DOCTORAL THESIS

SHIBAURA INSTITUTE OF TECHNOLOGY

THE ROLE OF TRADITIONAL ECOLOGICAL KNOWLEDGE IN CLIMATE CHANGE ADAPTATION

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DEDICATION

I dedicate this thesis to my late father who has never failed to give me consistent encouragement in my pursuit of learning during his lifetime. And to my mother, who strongly supports me every step of the way.

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ABSTRACT

The traditional knowledge of indigenous people is often neglected despite its significance in combating climate change. This study uncovers the potential of traditional ecological knowledge (TEK) from the perspective of indigenous communities in Sarawak, Malaysian Borneo, and explores how TEK helps them to observe and respond to local climate change. Data were collected through interviews and field work observations and analysed using thematic analysis based on the TEK framework. The results indicated that these communities have observed a significant increase in temperature, with uncertain weather and seasons. Consequently, drought and wildfires have had a substantial impact on their livelihoods. However, they have responded to this by managing their customary land and resources to ensure food and resource security, which provides a respectable example of the sustainable management of terrestrial and inland ecosystems. The social networks and institutions of indigenous communities enable collective action which strengthens the reciprocal relationships that they rely on when calamity strikes. Accordingly, the communities maintain their TEK through cultural festivals and oral traditions passed from one generation to another. TEK is a practical tool that helps indigenous communities adapt to climate risks and promotes socio-ecological resilience, which upholds social empowerment and sustainable resource management.

TABLE OF CONTENTS

DEDICATION i
ACKNOWLEDGEMENT ii
ABSTRACT iii
TABLE OF CONTENTS iv
LIST OF TABLES vii
LIST OF FIGURES viii
LIST OF ABBREVIATIONS ix
CHAPTER 1 1
INTRODUCTION 1
1.1 Introduction 1
1.2 Problem Statement 2
1.3 Research Objectives 3
1.4 Research Questions 3
1.5 Significance of Research 4
1.6 Scope of Research 4
1.7 Thesis Structure 5
CHAPTER 2 6
LITERATURE REVIEW 6
2.1 Traditional Ecological Knowledge (TEK) 6
2.1.1 Definition of TEK 6
2.1.2 Emergence of TEK at the international level 7
2.1.3 TEK is traditional science 9
2.2 TEK in climate change adaptation 10
2.2.1 Climate change adaptation 10
2.2.2 TEK and climate change adