai

Massive floods in Chiang Mai in 2005 were caused by a low pressure system settling over northern Thailand in August

- Aug 13th, heavy rain and flooding, especially in Mae Taeng District. The flood reached house roofs and submerged buildings.
- Aug 14th, swollen tributaries flowing into the Mae Ping caused the river to burst its banks.
- Aug 15th, flooding gradually decreased, but many areas were still under water, including many submerged vehicles.
- Aug 16th, water levels dropped considerably, leaving behind large amounts of mud and debris.

Case study

WASTEWATER

Wastewater is water that has been contaminated with sewage and toxic substances resulting in poor water quality. This includes the dumping of solid waste into natural water bodies. Organic matter can also cause sewage and a reservoir of pathogens, especially in densely populated communities and industrial areas.

Wastewater origins

- Household sewerage from bathrooms and toilets
- Agricultural waste, released from livestock production or runoff from agricultural fields contaminated with fertilizers and pesticides
- Industrial waste from factories and power stations from washing materials and equipment

Wastewater treatment

Wastewater treatment removes contaminants from water before consumption. There are 4 main steps:

1. Preliminary treatment

Large items (like twigs or grit), are screened out. The screens are cleaned mechanically, and the material buried. A comminutor may be used to grind and shred debris that passes through the screens. The shredded material is removed later by sedimentation or flotation.

2. Primary treatment

Suspended solids that pass through screens are removed in sedimentation tanks (primary clarifiers) over two hours. The settled solids—known as raw sludge—are moved along the tank bottom by mechanical scrapers into a digester for biological treatments. Surface-skimmers remove grease and other floating materials.

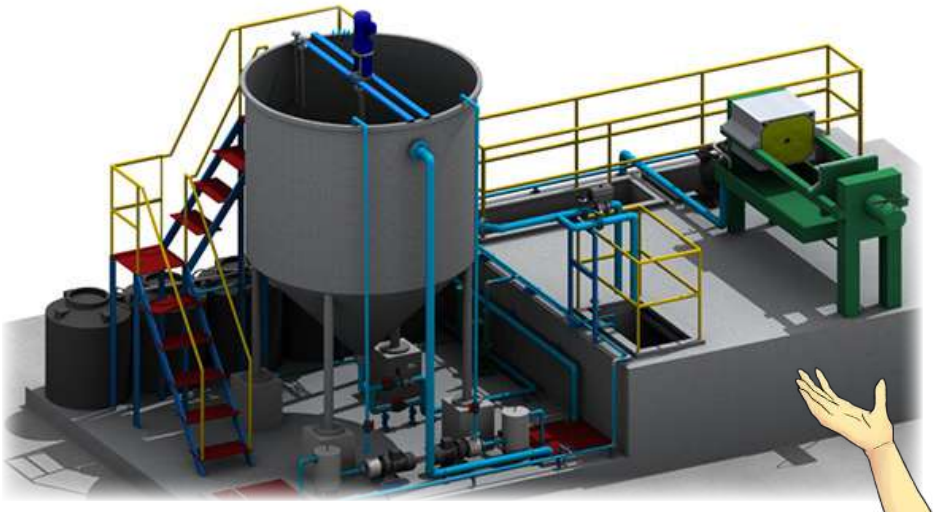
3. Secondary treatment

This involves oxidation, to remove remaining contaminants in 3 steps: i) **bio-filtration** uses sand filters, contact filters, or trickling filters, to remove remaining sediment, ii) **aeration** involves adding waste-consuming micro-organisms and aerating the mixture for up to 30 hours in a digester, whilst iii) **oxidation ponds** allow waste water to flow very slowly through water bodies, including natural wetlands, over several weeks. This allows natural chemical and biological processes to decontaminate the water. Oxidation ponds work particularly well in tropical climates.

4. Tertiary treatments

Finally, activated carbon and sand filters are used to remove dissolved phosphates, nitrates, heavy metals and pathogens from the water.

After stage 4, the water can be safely released into a natural water body. Not all these treatments are applied to waste water from Chiang Mai City. Can you find out how many are? The more you know about the process, the more ideas you may have about how to make a positive change.



Example of Wastewater treatment structure

www.crowntech-engineering.com/en/new/index.php/tw/company-performance/155-waste-water-treatment-project

CASE STUDY

Wastewater in the Mae Kha canal

The Mae Kha Canal used to be one of Chiang Mai's most important waterways—influencing King Mengrai's decision to build the city (see Chapter 2). It flushed waste from the city into a swamp near the northeast corner, which acted as a natural oxidation pond, before releasing clean water into the Mae Ping. It was also a transportation route, a source of fish and a source of irrigation water for agriculture. The canal absorbed flood waters from the Mae Ping, before they could inundate the city.

Over many years, road construction and unplanned buildings have gradually covered or narrowed the canal. Many businesses and homes empty untreated sewerage directly into it or clog it with garbage. Although filters have been provided, they are rarely used and maintained properly. In dry months, *all* water in the canal is untreated waste water; as no fresh water flows down from the mountains!

Although community efforts to clean the canal have increased, progress has been hindered by lack of co-ordinated management, until recently, when the Mae Kha Canal Master Plan 2018-2022 came into effect. For the first time, all stakeholders are involved in cleaning the canal, with a steering committee overseeing the plan's implementation, and several funding sources.

"Ten years ago, the Mae Kha Canal was dead. Today there are fish and a thriving ecology. With time and work, we can revive the canal and make it a vital contribution to the well-being of our city."
Wasan Jompakdee of the Department of Mechanical Engineering, Chiang Mai University, 2020.

The problem of garbage blocking the Mae Kha canal, making floods more likely to occur

Picture from http://www.chiangmainews.co.th/page/archives/563865

FOREST FIRES

Forest fires are fires that spread freely and uncontrollably in forest areas. They are frequently started by humans and rarely by lightening. The elements needed to sustain forest fires are heat, oxygen and fuel. This is known as the fire triangle. There are 3 types of forest fire according to the fuel being burned.

Ground fires	Surface fires	Crown fires
Burning of peat or coal underground. Such fires spread slowly, with few visible flames and little smoke. They are difficult to extinguish, but are exceedingly rare in northern Thailand, since there are no extensive peat-lands here.	Burning of leaf litter, grasses and other ground vegetation. Such fires start slowly but can spread fast. They are easy to extinguish with hand tools in the early stages, and are the most common type of forest fire around Chiang Mai .	Fires that leap up into tree crowns are very damaging. As trees burn, flying cinders start new fire spots elsewhere. They are extinguished by helicopters dropping water. Such fires occur around Chiang Mai every few years.

CAUSES OF FOREST FIRES

The fire season around Chiang Mai runs from late January until the first rains fall in April or May. Rarely (during El Niño years) it extends into June. Trees in deciduous forests drop their leaves and grasses die back, providing ample fuel for fires. Dry conditions, high temperatures and strong winds create ideal conditions for the spread of fires. But to start, fires need an ignition source. Most fires are started by humans for various purposes: to clear weeds from fields, to flush out game for hunting and to reveal mushrooms for collecting and selling. Some fires are started by lightning strikes, but thunder storms also come with rain, which prevents lightning fires from spreading.

Examples of human causes of forest fires around Chiang Mai

Astraeus hygrometricus is a fungus, which lives on tree roots, helping trees to absorb nutrients. Its star-like mushrooms emerge above the soil but are hidden beneath vegetation. They are good to eat and fetch a high price. So, collectors burn off the vegetation to make them easier to see, even though the fires actually kill the underground mycelium of the fungus! Such fires also spread, damaging the forest and polluting the air with smoke.

Astraeus hygrometricus

EFFECTS OF FIRE ON FORESTS

Fire destroys undergrowth, halting forest regeneration

Repeated fires kill tree seeds in the soil and seedlings, effectively preventing forest regeneration. As the old trees die, too few young trees survive to replace them. The forest thins out and gradually becomes a grassland. To survive a ground fire, trees must grow taller than 1.5 m and have bark thicker than 6 mm, which takes 3-4 years (without fire) to attain. Fire reduces soil fungi, responsible for organic matter decomposition for up to a year after burning. This prevents incorporation of organic matter into top soil and the release and cycling of inorganic nutrients for plant growth. Fire also burns off soil organic matter, which reduces soil moisture-holding capacity and further reduces plant nutrient availability. Calcium, potassium and magnesium are lost as fine particles, whilst nitrogen, phosphorus and sulphur are lost as gases.

Fire kills wildlife

Fire fuses clays, making clay-rich soils more compact and less permeable to water and oxygen. This also reduces plant growth. By destroying the vegetation, fires increase soil erosion up to 3-32 times. They also kill off ground-nesting birds and other wild animals that are unable to flee, although a few survive by burrowing. Fires also destroy food resources and habitat for wildlife.

EFFECTS OF FOREST FIRES ON HUMANS

Although few people are killed directly by forest fires, the smoke pollution they create is a major health hazard. Every fire season, tens of thousand of people in northern Thailand suffer from acute respiratory illnesses such as asthma, bronchitis etc. whilst some go on to contract life-threatening diseases such as lung cancer. So, forest fires are a major public health issue.

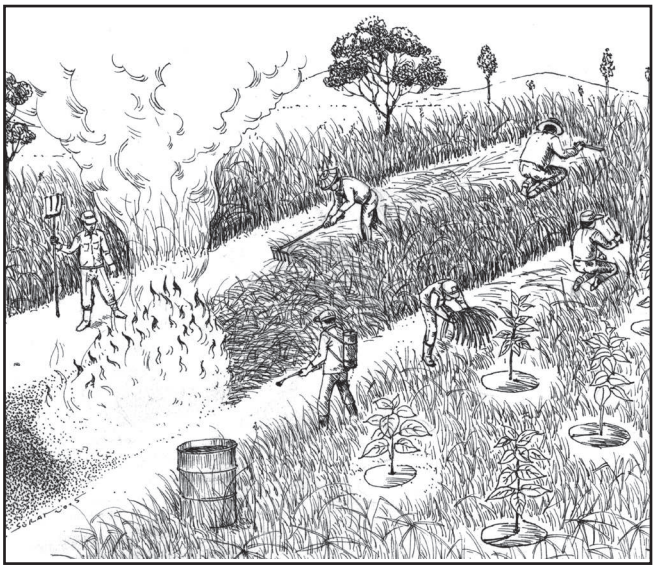
Smoke pollution is Chiang Mai's number one public health issue

Furthermore, fires can worsen rural poverty, since burning reduces forest productivity and the variety of forest products that can be collected to support rural livelihoods. Bamboo shoots, mushrooms, medicinal plants, fodder for cattle etc.— all are lost when forest fires burn extensively. Rural folk may also be further impoverished if they have to pay medical bills, to deal with smoke-related health issues.

WHAT CAN BE DONE ABOUT IT?

Educating communities about the impacts of forest fires on ecosystems, on health and on the economy is necessary before a well-co-ordinated collective response can be organized. But once all stakeholders are on board, here are a few actions to consider:

- Do not incinerate waste and leaf litter in agricultural areas or near forests in the dry season. Compost the materials or burn them well before the dry season.
- Learn how to spot and extinguish small fires safely at the Forest Fire Control Centre (behind Wat Umong 053 329393).
- Join volunteer fire look-out teams. They spot fires, inform authorities and call for assistance with fire suppression.
- Help to cut fire-breaks—strips of land cleared of fire fuel which stop fires spreading.



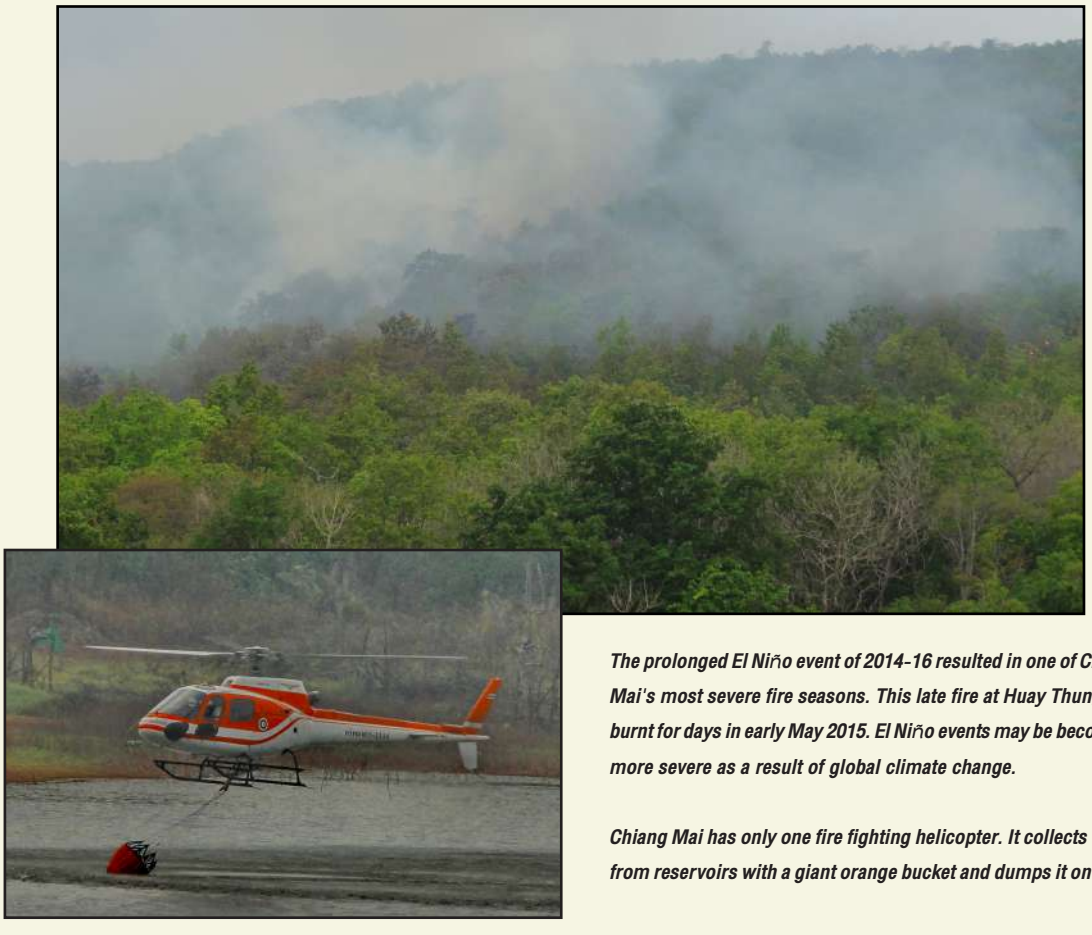
Using fire to prevent fire — in mid-January, cut two lines of vegetation about 8 m apart. Pile the cut vegetation into the centre and burn it. Have fire fighters standing by to prevent the fire escaping. This creates a wide strip with no fire fuel, so it limits the spread of fires and makes them easier to tackle.

CASE STUDY

Laws or Nature - what really determines the severity of the smoky season?

Over the last 10 years, smoke pollution in Chiang Mai has become a lot worse, due to various factors: global climate change, increasing human population and increasing areas under agriculture. In response to growing public concern, the Chiang Mai local government now implements an annual **burning ban** for 60 days from February to April. Farmers are forbidden to burn fields to clear weeds and crop residues. Garbage burning and even home barbecues are also banned. Penalties are severe. Violators can be imprisoned for up to 4 years and/or fined up to 4,000 bath.

Whilst such regulatory measures help, it seems that the weather overwhelmingly determines how severe the smoky season is. El Niño events nearly always result in widespread forest fires and horrendous smoke pollution the subsequent dry season, whereas a La Niña in December results in unusual rainfall during the subsequent dry season, which prevents fires and smoke. The La Niña event of December 2021 resulted in heavy rain in February and March 2022 and the fewest fires and lowest smoke levels for decades.



The prolonged El Niño event of 2014-16 resulted in one of Chiang Mai's most severe fire seasons. This late fire at Huay Thung Tao burnt for days in early May 2015. El Niño events may be becoming more severe as a result of global climate change.

Chiang Mai has only one fire fighting helicopter. It collects water from reservoirs with a giant orange bucket and dumps it on fires.

TREE CARBON SEQUESTRATION

Global climate change is having a huge impact on both forests and humans. It is also creating ideal conditions for forest fires. It is caused by the accumulation of greenhouse gases (particularly carbon dioxide) in the atmosphere, which trap heat. As trees grow, they absorb CO_2, converting its carbon into wood and releasing its oxygen. But when trees burn, the carbon they contain is converted back into CO_2, which worsens the greenhouse effect. The purpose of this activity is to enable students to calculate the amount of carbon in trees, so they can appreciate how much is absorbed as they grow, and how much would be released if burnt.

Objective

1. To introduce students to the concept of trees as stores of carbon.

Operating time 1 hour

Media and equipment

Equipment	Amount for 1 group (5 students)
Measuring tapes (1.5 meters and 50 meters)	1 each
Notebook	1
Scientific calculator	1

Implementation

1. Review global climate change causes and consequences from Chapter 1 and how trees can be both a sink for CO2, as they grow and a source of it when they burn.

2. Divide students into small groups. Each group selects 5 trees on the school campus, ranging from small to big.

3. Students will first calculate tree dry biomass by measuring the tree's diameter at breast height (**DBH measured in cm**) and using an **allometric equation** which correlates DBH with tree dry mass. Allometric equations predict difficult-to-measure variables (tree biomass) from easy-to-measure ones (DBH). The equations below were derived by measuring the DBH of hundreds of trees, after which the trees were felled, dried and weighed and a graph was plotted of DBH vs. dry biomass. It helps if students have already covered **Euler's number, natural logarithms and exponents** in mathematics class before doing this activity.

Dry forest: Tree Dry Biomass (kg) = $2.71828^{[-1.996 + (2.32 \times \ln(DBH))]}$

Moist forest: Tree Dry Biomass (kg) = $2.71828^{[-2.134 + (2.53 \times \ln(DBH))]}$

Lowland schools use the dry-forest equation;
those above 1,000 m elevation use the moist-forest equation.

3. DBH is derived from **girth at breast height** (GBH). Students first measure from the ground, up the tree trunk 1.3 m (official breast height). Next, measure GBH (in cm) at that point, making sure that the tape measure is exactly horizontal and tight around the tree. Convert GBH to DBH assuming the tree trunk is circular in cross section as follows:

$$\text{DBH (cm)} = \frac{\text{GBH (cm)}}{\text{Pi}}$$

… where Pi is 3.14159.

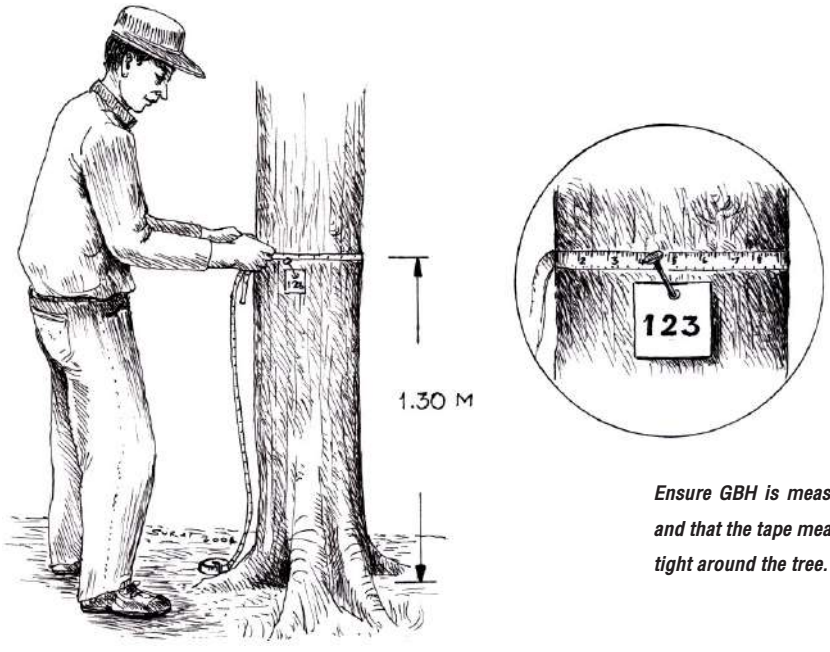
4. Substitute the DBH value into the appropriate allometric equation, to obtain an estimate of the dry biomass of the tree (kg).

5. The dry biomass of trees in northern Thailand is about 47% carbon. So to get the carbon content of a tree, simply multiply the result from the allometric equation by 0.47.

6. Ask the students to plot a graph of DBH vs. tree dry biomass (the data can be pooled from all groups). What are the limits of using allometric equations?

7. What assumptions have been used to measure tree carbon? How valid are they and how might the method be improved?

8. **Supplementary**: tag the trees with numbered metal labels (made from cutting up drinks cans) and repeat the activity a year later, to determine how much the trees have grown and how much additional carbon they have accumulated over 1-year's growth. Ask the students to calculate their carbon foot print (see page 137) and then calculate how many trees they would have to plant to offset their carbon footprint over a 20-year period.



Ensure GBH is measured exactly 1.3 m above ground and that the tape measure is exactly horizontal and held tight around the tree.

AIR POLLUTION

Air pollution in Chiang Mai is closely connected with forest fires, but they are not its *only* cause. Nitrogen oxides come from traffic fumes and attack the lungs, whilst sulphur dioxide comes from burning coal or lignite for power generation (e.g. Mae Moh Power Plant). It irritates eyes and mucous membranes and casues acid rain. But, of all the air pollutants, it is fine particulate matter in smoke, which has the most widespread effect on human health in Chiang Mai. Particles 2.5 microns in diameter or smaller clog the lungs and blood vessels causing bronchitis, strokes and heart attacks. Such pollution may also be responsible for Chiang Mai's unusually high rate of lung cancer.

PM: Particulate Matter

Airborne particulate matter ranges from 0.01 to 1000 microns in diameter, but most are smaller than 50 microns. Particles less than 10 microns in diameter are known as PM_{10}, whist particles smaller than 2.5 microns are $PM_{2.5}$. The smaller particles are most dangerous since they enter the blood stream straight from the lungs, causing inflammation of the heart and blood vessels. In the dry season, most comes from smoke, but other sources include vehicles, industry and even household products.

CAUSES OF AIR POLLUTION

Nature
- Weather variability
- Climate change

Human
- Forest fires
- Construction
- Weed incineration
- Solid waste incineration
- Use of fuel in production
- Vehicle fuel burning

Chiang Mai is particularly prone to air pollution, because of its location in a basin and frequent **inversions** in the dry season, when warmer air sits above cooler air (normally temperature *declines* with increasing altitude). This traps air pollution close to the ground, and reduces convection which would otherwise disperse the pollutants into the general atmosphere. So, pollutants accumulate in the stagnant air.

IMPACT OF AIR POLLUTION

Air pollution has long term effects on human health, which accumulate over years, according to length of exposure and concentration of pollutants. High risk groups include children, the elderly, pregnant women, and anyone with chronic cardio-vascular issues:

o Allergic reaction	o Inflammatory eye disease	o Heart disease	o Lung cancer
o Respiratory disease	o Dermatitis	o Stroke	o Asthma

CASE STUDY

Air pollution and Doi Suthep

Doi Suthep can be seen from most schools in Chiang Mai. The view of the mountain can be used as a rough indication of air pollution. Find a point, which provides the best view of the mountain. Set up a tripod and camera (or mobile phone) so that you can take a photo of *exactly* the same view many times, using the widest zoom setting. Take the photo at the same time each day. Use an air-quality meter to record the PM2.5 and PM10 levels. Examine the photos on a computer screen to determine the subjective pollution level number, using the table below. After recording the data for many days, you can determine the range of PM values for each pollution level. Then simply by looking at Doi Suthep, you can estimate the PM values and will know if you should wear a mask. You should wear a mask when PM2.5 levels exceed about 50. Plot a graph of date vs. PM readings and subjective pollution level, to understand how the values vary seasonally. Share your results on social media. If you cannot see Doi Suthep from your school, use another landmark and develop your own scale of pollution levels.

This is an example of pollution level 1 - can see forest canopy by not individual trees.

Looking from Doi Suthep towards Chiang Mai - the effectiveness of using photography to show seasonal changes in pollution levels is seen.

Subjective Pollution level	Level description	PM_{10} range	$PM_{2.5}$ range
0	Can see individual trees clearly		
1	Can see forest canopy clearly but not individual trees		
2	Can see forest canopy dimly with no details		
3	Can see mountain outline clearly but not the forest canopy		
4	Can see mountain outline dimly		
5	Cannot see mountain outline		

AIR QUALITY INDICATOR (AQI)

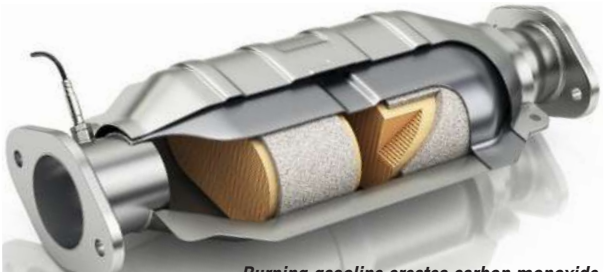
Air Quality Index combines levels of several different pollutants, to indicate the precautions to take to avoid the harmful effects of poor air quality. It includes carbon monoxide, nitrogen dioxide, ozone, sulphur dioxide, PM_{10} and $PM_{2.5}$. Most air-quality meters measure levels of both individual pollutants and the overall AQI.

AQI	Level	Color	Impact Prevention Guidelines
0-50	Good	Blue	No effect on health
51-100	Moderate	Green	Mild irritation. Asthma sufferers and those with allergies should wear a mask outdoors.
101-200	Less unhealthy	Yellow	Patients with respiratory diseases should limit exercising outdoors.
201-300	Unhealthy	Orange	Patients with respiratory diseases, children and the elderly should avoid outdoor activities.
>300	Very unhealthy	Red	Everyone should stay indoors and use and air filter.

Source: Pollution Control Department

WHAT CAN BE DONE?

1. Keep track of air quality with a meter and/or use a phone app such as AirVisual (www.iqair.com/commercial/air-quality-monitors/airvisual-platform/air-quality-app).
2. When $PM_{2.5}$ rises above 50 and/or AQI rises above 100, wear a face mask outside and start to use an air purifier at home.
3. Cut down on motorized transport. Use an electric car or a conventional car, fitted with a **catalytic converter** (an exhaust emission control device that converts toxic exhaust gases into less toxic pollutants by catalyzing a redox reaction).
4. Use a bicycle where possible (but not when air quality is poor).
5. Do not burn garden waste outside. Learn how to compost it instead.
6. Support local air-quality initiatives such as AirDeveloppa (airdeveloppa.co/).



Burning gasoline creates carbon monoxide, VOCs and nitrogen oxides forming smog. Catalytic converters transform them into less harmful substances. Whilst they don't eliminate pollution entirely, they can reduce it.

Protect Yourself from Air Pollution

When the AQI is in the orange or red zones ... wear a mask when you are outdoors. Buy a good quality mask. Regular surgical masks are not effective; $PM_{2.5}$ can pass right through them, because the particles are so very tiny. You should look for masks rated **N95**; they can filter out 95% of $PM_{2.5}$ particles. Look at the photos below to make sure you are wearing your mask correctly, covering both nose and mouth and adjust the nose band so that the mask fits snug against your face. When AQI is red, even with a mask, you should limit your exposure outside to 20 minutes or less per day. Stay indoors, seal doors and windows and run an air purifier. Make sure that it is powerful enough for the size of the room and change the filters at the start of each smoky season. Make sure that you have a good supply of medication for those with asthma, allergies or cardiovascular conditions. If symptoms occur, do not delay in contacting the nearest health care facility.

3M VFlex™ 9105

3M 8210

3M 9010

CARBON FOOTPRINT

The carbon footprint of an individual is the amount of greenhouse gases emitted by that person's economic activity over 1 year. Since different greenhouse gases warm the atmosphere by different amounts, the foot print is usually expressed as equivalent tons of CO_2 i.e., the mass of CO_2 that would have the same warming effect as all greenhouse gas emissions combined. For example 1 ton of methane has the same warming effect as 80 tons of CO_2. Knowing one's carbon footprint is the first step towards reducing it or offsetting it, e,g,, by planting trees.

Objectives

1. To teach students how to calculate their carbon footprints.
2. To discuss how to reduce or offset greenhouse gas emissions.

Operating time 1 hour

Media and equipment

Equipment	Amount for 1 group (5 students)
Internet access and energy bills	1 set

Implementation

1. Start by calculating the carbon footprint of the school. Prepare, by familiarizing yourself with online carbon-footprint calculators and copying the school's bills for energy, transport, food and drink, paper consumption etc. There are many calculators to choose from, each with pros and cons. Most do not account for methane and few allow calculations in Thai Baht. So, knowing the Thai Baht to US$ exchange rate in advance would be helpful. The best calculators are reviewed here: footprinthero.com/best-carbon-footprint-calculators . Select the one which you find easiest use and is in tune with the cost categories of your school.

2. Take the students through the calculator step by step, providing the figures for school energy consumption, paper use, meals produced etc. as they come up. Do not include travel to/from the school by students (because that can be included in the household footprint). Divide the final answer by the numbers of students + staff, to arrive at the footprint per head.

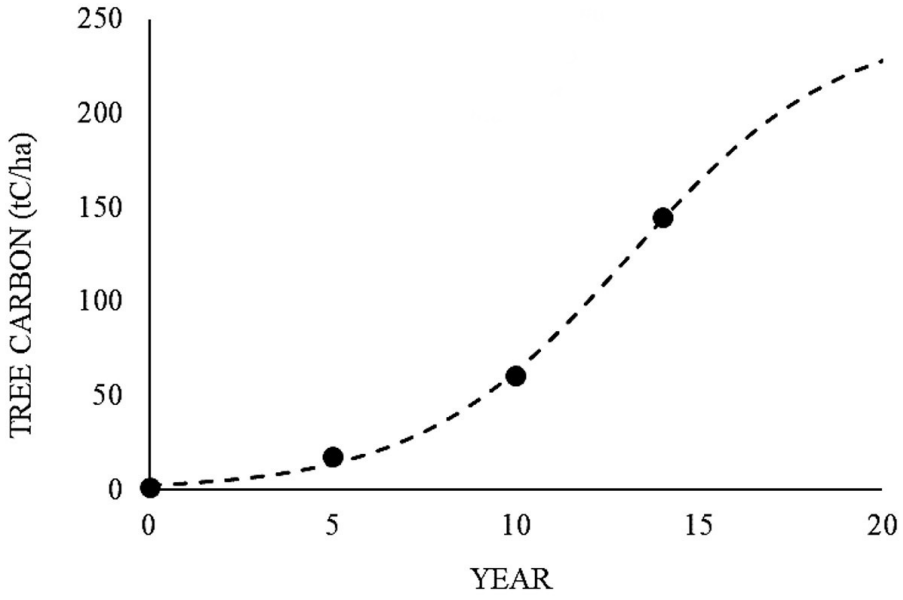
3. Once the students are familiar with the calculator, ask them to do the same calculation for their households, as homework, dividing the household footprint by the number of folk in the household to arrive at the student's individual home footprint. Since this process could be viewed as a privacy issue, it is best that students do this at home with their parents, rather than bringing household energy bills etc. into class. As the energy costs of education have already been calculated in school, the students should be instructed to ignore the section of the calculator dealing with education costs, when working at home. However, they should include the carbon emissions of travelling to/from school.

4. Back in the classroom, add the individual home footprint to the individual school footprint, to arrive at the overall individual footprint.

5. The average footprint per person in Thailand is 3.9 tons CO_2 per year. How do the individual footprints of the students compare? Also calculate the class average and compare with 3.9.

6. Finally, facilitate a discussion on how to i) reduce the carbon footprint of the school and the student's households and ii) how to offset remaining carbon emissions by such activities as tree planting or restoring coral reefs (as calcium carbonate). For example 1 hectare of restored forest accumulates 143 tC/ha in trees and 8.5 tC/ha in soil over 14 years (totally 151.5 tons of carbon). How many hectares would have to be planted, to offset the whole class' carbon emissions? Be aware that 1 ton of CO_2 contains only 12/44 (0.27) tons of carbon (the rest is oxygen), so don't forget to use this conversion factor when performing the calculation. Students should be encouraged to use the periodic table in chemistry class to confirm the ratio.

Tree planting is one way to offset carbon footprints but there's not enough land available to do this for long. Ultimately reducing carbon footprints to zero is the only long-term solution.



Accumulation of carbon in trees (tons carbon per hectare) over the first 20 years following forest restoration on a deforested site by the framework species method. To convert tons carbon to equivalent tons CO_2 multiply by 44/12. (www.forru.org/library/0000228)

This lesson focuses on problems affecting forests and wildlife, particularly deforestation and hunting, and how to address them. It aims to provide knowledge about the problems and solutions and increase awareness of conservation principles. It touches on legal mechanisms and explores how forest restoration can directly reverse deforestation.

CHAPTER 6

CONSERVING FORESTS AND WILDLIFE

DEFORESTATION

Tropical forests are home to more than half of Earth's terrestrial plant and animal species, so their destruction has a severe effect on biodiversity. The ultimate reason for deforestation is the growing human population, which increases the demand for timber as well as food and the agricultural land needed to produce it.

FOREST SITUATION

The National Economic and Social Development Plan was first published in 1961, to protect forests as national treasures. At that time, forests covered around 27 million ha, or 53 % of the country. Initially, the greatest cause of deforestation was logging for timber, first by foreign countries at the end of the 19th century, and then by Thai companies. However in 1988, flash floods and landslides coming from logging concessions in southern Thailand killed hundreds of people. There was a public outcry against logging, and in January 1989 the government banned logging in natural forests—a ban which remains in force today. Thailand currently retains 7 million ha of its original forests (covering 14% of the country).

Forest Concessions

In 1855, Siam signed a trade agreement with Britain, called the Bowring Treaty. This opened the way for British timber companies to exploit the northern forests. Areas where the companies were allowed to log were called concessions. The companies paid the government tax on each log exported. Teak was the target, due to the colour and durability of its wood, and the ease with which it could be carved. It was used for furniture, flooring and ships. Since Britain had destroyed its own forests, centuries earlier, it had no domestic timber supply, so demand for teak was high. Therefore, teak logging was highly profitable. French and Dutch companies were also granted concessions in the 1890's and, as the logging accelerated, the forests were rapidly destroyed. To address the problem, the government created a Forest Department, and appointed an Englishman, Herbert Slade, as its first director and asked him to devise a sustainable forestry plan. Foreign concessions ended in 1945, but Thai companies continued destroying the forests even more rapidly. Forest destruction peaked at 6% per year in the 1970's. With growing public opposition to the industry, the logging ban in 1989 finally ended it. Teak forests are now regenerating in several places.

In the past, elephants were used to transport logs

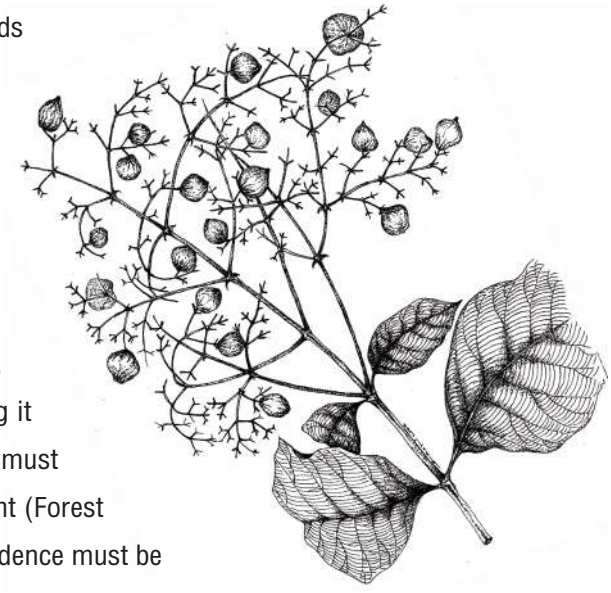
Despite the ravages of the logging industry, northern Thailand still retains higher per cent forest cover compared with Thailand's other regions. Chiang Mai is in the top 5 Provinces with respect to forest cover.

Thailand's Northern Provinces Ranked in Descending Order of Per Cent Forest Cover

Province	Area (km^2)	Percentage
Chiang Mai	15,337.97	27.98
Tak	12,448.78	22.71
Mae Hong Son	10,872.29	19.83
Lampang	8,739.04	15.94
Nan	7,425.20	13.54

Source : Royal Thai Forest Department

Tectona grandis (Teak) is perhaps Thailand' s most famous tree species. Easily recognized by its sandy brown bark, with shallow, longitudinal fissures, and a crown of large leaves, this deciduous tree once dominated much of northern Thailand's lowland forests - but the logging industry ended that, converting teak forests into bamboo-deciduous forests (BB-DF). Today, large natural teak trees are a very rare sight, except in a few national parks such as Mae Wong and Mae Yom. Teak has remarkable powers of natural regeneration and, where even just a few mature teak trees remain, teak seedlings readily establish, especially on moister sites. Teak can be planted to rehabilitate BB-DF. It may also be planted, where a forest with high future economic value is desirable, but mono-species teak plantations are of little ecological value. Since this species is valuable, many tree nurseries grow it, but selective breeding has begun to domesticate the species. So, if you want to obtain seedlings from nurseries make sure they have been grown from local, wild seed sources. Alternatively, collect seeds from beneath local forest trees that are older than 20 years (not plantations). Air dry the fruits for 2-3 days and remove the thin, inflated calyx. Soak fruits over night; then sun-dry them by day. Repeat this cycle for 1-2 weeks. Sow seeds sparsely in germination trays in full sunlight, making sure that fully germinated seedlings do not shade germinating seeds. Germination starts after 10 days and continues for about 90 days. Total germination per cent usually exceeds 50%. Grow-on seedlings in containers in light shade. Saplings are usually ready for planting within a year after seed collection. Legally, teak is a restricted A-type wood, which means logging it is prohibited. If you want to cut down a teak tree, you must get permission from the Royal Thai Forest Department (Forest Act, B.E. 2484). Even if a teak tree falls on a house, evidence must be presented before removing it.



CASE STUDY

Doi Suthep-Pui National Park

The teak trees on Doi Suthep were probably removed in ancient times to construct and maintain Chiang Mai city. Being so close to the city, the mountain's forest have been under constant threat for centuries, to provide timber and land for agriculture, and more recently from urban sprawl. However, the mountain's sacred status and its role as the city's main water source, probably protected it from complete deforestation. Today, the main threat is conversion of forest to tourist attractions—the night Safari, Rajapruek Flora, various resorts etc. and encroachment mainly by government agencies. Thirty-four lay claim to about 10 km^2 of the park (TV transmitters, agricultural research stations, police and army posts, law courts and Chiang Mai University etc.).

In 1964, a survey recorded 369 people living in the park area. By 1988, that number had swelled to 13,694. The park's rapidly increasing human population, coupled with the growth of Chiang Mai, as a market for agricultural products, led to widespread agricultural encroachment, with about 44 % of the park being cleared for crops. However, a campaign to restore forest in the park in the early 1990's, helped to restore some of the balance. These days, fire is also a serious threat to Doi Suthep's forests. The fires of 2015-16 burnt huge areas. Although burnt forest can slowly regenerate naturally, the park authority joined with several local community groups to plant trees and speed up the process.

Deforestation can be reversed—these two shots of Ban Hmong Doi Pui, taken from the view point above the village, show the effects of a forest restoration program in the 1990's—the "Plook Pah Chalerm Prakit" project, to honour King Rama 9, on the occasion of his golden jubilee. Villagers all over the park joined with park officers to plant native forest trees. In 1990, forest cover on the slopes behind the village was vary patchy, due to clearance for opium poppy cultivation decades previously. By 2015, trees planted in 1992 had restored complete forest cover, even though the population of the village had grown. The key factor was that the livelihoods of the villagers had changed from being mainly based on agriculture to being mainly based on tourism. The villagers no longer needed to clear forest to earn a living.

Small-scale tree chopping still goes on though ...

Forest resources and regulations

Sometimes the needs of individuals conflict with the needs of society as a whole. For example, clearing forest to grow crops may provide livelihoods for individual families, but it might also worsen floods and climate change, which affects everyone. Laws, passed by a democratic government, supported by the majority of people in a country, are the main legal tool, used to address such issues. In Thailand, several laws to protect forests impinge on the rights of individuals for the greater public good. Rural families, whose livelihoods may depend on forest clearance, are greatly affected by forest-protection laws, whereas city dwellers benefit from them. So forest-protection laws must be accompanied by measures to compensate those most adversely affected by them, through no fault of their own. Otherwise, such laws will inevitably be broken. Note the overlap in the laws below.

Section 16 of the National Park Act, prohibits land seizure or possession which includes constructing, clearing, burning, collecting and taking over the forest, destroying or degrading natural resources, or capturing animals. It also includes altering waterways, or causing water in streams, creeks, or swamps to overflow or dry up. Violators face a maximum sentence of five years in prison or a fine not exceeding 20,000 baht, or both.

Section 54 of the Forest Act, prohibits anybody from constructing, removing, or burning a forest in any form, unless it is done within the area that has been categorized as agriculture, as published by the Ministry of the Environment in the Government Gazette. This includes the destruction or taking over of the forest or the occupation of forest for oneself or others. People may obtain a license from a competent official, but violators face a maximum sentence of five years in prison or a fine of 50,000 baht, or both.

Section 14 of the National Reserved Forests Act : no one shall own, possess, use, live on the land, construct, clear, burn or collect forest products in any way that destroys National Reserved Forests or degrades their natural condition. Violators face six-months to five-years in prison and a fine ranging from 5,000 to 50,000 baht, or both.

Section 38 of the Wildlife Preservation and Protection Act: no one shall own or occupy the land, plant, or build anything, cut down, clear, burn, or destroy any trees or other flora, dig for minerals, soil, stones, raise or release animals, alter waterways, cause the water in streams, creeks or swamps to overflow, decline or become toxic or dangerous to wildlife. Violators face a sentence of up to seven years in prison, or a fine of not more than 100,000 baht, or both.

FOREST RESTORATION GETTING STARTED

Forest Restoration Enhances Natural Forest Regeneration

The Doi Suthep Case Study illustrates that forest ecosystems ***can*** be restored. Natural forest regeneration is a slow process, but it can be accelerated by tree planting and other measures. This is called **forest restoration**. It requires understanding of the natural mechanisms of forest recovery and knowing when and how to intervene to enhance them.

What is the difference between reforestation and forest restoration?

Reforestation means putting back *any* kind of tree cover, on deforested sites. There are many kinds including: agroforestry, community forestry and forest plantations, where just one economic tree species is planted (e.g., rubber, eucalyptus etc.)—such plantations are called **mono-cultures** and are of little ecological value. Forest restoration is the re-establishment of forest ecosystems, as similar as possible to the original forest type. It is therefore a specialized form of reforestation. The technical definition is:

> ***"Directing and accelerating forest regeneration towards a target forest type of the maximum biomass, structural complexity, biodiversity and ecological functioning that can be self-sustained within prevailing climatic and soil limitations."***

Does the type of forest affect the way it is restored?

The target forest type is exemplified by the nearest intact forest to the restoration site at the same elevation. Getting to know the target forest type is essential, to start planning forest restoration. First, identify tree species there. Label the largest ones and record their GPS, because you will want to relocate them later to collect seeds for growing trees. Next, consider the forest features that may affect the restoration strategy. For example, restoring evergreen forest requires planting more species than deciduous forests. Bamboos inhibit tree growth, so you need to control them on the restoration site.

Which areas should be restored first?

Since evergreen forests above 1,000 m elevation are the most biodiverse, prioritizing them for restoration maximizes the conservation value of the activity. However, mixed evergreen-deciduous forests are also diverse and are much rarer than all other forest types in northern Thailand. They are also highly threatened by development, so restoring them also has great conservation value. Ultimately though, selecting restoration sites is a compromise between maximizing ecological benefits and ease of access.

Restoring Forests Without Planting Trees

Where the density of natural regenerants (any trees taller than 50 cm and live tree stumps) exceeds 3,000 per hectare, there's no need to plants trees. Simply weeding around the regenerants and applying fertilizer to accelerate their growth, preventing fires and excluding cattle will achieve canopy closure in about 3 years. This is called **assisted natural regeneration or ANR**.

Thinking before planting - Forest degradation and forest restoration methods

START

Forest canopy cover sufficient to shade out weeds

YES → Natural regenerants more than 3000 trees per hectare

NO → Viable soil seed bank remains and plenty of seed dispersing animals survive

NO → Signs of forest fires evident and tree cover sparse

YES → Seed dispersing animals remain common

NO → Soil quality remains high

YES → Remnant forest nearby

YES → Seed dispersing animals remain common

YES → Weeds inhibit natural regenerants

YES → **PROTECTION AND PREVENT ENCROACHMENT**

NO → **MAXIMUM DIVERSITY METHOD (MDM)**

NO → **NURSE TREE PLANTATIONS TO IMPROVE SOIL OF FIGS AND LEGUME TREES, FOLLOWED BY "FSM" OR "MDM" METHODS**

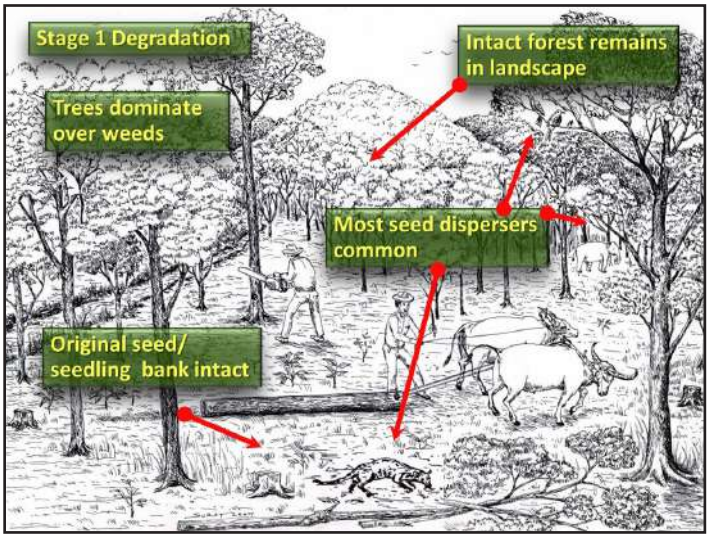
YES → **FRAMEWORK SPECIES METHOD (FSM)**

YES → **"PROTECTION + ANR (ACCELERATED NATURAL REGENERATION)**

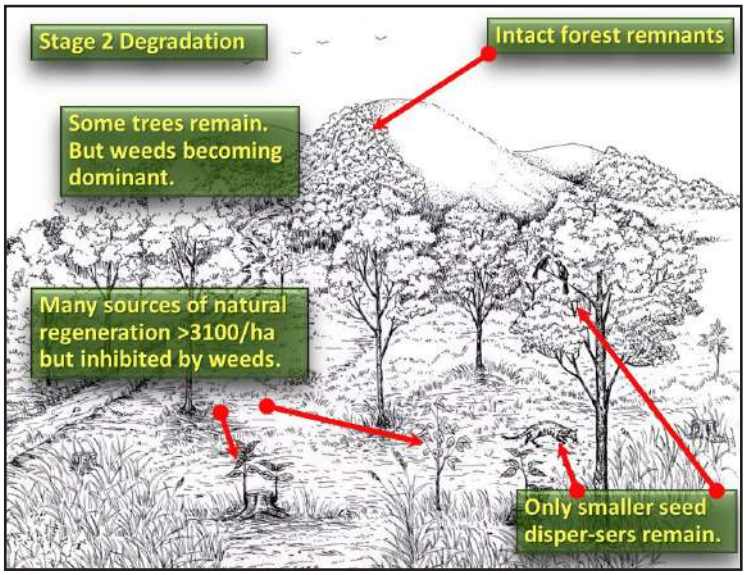
**If the risk of forest fire is high

Reintroducing extirpated seed-dispersing animals would increase the efficiency of forest restoration

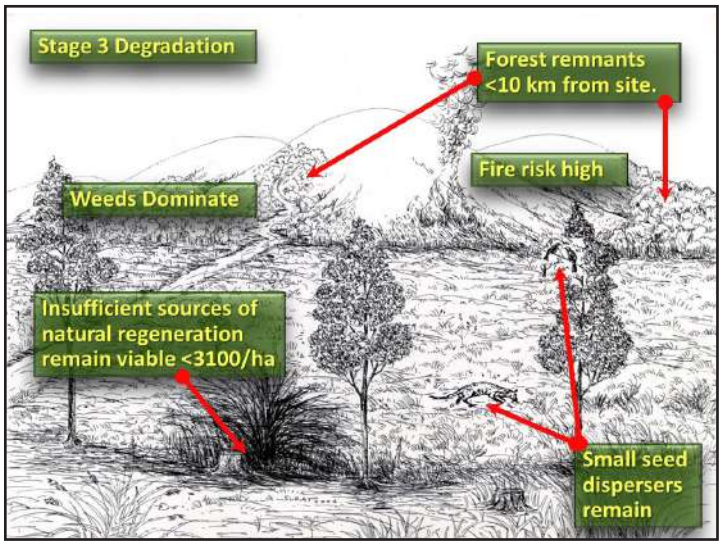
5 STAGES OF FOREST DEGRADATION



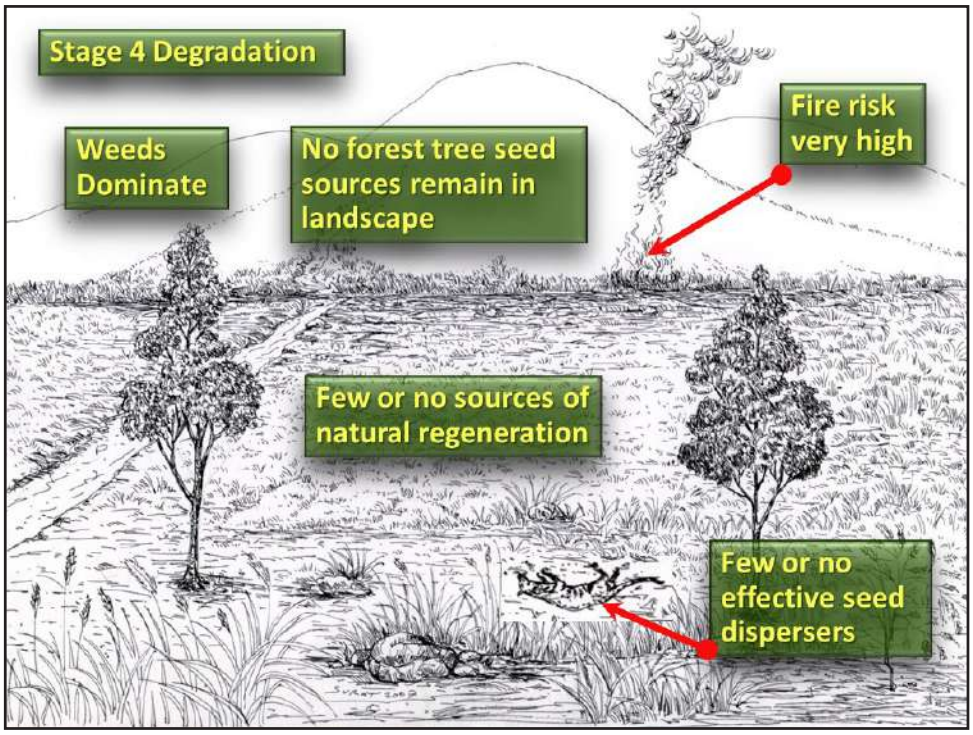
1. The is the forest condition immediately after selective logging. Density of natural regenerants is high and they are not suppressed by weeds, so simple **protection** is sufficient. Prevent encroachment, by controlling access. Prevent fires, cattle grazing and hunting of seed dispersers, to allow natural forest regeneration to proceed unhindered.



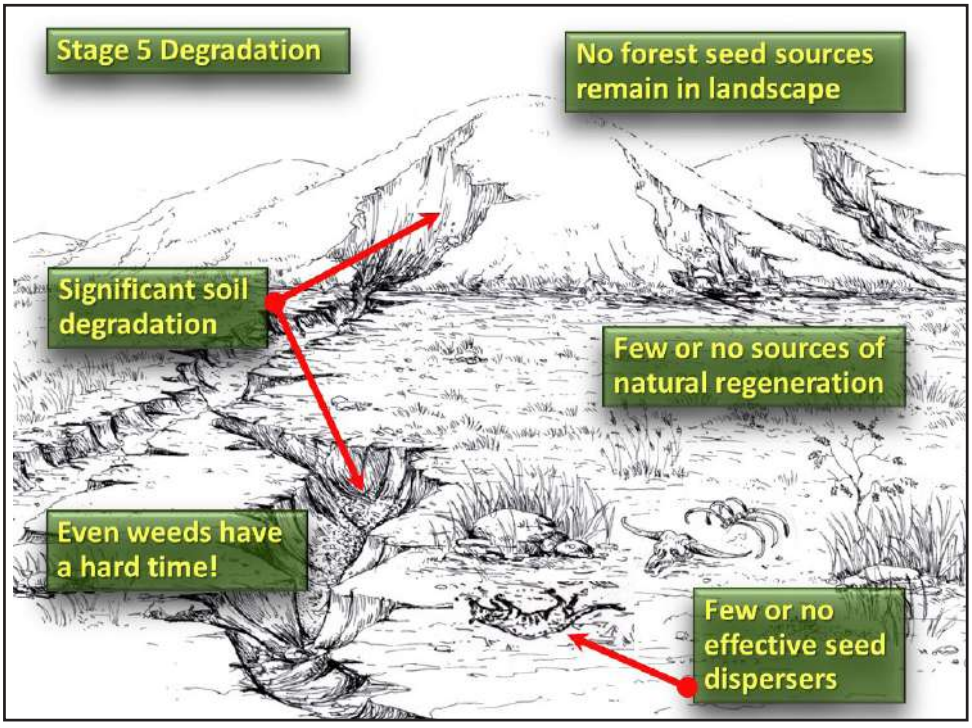
2. Accelerated natural regeneration "ANR" - when weeds inhibit natural regeneration. Dig them out from around natural regenerants, including roots and apply fertilizer. In addition, apply the protective measures, described for Stage-1 degradation, to prevent further deterioration in forest condition.



3. Framework species method - when regenerant density falls below 3,000 per hectare, augment it, by planting framework trees species—characteristic of the target forest type, with high survival and growth rates, dense crowns, which shade out weeds and production of fruits etc. to attract seed-dispersing animals. Apply ANR to surviving regenerants and protective measures.



4. Maximum diversity method - when there is no forest or seed dispersers near the restoration site, natural seed dispersal is not possible. Under such circumstances planting a few framework species cannot catalyze recovery of tree species richness. So, ***all*** tree species that comprise the target forest must be planted. This is very expensive.



5. Nurse trees - where soil erosion is severe or soil has been removed (e.g. mines), planting a few hardy tree species, to recover the soil ecosystem is necessary, before framework or maximum diversity species can be planted. Nurse trees include *Ficus* spp to improve soil structure and legumes to add nutrients.

PLANNING FOREST RESTORATION

The forest restoration method applied is determined by the condition of the restoration site and its proximity to natural forest. Selecting the most appropriate method increases the efficiency of forest restoration, whilst reducing costs. This activity encourages students to analyse conditions on the ground, to arrive at an appropriate technical solution to a key environmental problem—deforestation.

Objectives

1. To develop students' ability to critically observe the environment and develop a solution to an environmental problem.

Operating time 1 hour

Media and Equipment

Equipment	Amount for 1 group (5 students)
"5 Stages of Forest Degradation" diagrams	1 set
"Thinking Before Planting" flowchart	1 sheet

Implementation

1. Locate a deforested site or severely degraded forest near your school. The area should be unused, with a potential for restoration; not agricultural land, urban land or a recreational area.
2. Take students to visit the site. Provide them with the flow chart "Thinking Before Planting" and "5 Stages of Degradation" diagrams.
3. Assist the students to describe the site:
    - Find natural regenerants: large trees, live tree stumps (with shoots (**coppices**) growing from them) and tree saplings, taller than 50 cm (look under the grass and weeds for the smaller ones). How might the density of regenerants per hectare be estimated? Is tree planting necessary?
    - Describe the density of weed cover and estimate the average height of the weed canopy. Are weeds shading out small tree saplings? Is weed control necessary?
    - Look for signs of cattle. Are cattle a danger to small trees? How might cattle be excluded?
    - Has the area been burnt recently (look for charcoal on the ground)? Is fire prevention needed?
    - Look for signs of severe soil erosion? Must the soil be improved before tree planting?
4. Use a tablet to look at the site on Google Earth. How far away is the nearest natural forest? Is it possible that animals could disperse seeds from the forest into the restoration site?
5. Ask each group to prepare a plan to restore forest to the site. The plan should include a bullet point list of all the actions needed to restore a forest ecosystem to the site in the order each action should be carried out. If tree planting is needed, where will the trees come from?
6. **Optional**: take students to visit the nearest remnant of target forest and ask them to describe the forest structure and list any tree species they can name. This helps to define the goals of restoration.

FOREST RESTORATION BY THE FRAMEWORK SPECIES METHOD

The most common degradation stage across Thailand's northern mountains is Stage-3, where the density of natural regenerants has fallen below 3,000/ha, and tree planting becomes necessary to fill the gaps. If remnant forest remains nearby, the framework species method is the most appropriate restoration strategy. It involves planting the fewest trees, necessary to shade out weeds (i.e., **re-capture the site**) and attract seed-dispersing animals. For the method to work, remnants of target forest must survive within a few kilometres of the restoration site (as a seed source). Animals (birds, bats and civets), able to disperse seeds from remnant forest to exposed restoration sites, must be fairly common. The method enhances natural seed-dispersal, to achieve rapid tree-species recruitment. Consequently, recovery of biodiversity levels, typical of the target forest, is attained, without having to plant *all* the target ecosystem species. Furthermore, the planted trees rapidly re-establish forest structure and ecological functioning, and create cool shady conditions on the forest floor that are conducive to germination of tree seeds and seedling establishment.

What are framework tree species?

The framework species method involves planting mixtures of 20-30 tree species that are typical of the target forest type, but which also share the following ecological characteristics:

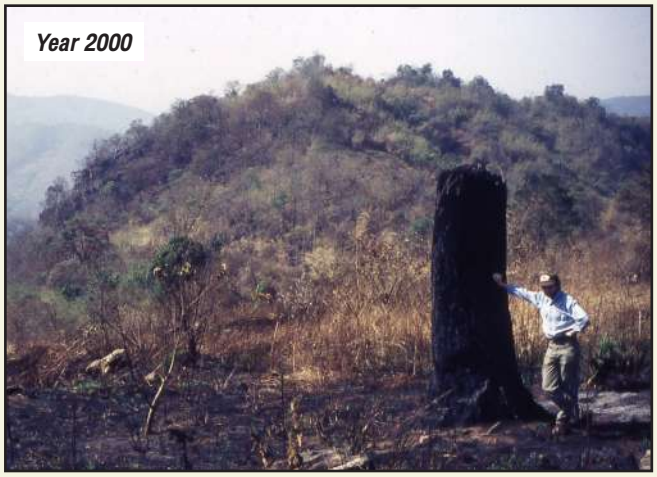
- high survival and rapid growth, when planted out in exposed deforested sites,
- dense, spreading crowns that shade out herbaceous weeds and
- flowering, fruiting, or providing other resources, at a young age, which attract seed-dispersing wildlife.

Mixtures of framework tree species should include both fast growing, light-loving, pioneer species and shade-tolerant climax species. The planted pioneer trees contribute most to early canopy closure and shading out weeds. They fruit as early as 2-3 years after planting, so rapidly attract seed-dispersers. Planting climax species short circuits ecological succession. Lists of framework tree species, specific for forest types around Chiang Mai, can be found at www.forru.org, or use the “contact us” tab there to enquire directly with FORRU-CMU staff. Plant sufficient framework trees to raise the stocking density to about 3,000/ha (1.8 m spacing). Remove weeds from around both planted and natural trees, and apply fertilizer at 4-6 weekly intervals during the first and second rainy seasons after planting. Monitor survival and growth of the planted trees and biodiversity recovery (use the bird survey method in Chapter 3), to improve future selection of framework tree species.

All the information you need, to support your class' forest restoration projects can be downloaded completely free of charge here:
https://www.forru.org/

CASE STUDY

Results of the framework species method



Deforested, over-cultivated, exhausted and burnt, this site, in the upper Mae Sa Valley of Doi Suthep-Pui National Park at 1300 m elevation, is typical of Stage-3 degradation, requiring restoration by the framework species method. In June 2000, 29 framework tree species, characteristic of evergreen forest, were planted. The landmark tree stump comes from the original forest.

Within 18 months, the crowns of some of the planted trees were already clearly visible above the grasses and weeds. Weeds were cut and fertilizer applied 3 times in the first rainy season after planting and 3 times over the 2nd rainy season, about 6 weeks between treatments

Eleven years later the forest had the look-and-feel of a natural forest. Biodiversity was returning and carbon accumulating rapidly in the trees and soil. The weeds had been replaced with naturally regenerating tree seedlings, germinating from seeds brought in mostly by birds, attracted by the planted trees.

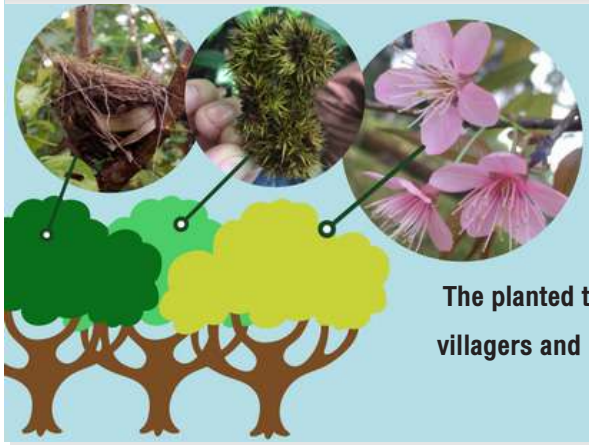
FOREST RECOVERY AFTER FOREST RESTORATION

3

Three years after tree planting, camera traps revealed that civets, deer and badgers, were attracted by the food and security, which the planted trees provided. They brought in the seeds of many non-planted tree species (recruit species), which they had swallowed while feeding in nearby forest, adding greatly to tree species richness. Even the leopard cat returned, feeding on rats and mice and helping to control the populations of those seed predators.

6

Six years after planting 29 framework tree species, the number of bird species, recorded in the plots increased from 30 (before planting) to 87, representing 63 percent of the bird community of the target forest ecosystem.



7

After 7 years

The planted trees began to provide natural resources for villagers and benefited local wildlife by providing nesting grounds, food and nectar.

8-9

- 72 non-planted (recruit tree species) had established, which along with the 29 planted species resulted in a tree species richness of >100.
- Mycorrhizal fungi, which help trees absorb nutrients increased from 6 to 21 species (higher than natural forest).
- The number of lichen species found was double that of natural forest.

START A SCHOOL TREE NURSERY

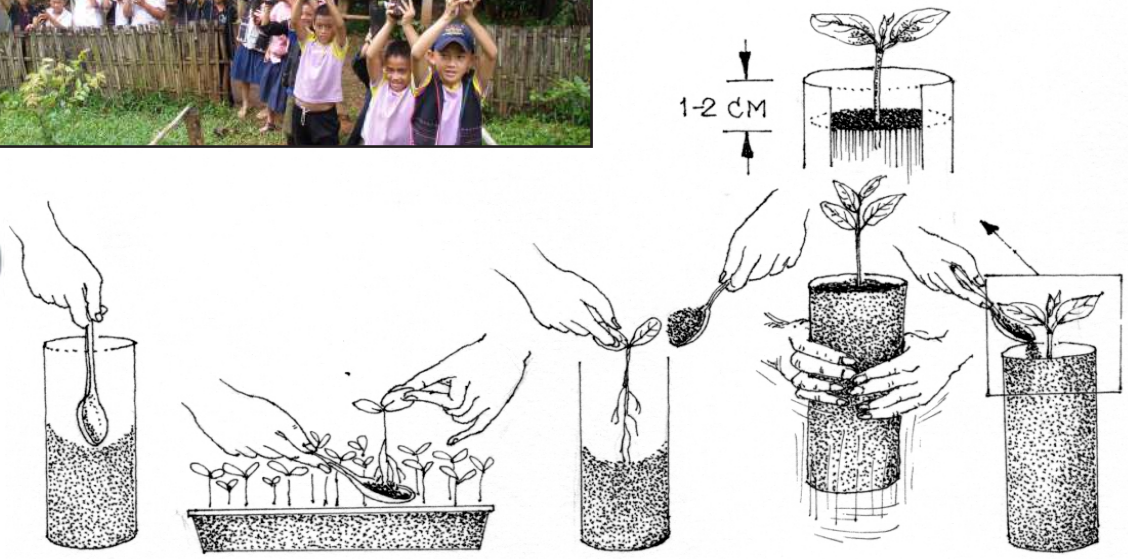
Growing the trees needed for forest restoration in your school is a great way to empower students to become directly involved in restoring forests—their future environment, as young people have the most to gain from tree planting.

Implementation

1. Find a spare flat space (at least 10 x 10 m) on the school campus. Divide it into i) 1/3 seed germination area, with benches to take modular germination trays, and ii) 2/3 seedling growth area (**standing down area**) with beds wide enough to take 10 containerized seedlings across. Cover the area with shade netting (**slan**) on poles and install a water supply. Fence out dogs if necessary.
2. Organize students to collect seeds from trees around the school campus or join seed-collection days with FORRU-CMU in target forest ecosystems (www.forru.org, "contact us" tab).
3. Run activities to clean the seeds, apply appropriate germination treatments and sow them into modular germination trays. Record the numbers of seeds germinating daily. Plot germination curves in class. Calculate germination rates and the median length of dormancy (**MLD**).
4. Once the seedlings have grown 1-2 pairs of true leaves (not including **cotyledons**), organize students to pot them up into plastics bags (9"x2.5"). Water them and apply fertilizer (**Osmocote**) as needed.
5. Seedlings are ready to plant out in the field, once they have grown 30-50 cm tall by mid-June.
6. For tree nursery design and best nursery practices, please see Part 6 of "How to Plant a Forest" (free download from **https://www.forru.org/library/0000153**). For species-specific propagation procedures, please see Part 9 of the same book.

Left: *a simple school tree nursery on Doi Mae Salong—directly involving school children in the future of their own environment.*

Below: *how to pot up tree seedlings into containers. Paper cups from the school canteen are a more environmentally friendly alternative to plastic bags.*



READY TO PLANT TREES?

Tree planting is the "main event" of most forest restoration projects (apart from those based solely on ANR), but it is not the last. Weeding, fertilizer application, fire prevention and monitoring are all essential subsequent steps. As a teacher, organizing your own tree-planting event is a daunting task, but luckily, there are now many local tree-planting initiatives occurring annually around Chiang Mai, during the rainy season. So, it is easier to arrange to have your class join one of those. For news of tree-planting activities, please see the events section of FORRU-CMU's FaceBook page **(https://www.facebook.com/forestrestorationresearchunit)** or enquire through **(https://www.forru.org/)** "contact us" tab.

Objective

1. To gain hands-on experience of forest restoration practices.
2. To empower students to take direct action to restore their long-term future environment.

Implementation

1. Around April or May, contact FORRU-CMU or local forest authorities, to find out when and where tree planting projects will be taking place over the subsequent rainy season. Ask if it is possible for your students to join the activities as volunteers and offer to donate trees from the school nursery.
2. Site clearance: before planting, weeds are cleared from the site. This is physically demanding, so consider if it is an appropriate activity for your students to join. Often, it is done by local people or forest officers a few days before planting.
3. Transporting trees and materials to the site: it is a good idea to label trees from your school nursery so that students can plant the ones they have a personal connection with. Trees are transported to the site 1-2 days before planting. Provide them with water and shade at the site, so they remain healthy till planting day. Sacks of fertilizer and bamboo poles are transported to the site at the same time. Again, this is physically demanding, so consider if your students are fit enough to join the activity.

When clearing weeds, mark natural regenerants with poles, so they don't get cut. Every natural regenerant conserved means one less tree planted. So, they are highly valuable.

4. In advance of planting day, familiarize students with the following steps:

Stake out the planting points, about 1.8 m apart (or same distance away from natural regenerants).

Dig holes twice the size of the containers.

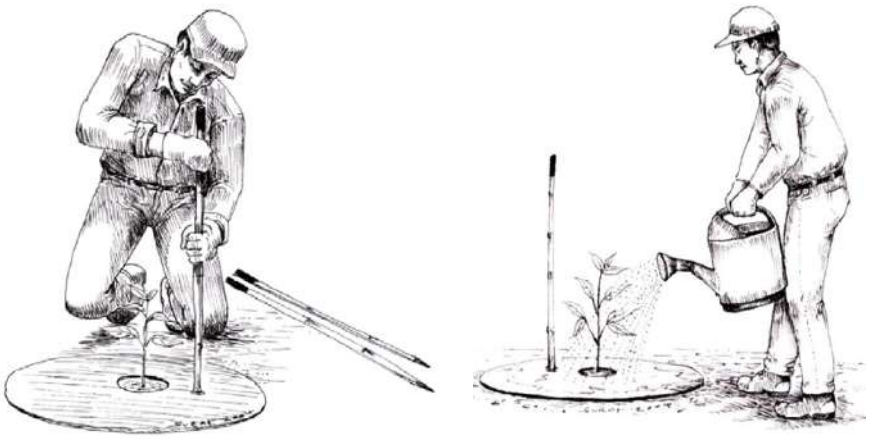
Slice open the plastic bag with a blade and carefully remove the tree, keeping the root ball intact.

Place the tree in the hole and fill in with soil. Place plastic bag on pole, to indicate tree planted.

Firm down the soil, making sure that the planted tree is perfectly upright.

Spread 50 gm fertilizer in a ring about 20 cm away from the base of the tree.

In dry deciduous forests, cardboard mulch mats increase survival and growth rates, but they have little effect on evergreen forest sites. Water the trees if there's a water supply nearby. Otherwise plant when rainfall becomes reliable (**usually mid-June**).



Finally clear the site of plastic bags and any other garbage.

Things to organize:

- Transport - how close is the site to a road with vehicular access? 4WD vehicles may be needed if the site is a long way along a dirt track.
- Food and drink - tree planting is thirsty work. Make sure all students bring a water bottle, as well as a packed lunch.
- Clothing - deforested sites are rough, often with thorns and biting insects. Long trousers, long-sleeved shirts, a hat and boots or strong shoes are essential.
- First aid kit - accidents can happen - come prepared.
- Provide every student with a pair of work gloves and a box cutter.

Consider involving students in these follow-up activities:

- First monitoring (**baseline monitoring**) takes place about 2 weeks after planting (to allow the trees to settle). Live trees are counted and measured, so that % survival and growth rate can be calculated subsequently.
- Maintenance - weeding and fertilizer application are performed around both planted trees and natural regenerants, 3 times in the first rainy season.
- Second monitoring—takes place at the end of the first rainy season.
- Fire prevention—see Chapter 5.
- Year 2 maintenance— weeding and fertilizer application 3 times in the second rainy season.
- Year 2 monitoring at the end of the second rainy season. By this time, students should be able to see clear results. Many trees will have grown 2-3 m tall and canopy closure will be starting. Engage the students in calculating **% survival** and **relative growth rates**, using the monitoring data.

For more details on tree planting see Part 7 of "How to Plant a Forest"
https://www.forru.org/library/0000153

HUNTING

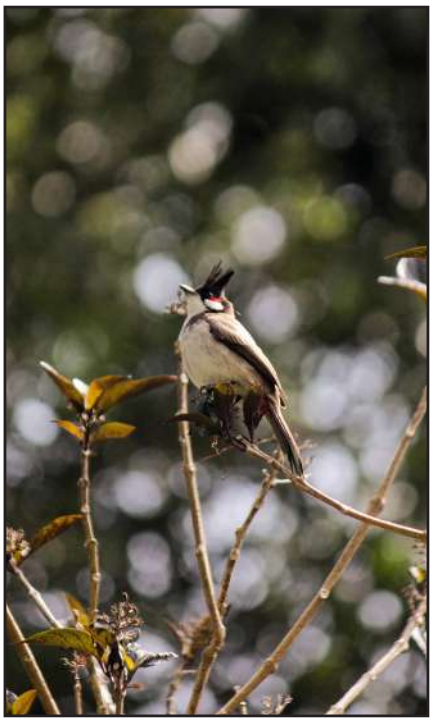
CAUSES OF HUNTING

A camera trap captured this villager carrying a home-made rifle into the forest for hunting

The market in live wild animals, as pets, and animal parts as medicinal products, food and ornaments is unfortunately highly lucrative. So, capturing or shooting wild animals is highly profitable. Skins, antlers and horns are the main decorative items. Song birds are the main live animals captured around Chiang Mai, particularly the red whiskered bulbul. Wildlife markets at Thung Kwian (Lampang) and around Chiang Mai City were closed down in the 1990's, so the wildlife trade is not as visible as it once was.

EFFECTS OF HUNTING

Hunting not only leads to species extirpations and reduced biodiversity, it can unbalance entire ecosystems. Previous sections of this book have emphasized the seed-dispersal role of animals as vital to natural forest regeneration. About 85% of tree species in evergreen forest are dispersed by animals, and many are pollinated by them. Large seeds, in large fruits, can only be dispersed by large animals, such as elephants, rhinos and wild cattle. Hunting has extirpated all these species from Chiang Mai's foests. Consequently, large-seeded tree species will gradually disappear, if humans do not plant them during forest restoration projects.



Red whiskered bulbuls have nearly vanished from most of Thailand, due to illegal trapping of wild birds for sale, as caged song birds, for bird song contests, particularly in southern Thailand. Chiang Mai is one of few places where the species is still fairly common.

SOLUTIONS

Laws that protect wildlife, particularly rare species, are one way to try to reduce or prevent hunting. Thailand's Wildlife Preservation and Protection Act, B.E. 2535, lists reserved wild animals, the hunting of which is completely prohibited. It also covers the import and export of endangered species and their products and the protection of wildlife habitats, to allow reproduction of rare species.

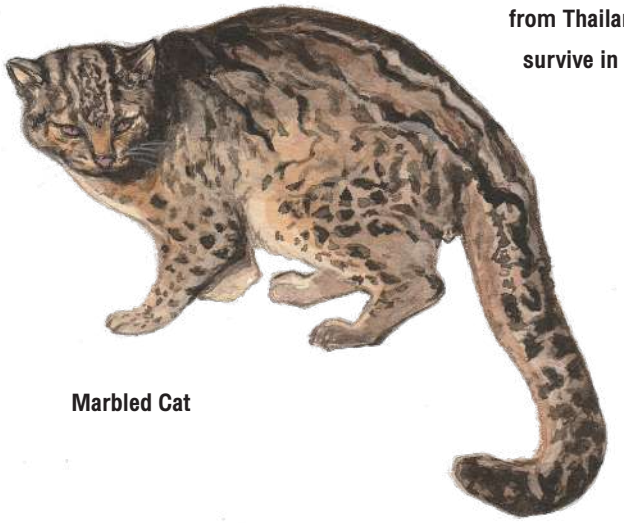
Reserved Wild Animals

It is strictly prohibited to hunt or possess reserved wild animals—both live animals and products derived from them, such as skins, tusks, shells or horns etc. They are all endangered species and some are already extinct, but they retain this highest protected status, just in case any live ones may be found in the future. The law prohibits hunting, possessing, or trading any of such species, except for scientific research (with a permit) or display in authorised public zoos. Currently 19 species have this highest level of protection.

Examples of Reserved Wild Animals

White-eyed River-Martin - Extinct

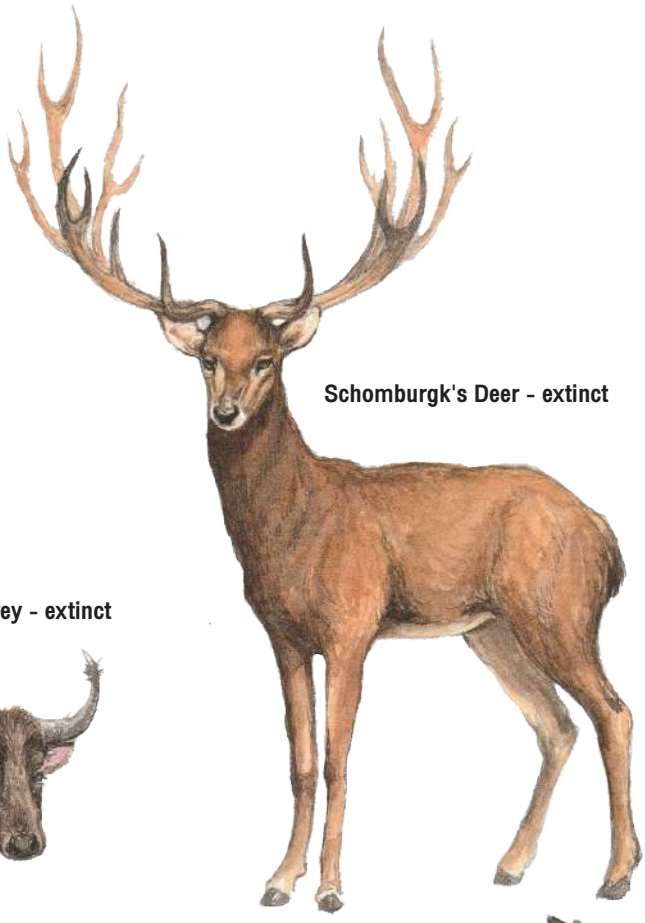
Gurney's Pitta - extirpated from Thailand but may survive in Myanmar



Marbled Cat

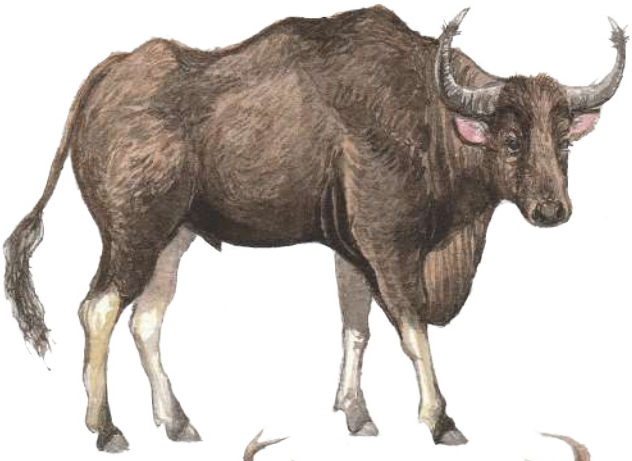
Sarus Crane

Asiatic or Wild Water Buffalo



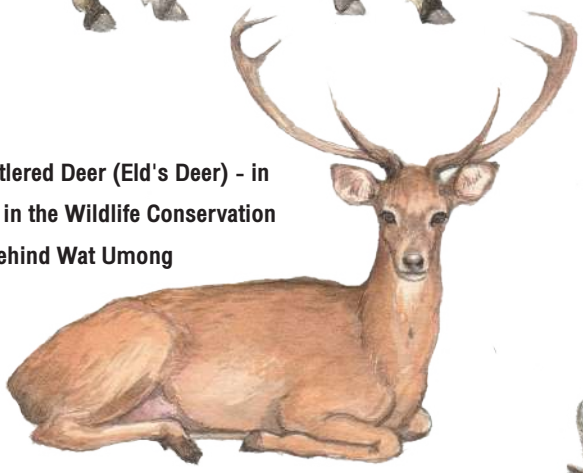
Schomburgk's Deer - extinct

Kouprey - extinct

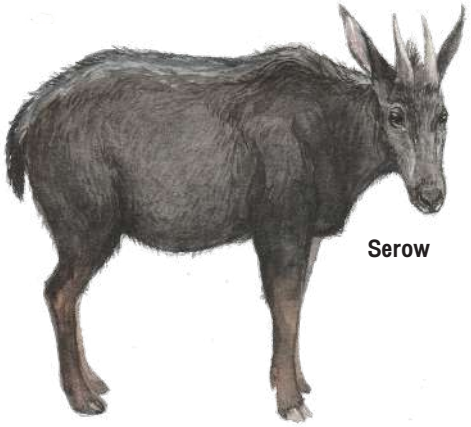


Grey Chinese Goral

Brow-antlered Deer (Eld's Deer) - in captivity in the Wildlife Conservation Centre behind Wat Umong



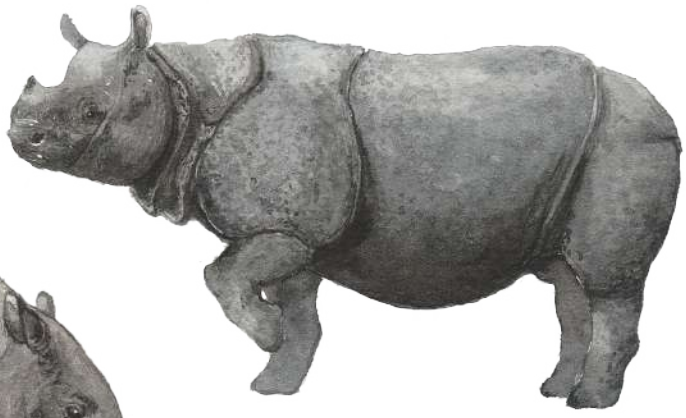
Fea's Barking Deer

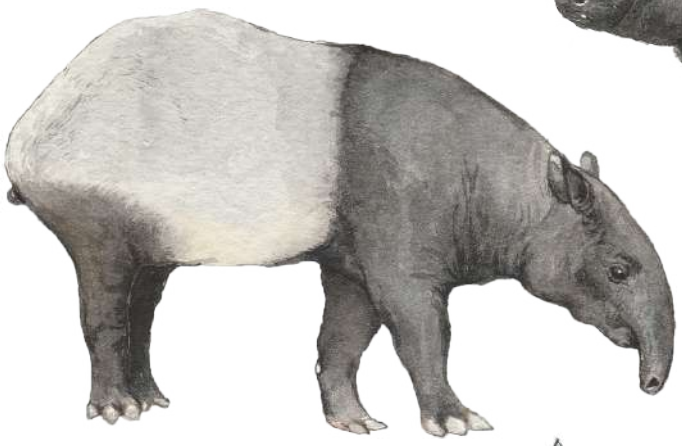


Serow

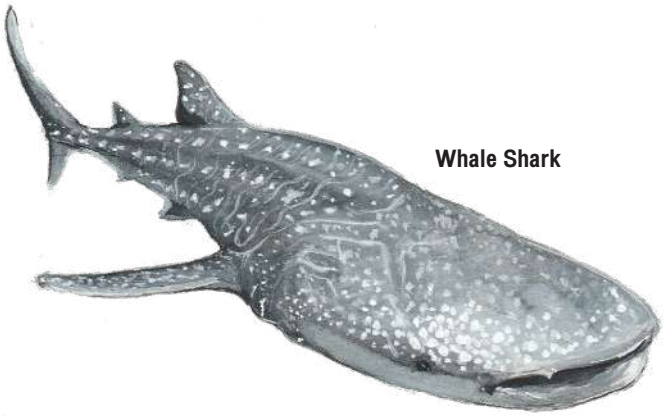
Sumatran Rhinoceros - a few used to migrate into Thailand from Malaysia up to the 1990's, but they have now been extirpated from both Malaysia nad Thailand. A few survive on Sumatra.

Javan Rhinoceros - common in northern Thailand up until the early 20th century. Extirpated in the 1930's.





Malayan Tapir - a few survive in southern Thailand



Whale Shark

Leatherback Sea Turtle

Dugong

Bryde's whale

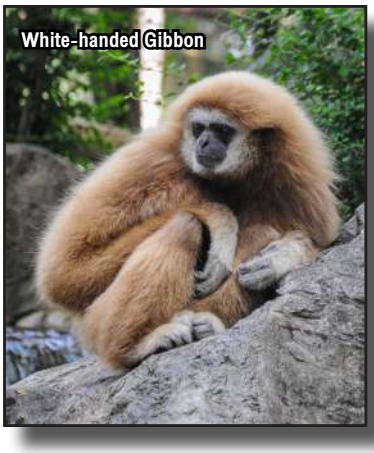
Omura's whale

Protected Wild Animals

In Thai law, the distinction between "reserved" and "protected" wild animals is marginal, except that the former tend to be closer to extinction (or actually extinct). Killing, capturing or trading in protected or reserved wild animals or destroying their habitats (particularly in Wildlife Sanctuaries) are punishable by various fines (up to 40,000 baht) and imprisonment terms (up to 5 years), depending on the type of offense, although some animals may be kept with a licence. Unfortunately legislation has not prevented the extirpation of species from many parts of the country and the outright extinction of several.

Examples of Some Protected Wild Animals


Southern Pig-tailed Macaque


White-handed Gibbon


Blue-crested Lizard


Binturong


Painted Stork


Small-clawed Otter

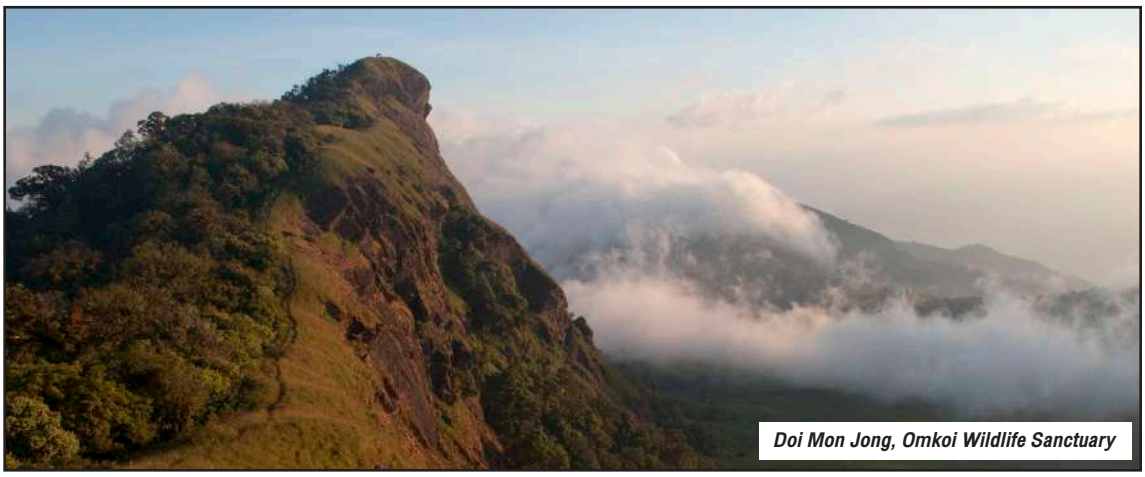

Silver Pheasant (Female)

CONSERVATION AREAS

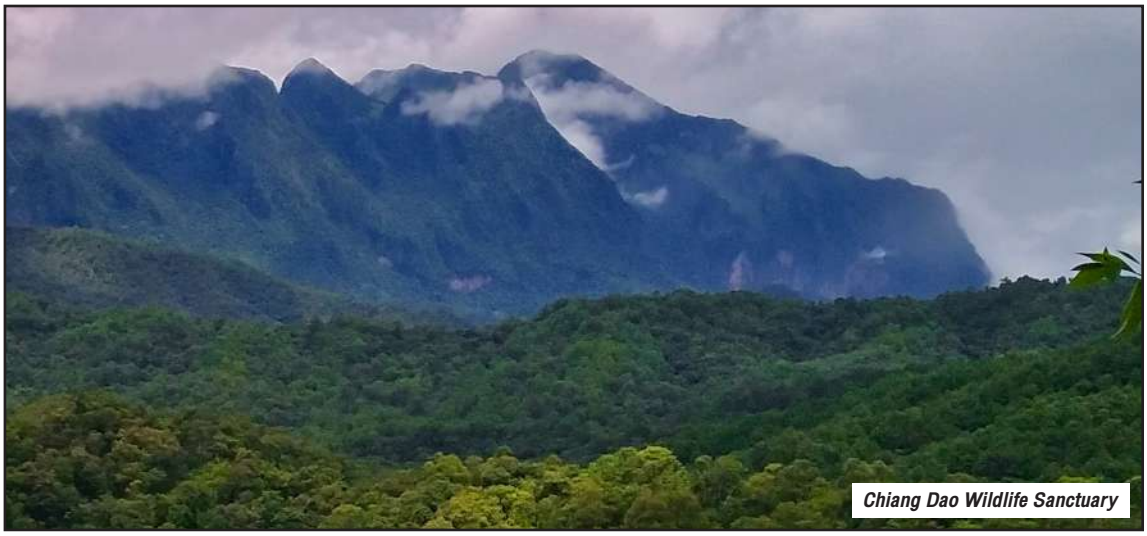
Wildlife cannot survive without habitat, so protection of wildlife habitat is the most cost-effective way to conserve wildlife. Protected areas cover about 19% of Thailand. There are two types specifically for wildlife conservation, under the Wildlife Preservation and Protection Act: Wildlife Sanctuaries and Non-Hunting Areas. Although wildlife is also protected in National Parks, which cover about twice the area of Wildlife Sanctuaries and Non-Hunting areas, their primary function is: "education and enjoyment" rather than wildlife conservation.

Wildlife Sanctuaries are "preserved so that wild animal species can be preserved and breed in a natural environment". They are **large areas** of fertile forest, with sufficient food resources, and they provide a safe environment away from human disturbance. Famous ones near Chiang Mai include: Chang Dhao, Omkoi, Samoeng and Mae Lao-Mae Sae. There are 55 nationwide.

Non-hunting Areas are "preserved for the protection of specific wildlife species but are **too small to be wildlife sanctuaries**". Hunting of all animals (regardless of their protected status) and land occupation are prohibited. Their purpose is restoration of wildlife habitat. There are 79 nationwide. The nearest one is just behind Wat Umong, where the Doi Suthep Nature and Wildlife Education Centre is located.



Doi Mon Jong, Omkoi Wildlife Sanctuary



Chiang Dao Wildlife Sanctuary

VISIT DOI SUTHEP NATURE & WILDLIFE EDUCATION CENTRE

It is almost impossible to provide students with the thrill of spotting large animals in the wild around Chiang Mai. But, there is a place, where students can get close to a few large semi-wild animals on the outskirts of Chiang Mai city. The Doi Suthep Nature and Wildlife Education Centre is both a wildlife rescue centre and a breeding station for two endangered large native mammals, Eld's Deer and Banteng—long gone from Chiang Mai's forests. There's also a display of illegal wildlife products. Away from the Centre, there are trails through deciduous forest, where Sambar Deer and Hog Deer can be seen roaming freely. The Centre's staff are friendly and informative, always willing to help educate visiting students.

Objectives

1. To provide students with an opportunity to see large wildlife species in semi-natural conditions.
2. To learn how to recognize some rare mammals and birds.
3. To learn how captive breeding and re-introduction can save endangered wildlife.

Implementation

1. They provide various educational experiences for both primary and secondary school students.
2. For students who want to do school projects about wildlife behaviour, please contact the director (telephone number below).

- **One-day camp:** accommodates up to 100 students with lectures about wildlife conservation and wildlife behaviour in the morning, and hands-on activities in the afternoon.
- **Overnight camp:** accommodates up to 30 students. This requires personal tents and food. The centre will provide lectures about wildlife conservation and wildlife behaviour, as well as hiking to observe wildlife in the forest.

Doi Suthep Nature and Wildlife Education Centre is located at 163 Moo 10, Suthep Subdistrict, Mueang District, Chiang Mai Province 50200. Tel: 053 277 402

Make an appointment to see the confiscated wildlife products.

How many of these species can you name?

It's also possible to just turn up for a **1/2-day visit (no entrance fee)**. Take along some bird and mammal identification guides, and ask students to Identify the species they see. Observe the conditions under which the animals are kept. Are they better or worse than a regular zoo?

Ask an officer about:

a) How animals come to the centre ?

b) How they are cared for ?

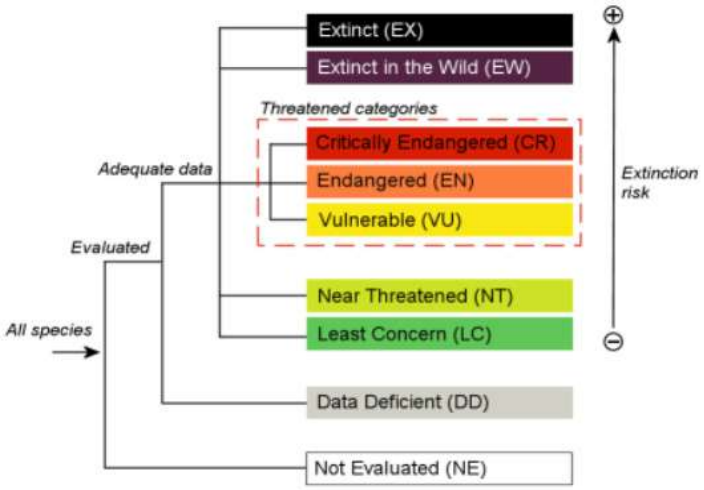
c) How they are rehabilitated for release into the wild ?

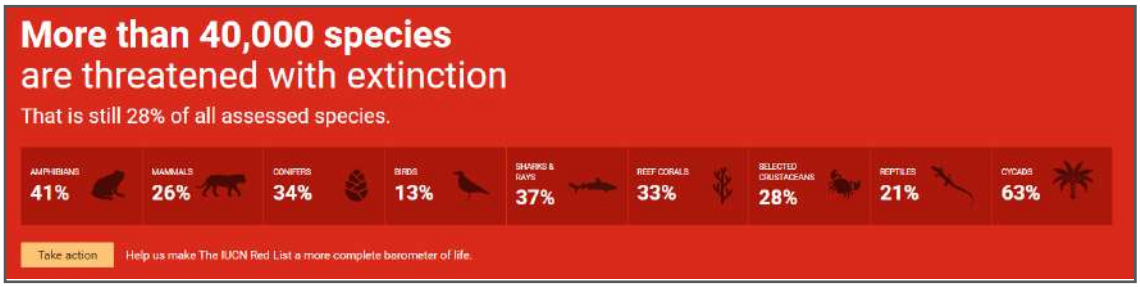
d) What has been the success rate of releasing animals from the centre into their natural habitats ?

Recognizing threatened species

The International Union for the Conservation of Nature is responsible for determining how close species are to extinction. It is a global network of scientists, who work mostly voluntarily to compile so-called Red Data Lists (red for danger?) of endangered species. They are usually highly specialized taxonomists with long experience of working on particular groups of plants or animals. The activity suggested here provides students with a chance to review the plant and animal species they have seen during previous activities and find out how many of them may be close to extinction. Such work focuses conservation efforts on saving the species most at risk.

1. **Not Evaluated - NE**
2. **Data Deficient - DD**
3. **Least Concern - LC**
4. **Near Threatened - NT**
5. **Vulnerable - VU**
6. **Endangered - EN**
7. **Critically Endangered - CR**
8. **Extinct in the Wild - EW**
9. **Extinct - EX**





https://www.iucnredlist.org/

Back to search results Jump to Eld's Deer: In detail

Eld's Deer

Rucervus eldii

ABSTRACT

Eld's Deer *Rucervus eldii* has most recently been assessed for *The IUCN Red List of Threatened Species* in 2014. *Rucervus eldii* is listed as Endangered under criteria A2cd+3cd+4cd.

1. Work in pairs. Ask students to recall any plant or animal species they have encountered whilst performing any of the activities in this book.
2. Students list the species and to confirm the spelling of both their common and scientific names online. This is a great opportunity to explain the nature and importance of the scientific naming system for plants and animals.
3. Ask students to nominate five species which they think are most likely to be endangered, vulnerable or threatened and write down their reasons.
4. Students open the IUCN Red List website and search for their listed species. They determine the conservation status of each and learn the reasons why some may be endangered.
5. Facilitate a discussion as to what measures should be taken to prevent extinction of the endangered species found.

Carl Linnaeus (1707 – 1778), was a Swedish naturalist who formalized binomial nomenclature: the scientific system of naming organisms, which he published in his famous book Species *Plantarum* in 1753. He is known as the "father of modern taxonomy"—the science of naming organisms. Scientific names are written in Latin, a neutral non-national language, acceptable to scientists of all nations. The first part of the name is the genus to which a species belongs, whilst the second part is the species name. A genus may have many similar species belonging to it. Having a single official name for each species is useful to communicate information about each species.

Local names are not so useful since, there are often many different local names for the same species, and sometimes a single local name is used for many different species. Grouping similar species together in genera, helps with understanding evolution and relatedness. Latin names are written in ***italics***, to make them stand out from the rest of the text and to indicate that they are written in a foreign language. When using a Latin name for the first time in a text, the full name is written (e.g., *Sapria himalayana*), but subsequently, the genus is abbreviated to its initial (e.g., *S. himalayana*).

APPENDICES

Some Framework Tree Species

Glossary

Index

Female wild cattle, Banteng. Meet them roaming freely, very near Chiang Mai city, in the activity in Chapter 6.

Bischofia javanica Bl. (EUPHORBIACEAE)

Dteum

A large, common, light-demanding, evergreen (or leaf-exchanging) tree, growing up to 35 m tall (DBH to 80 cm).

Where does it grow?

From the Himalayas to China, Indochina, East Asia, Malaysia, N. Australia and the Pacific islands of Tonga and Samoa. In N. Thailand, it grows in EGF, MXF and BB-DF, often along streams at elevations of 525 to 1250 m.

What are its distinguishing characteristics?

Bark: thin, vertically fissured, scaly or flakey, reddish brown; sap dark red. ***Leaves:*** spirally arranged, trifoliate; blades, ovate or elliptic, hairless, 6.5-14.5 x 3.5-6.5 cm; margin shallowly serrate; leaf-exchanging February to March at low elevations. ***Flowers:*** numerous in axillary panicles, greenish-yellow, without petals, c.2 mm long; February to March. ***Fruits:*** slightly fleshy drupes, globose, brown-black when ripe, 5-10 x 5-10 mm; 3 or 4 locules per fruit, each containing up to 2 seeds, 4.6 x 3.3 mm; fruiting June to February; animal-dispersed.

Why is it a framework species?

Survival of planted saplings is usually high (60-80% by end of the 2nd rainy season), but growth can be slow. Birds nest in this species by the 5th year after planting and it fruits within 6 years. Natural recruitment of tree species occurs beneath 6-year-old trees. It coppices and survives well after fire (>80% survival of trees burnt 33 months after planting; RCD>20 mm).

How are saplings grown?

Collect ripe fruits in October (the earlier the better). Crush them and extract seeds in a sieve under running water. Sun-dry seeds and sow them shallowly and well-spaced in 1:1 forest soil and sand, to prevent damping-off. Germination is asynchronous, continuing for 6 weeks: GP up to 80%; MLD 26 days. Prick out seedlings after expansion of first true-leaf pairs. Fertiliser application is important for this species. Seedlings are prone to caterpillars, stem gall larvae and sap-sucking mites, which cause leaf curling. Destroy diseased plants and spray survivors. If fertilizer is applied, saplings are ready for planting by the 1st planting season (TNT 9 months).

How should saplings be planted and cared for?

B. javanica responds well to cardboard mulch and fertilizer. Make sure planted saplings do not become shaded by neighbouring trees.

What can the species be used for?

Timber used for construction, beams, flooring, furniture, joinery, carving and charcoal. Also used for paper-making. Bark produces a red dye and contains tannin.

Erythrina subumbrans (Hassk.) Merr. Tawng Lahng Bah (Leguminosae, Papilionoideae)

A medium-sized, pioneer, deciduous tree, growing up to 25 m tall (DBH to 86 cm).

Where does it grow?

From India, Myanmar and Indochina to Malaysia, Fiji and Samoa. In N. Thailand, it grows sparsely in EGF and MXF at elevations of 500 to 1680 m.

What are its distinguishing characteristics?

Bark: soft, grey, with spine-tipped black tubercles. ***Leaves:*** spirally arranged, trifoliate; leaflet blades ovate, margin entire, terminal leaflet 10-14 x 8-12 mm. ***Flowers:*** bisexual, 4-5 cm long; petals bright red; December to March, often when leafless. ***Fruits:*** pods, brown, 15.5 x 1 cm; seeds smooth, dark brown, kidney-shaped, 1 x 0.9 cm; March to April; pods wind-dispersed.

Why is it a framework species?

E. subumbrans saplings achieve excellent survival and growth rates after planting out (>80% survival; >2.5 m tall, crowns 2.6-2.8 m across, by end of 2nd rainy season). Their broad, deciduous, crowns produce dense leaf litter, creating excellent conditions for germination of tree seeds on the forest floor. They flower, fruit and attract nesting birds from the 4th year after planting. The vivid scarlet flowers produce nectar, which attracts many bird and squirrel species. The seed rain from these animals results in natural recruitment of many tree species around *E. subumbrans* trees within 5 years. As a legume, this species adds nitrogen to nutrient-poor soils.

How are saplings grown?

Collect seeds from fallen pods in March. Soak them in water overnight. Sow those that start to swell and discard any non-viable ones, which float. Sow seeds directly into containers, in full sunlight, and use wire mesh to protect them from rats and squirrels. GP typically 40-60%; MLD 7-14 days. Take precautions against leaf-folding caterpillars (Lepidoptera, Pyralidae), which defoliate seedlings in the late rainy season. Do not apply fertilizer or prune this species. Saplings can be planted out when 30 cm tall, usually 3-4 months after germination.

How should saplings be planted and cared for?

E. subumbrans saplings have weak stems, so care is needed when handling them. Staking can reduce post-planting mortality. They respond well to fertilizer application and mulching after planting. However, planted trees are susceptible to a stem-boring insect pest, which can kill even mature trees. Do not plant *E. subumbrans* tree where they might become shaded.

What can the species be used for?

Cut branches of *E. subumbrans* root well, when planted in soil, so they are used to construct "living fences". Its lightweight timber is used for carving and for making various utensils. Its foliage is used for cattle fodder.

Gmelina arborea Roxb. (VERBENACEAE)

Saw

A briefly deciduous, pioneer tree, growing up to 30 m tall (DBH to 64 cm).

Where does it grow?

From Nepal, Pakistan, India, Sri Lanka and Myanmar across Indochina to S. China and Vietnam. In N. Thailand, this species grows sparsely in DOF, BB-DF, MXF and EGF-PINE, at elevations of 350 to 1475 m. It also establishes naturally in deforested sites.

What are its distinguishing characteristics?

Bark: thin, smooth, brown with conspicuous lenticels, becoming grey and peeling with age. ***Leaves:*** opposite, simple; blades, ovoid with pointed apex, 13-21 x 13-16 cm; upper surface dark green with 2 basal glands, lower surface silvery grey and hairy. ***Flowers:*** numerous in terminal inflorescences; flowers have 5-lobed, tubular, yellow corollas, 2.5-4.0 cm; February to March when leafless. ***Fruits:*** drupes, ovoid, yellow when ripe, averaging 26 x 18 mm, each containing a pyrene with 4 (rarely 5) chambers, of which rarely more than two contain seeds 6-9 mm long; fruiting; March to May; animal-dispersed.

Why is it a framework species?

G. arborea is an excellent framework species. Saplings survive well and grow rapidly after planting out in both lowland and upland sites, (>70% survival; 160-180 cm tall by end of 2nd rainy season). Their dense crowns shade out weeds well and support nesting birds by the 3rd year. Flowering and fruiting commence in the 5th year after planting. Fruits attract many bird and mammal species. The trees are resilient after fire (83% survival of trees burnt 21 months after planting, RCD >90 mm).

How are saplings grown?

Collect yellow fruits in April-June. Soak them in water overnight, then scrape off fruit flesh. Sun-dry the pyrenes for 1-2 days. Drop them into water and discard non-viable ones, which float. Put viable pyrenes into airtight containers with silica gel. Store at room temperature for 6 months. Sow pyrenes in mid-October in germination trays in full sunlight. Guard against seed predators. GP >60%; MLD 15-35 days. Prick out seedlings after expansion of first true-leaf pairs. Seedlings are prone to stem-boring beetles and leaf miners. Use insecticide and prune back affected tissues. Saplings ready for planting by June (TNT, excluding seed storage 8 months).

How should saplings be planted and cared for?

Do not plant this species where it is likely to become shaded. Cardboard mulch mats significantly increase survival of planted saplings. This species is prone to defoliation by beetles.

What can the species be used for?

G. arborea wood is used for pulp, plywood, and veneer; carpentry, light construction, boats, tools and carving. The wood makes good charcoal and firewood.

Hovenia dulcis Thunb. (Rhamnaceae)

Mawn Hin

A large, briefly deciduous tree, growing up to 30 m tall (DBH to 50 cm).

Where does it grow?

From the Himalayas, to N. Thailand, China, Japan and Korea. In N. Thailand, it is a recently discovered, rare species (Maxwell, 1994) in EGF often along streams, at elevations of 1025 m to 1325 m.

What are its distinguishing characteristics?

Bark: thick, with broad, longitudinal, grey or brown ridges, separated by narrow brick-red fissures. ***Leaves:*** spirally arranged, simple; blades, thin, ovate to elliptic, 11-14 x 5-9 cm; margin serrulate. ***Flowers:*** in cymes, numerous, light green and cream, small (2.5 mm); March to May. ***Fruits:*** fruit stalks (pedicels) very thin and curving for 2-3 mm above each fruit, but further along, swollen and fleshy, green when fruits are unripe, turning red-brown or black as fruits ripen; capsules septicidal, brown or black and drying out when ripe, 7-8.5 x 6-7.5 mm, usually 3-lobed with 1 smooth, glossy, black seed (5-6 x 5-6 mm) per locule; August to February; bird-dsipersed, particularly by pigeons (Hitchcock and Elliott, 1999).

Why is it a framework species?

An excellent framework species, *H. dulcis* saplings survive well (>80% by end of 2nd rainy season) and grow rapidly (>1.5 m tall) after planting out. They develop broad crowns, which effectively shade out weeds and attract nesting birds by the 4th year. This species' deciduous habit protects it against drought. It is particularly resilient after chopping or fire (72% survival of trees burnt 21 months after planting; RCD >42 mm). *H. dulcis* fruits and the swollen axes of the infructescence are very attractive to birds, but flowering does not commence <8 years after planting.

How are saplings grown?

Cut brown or black fruits from trees in October-November (as soon as ripe). Remove seeds from capsules and drop them into water. Discard those that float. Sow seeds immediately into trays in shade (about 25% full sunlight) and protect them from rats. Germination variable, but usually synchronous. GP 50-70%; MLD 45-90 days. Water seedlings well and prick them out as soon as first true-leaf pairs expand (ideally January or February). Apply fertilizer frequently, saplings grow rapidly in containers, reaching a plantable size of 30 cm by the 1st planting season after seed collection (TNT 8-9 months).

How should saplings be planted and cared for?

This species thrives, even where aftercare procedures are neglected, but responds particularly well to fertilizer application.

What can the species be used for?

Wood is suitable for pulp and fibre. The swollen axes of the infructescence are used traditionally to alleviate hangovers.

Prunus cerasoides D. Don (ROSACEAE) — Nang Paya Sua Krong

A medium-sized, pioneer, deciduous tree, growing up to 16 m tall (DBH to 38 cm).

Where does it grow?

From the Himalayas and S. China to Myanmar and N. Indochina. In N. Thailand, it is rare in EGF, MXF and EGF-PINE, often in disturbed areas, at elevations of 1040 to 2400 m.

What are its distinguishing characteristics?

Bark: shiny, red-brown, with large, raised, brown lenticels; outer layer peeling horizontally. ***Leaves:*** spirally arranged, simple; blades 9-12 x 3-5 cm; margin finely serrate; 1-2 dark red, stalked, glands where petiole meets blade. ***Flowers:*** in axillary clusters, 1-2.5 cm across, petals, 5, pink; on leafless trees December to January. ***Fruits:*** drupes (small cherries), ovoid, red when ripe, 1-1.5 cm, each containing a single-seeded pyrene; March to May; dispersed by birds, squirrels and other small mammals.

Why is it a framework species?

P. cerasoides is an excellent framework species. Planted saplings survive very well and grow rapidly when planted out (>80% survival and >3 m tall by end of 2nd rainy season). They develop broad crowns (>2.4 m across), which effectively shade out weeds and they flower, fruit and provide bird nest sites by the 3rd year after planting. Birds such as, Sunbirds, Spiderhunters and White-eyes feed on the nectar, whilst bulbuls eat the fruits.

How are saplings grown?

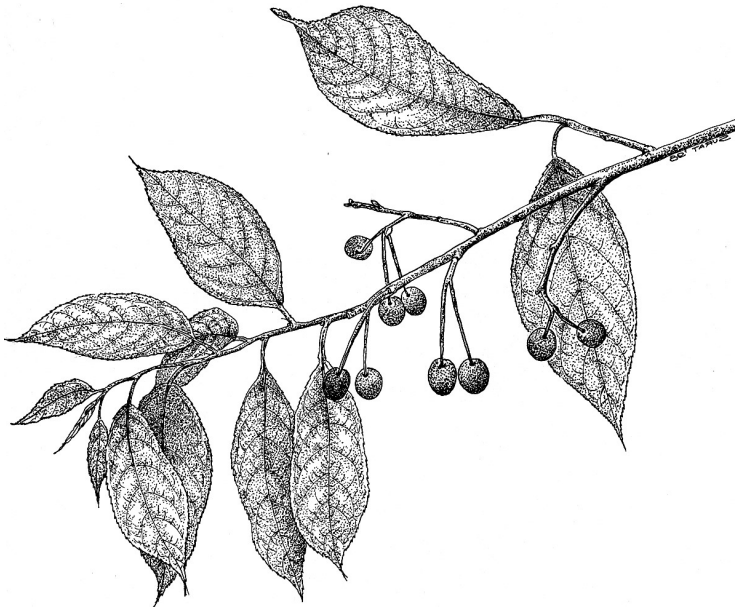
Collect ripe fruits mid-March. Scrape off the fruit pulp with a knife, under running water to expose the woody pyrene. Sun-dry the pyrenes. Place them in airtight containers with silica gel for 2 days, then change the silca gel and store the containers in a refridgerator at 5 degrees centigrade. The following January, take the pyrenes out of storage and sow them in germination trays in full sunlight. GP typically >70%; MLD 48-52 days. Prick out seedlings when they are 5-7 cm tall, with 4-5 leaves (usually 7-10 days after germination). Apply no fertiliser, unless nutrient defidiency symptoms develop and if necessary, prune the plants to prevent them from outgrowing their containers. Saplings are ready for planting, when 30 cm tall (TNT 5 months, excluding seed storage).

How should saplings be planted and cared for?

P. cerasoides responds well to cardboard mulching, repeated for two years. The species is also suitable for direct seeding. Prepare and store pyrenes as described above, then sow them directly into deforested sites at the beginning of the rainy season. (see Part 4).

What can this species be used for?

Wood used for construction, furniture, cabinet-work, interior finish and firewood. Leaves for fodder. A popular ornamental tree in gardens and along roadsides. Plantations have been established in Nepal.



Sapindus rarak DC. (SAPINDACEAE)

Mah Sak

A medium-sized, light-demanding, deciduous tree, growing up to 25 m tall (DBH 25 cm).

Where does it grow?

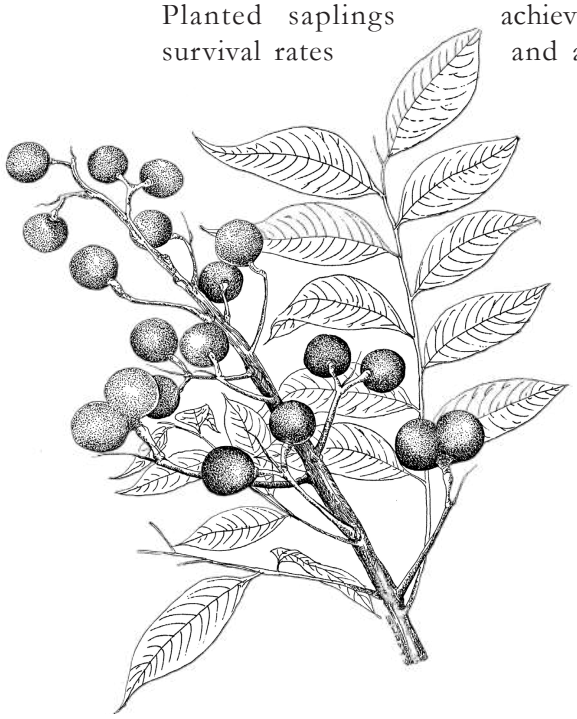
In India (Assam), Myanmar, Indochina, and Indonesia. In N. Thailand, it is common in EGF and MXF, often on disturbed sites or along streams, at elevations of 625 to 1620 m.

What are its distinguishing characteristics?

Bark: grey or light brown, becoming fissured with age. ***Leaves:*** spirally arranged, paripinnate, 38-44 cm long; leaflets 8-10, mostly opposite; leaflet blades asymmetrically lanceolate to oblong, 7-13 x 2.5-3.5 cm. ***Flowers:*** inflorescences terminal, 23-35 cm long; flowers numerous, bisexual, 4 mm long, petals white; March to April. ***Fruits:*** drupes, globose, leathery and wrinkled; yellow-brown when ripe, 25 x 23 mm; seed, one per drupe, black 16 x 15 mm; July to January; animal-dispersed.

Why is it a framework species?

S. rarak is an acceptable framework species. Planted saplings achieve excellent survival rates and acceptable growth rates (c.80% survival; averaging 1.25 m tall, by end of 2nd rainy season). Despite a narrow crown, the species effectively suppresses weed growth. It fruits prolifically, but takes longer than 7 years before fruiting commences. Its fruits are eaten by wild pigs and deer. This species survives moderate fires and regenerates well after burning (100% survival of trees burnt 33 months after planting; RCD >10 mm).



How are saplings grown?

Cut fruits from trees as soon as ripe ones are first seen (ideally August). Remove fruit flesh. Put pyrenes in water and discard non-viable ones, which float. Sow those that sink, in germination trays in full sunlight. GP usually >80%; MLD 45-52 days. Germination is asynchronous, continuing for >130 days. Prick out seedlings at frequent intervals after expansion of first true-leaf pairs. If fertilizer is applied, containerized saplings usually grow tall enough for planting out by 1st planting season after seed collection (TNT 10 months).

How should saplings be planted and cared for?

Standard planting and after-care procedures (Part 7), with cardboard mulching, usually yield good results. *S rarak* grows best in moist but sunny locations. If surrounded by faster-growing tree species, shade suppresses growth. It is susceptible to attack by white aphids.

What can the species be used for?

Saponins, from the fruits, are used to make soaps and shampoos and have antibacterial properties. The fruits are also used to make insecticides. *S. rarak* wood can be used for general construction and furniture, but it is not durable. Seeds can be used for buttons or beads.

Glossary

Accelerated (assisted) natural regeneration ANR: forest restoration performed by enhancing the survival and growth of tree seedlings and saplings already present (without tree planting).

Alluvium: the parent material of alluvial soils: sand, silt, clay and gravel deposited by fluvial systems.

Biodiversity: the variety of life encompassing genes, species and ecosystems.

Buttress: a vertical projection at the base of a tree trunk, originating from a lateral root.

Climate Change: progressive changes in average weather conditions influenced by human activities such as burning fossil fuels, cutting down forests, farming livestock etc.

Climax forest: dynamically stable forest with biomass, structure, biodiversity and ecological functioning, sustainable within prevailing soil and climatic conditions.

Deciduous: shedding leaves annually or periodically; not evergreen.

Ecology: the scientific study of the factors determining the distribution and abundance of plants and animals.

Ecosystem: any area or space, within which living organisms and the non-living environment interact to bring about an exchange of materials between the living and non-living parts of the system.

Epiphyte: (adjective epiphytic): a plant growing upon, but not nourished by, another plant.

Evergreen: a plant that retains green foliage throughout the year.

Exotic: of species - introduced, not native.

Extinction: the complete loss of a species globally, when no more individuals of a species exist.

Extirpation: loss of a species locally e.g. from a park , province, country or region.

Fault (geology): a planar rock fracture that shows evidence of the Earth's crust where the tectonic plates move and rub against one another.

Fire break: a strip of land cleared of vegetation, to prevent the spread of wildfires.

Forest restoration: any activity aimed at re-establishing the forest ecosystem originally present on a deforested site before deforestation occurred; one particular kind of reforestation.

Framework species method: planting indigenous forest tree species, which can rapidly re-establish canopy cover and attract seed dispersing wildlife, to accelerate forest regeneration and biodiversity recovery.

Geomorphology: the study of landforms, their processes, form, and sediments at the surface of the Earth.

Graben: a valley or depressed block of the crust, often occurring side-by-side with horsts bordered by parallel normal faults

Greenhouse effect: trapping of heat in the atmosphere by greenhouse gases such as carbon dioxide and methane.

Habit: the characteristic growth form of a plant species e.g. as a tree, shrub, herb etc.

Herbarium: a collection of dried plant specimens for scientific study.

Indigenous: native to an area, not introduced: the opposite of exotic.

Keystone species: a species which plays a disproportionately large role in maintaining ecosystem stability. .

Monsoon: a major wind system that seasonally reverses its direction, across South and SE Asia and the Pacific and Indian Ocean.

Mutation: changes in the genetic sequence or in the nucleotide sequence of the genome of an organism.

Natural selection: the differential survival and reproduction of individual plants and animals due to differences in their form and genetic make up.

Particulate Matter (PM): suspended particles in air, mixture of various chemical composition and size caused by nature and human activities, considered pollutants.

Phenology: the study of seasonal cycles of biological phenomena e.g. the periodic flowering and fruiting of trees.

Photosynthesis: process used by plants, algae, and certain bacteria to turn sunlight, carbon dioxide and water into sugars, as a metabolic energy source, and oxygen.

Primary forest: climax forest which has never been substantially disturbed by human activities, where evolution has continued for millennia uninterrupted.

Reforestation: planting trees to re-establish tree cover of any kind; includes plantation forestry, agroforestry, community forestry and forest restoration.

Sapling: a young tree, larger than a seedling, but not yet mature.

Seed predator: any animal, which destroys seeds without successfully dispersing them.

Soil profile: a vertical section through soil to display soil layers.

Solid waste: unwanted or useless solid materials generated from human activities in residential, industrial, or agricultural areas.

Watershed: a ridge of high land or hill separating two areas that are drained by different river systems.

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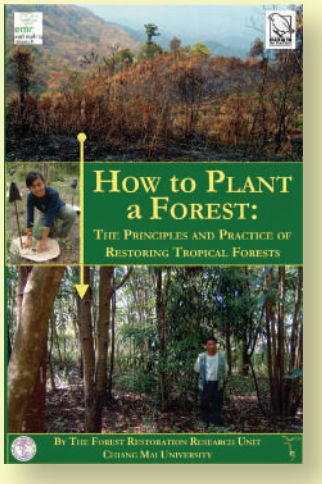

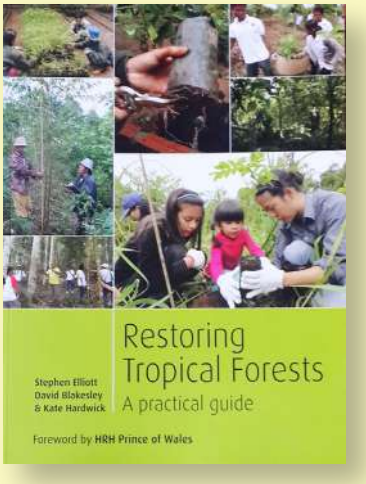

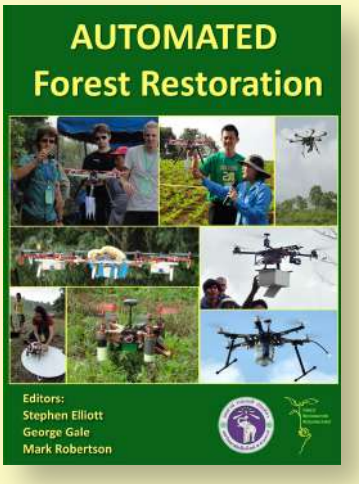

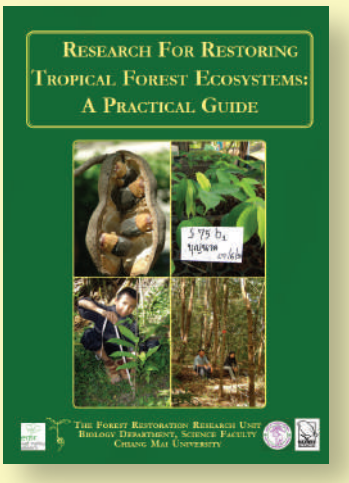

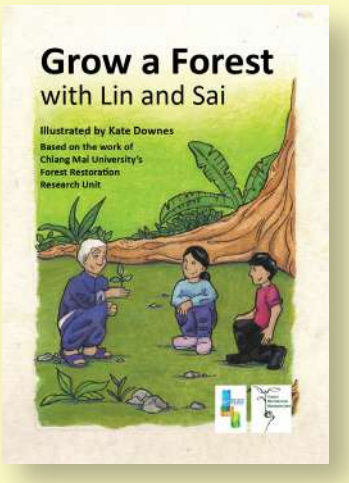

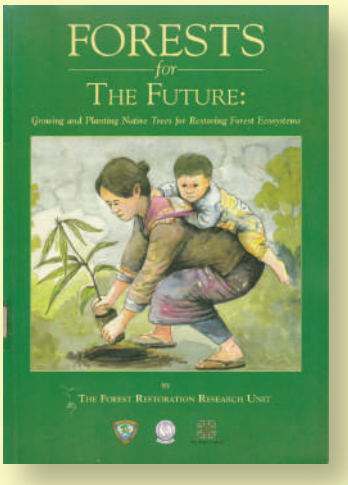

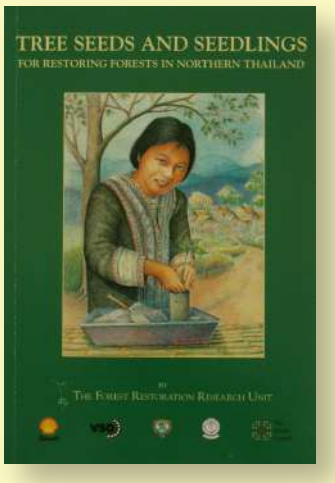

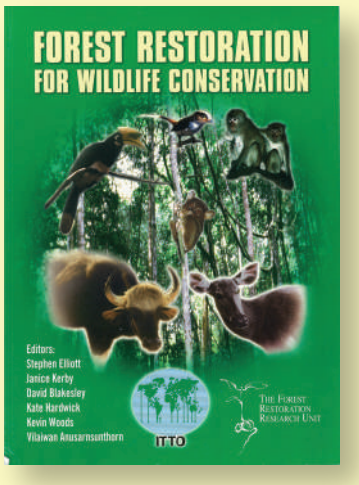

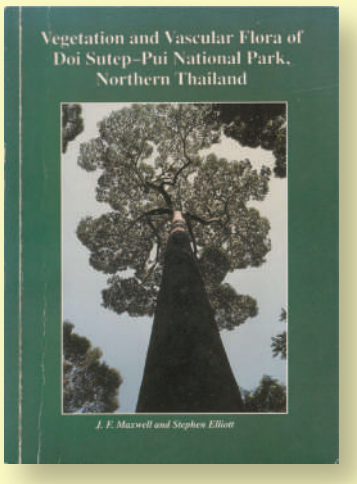

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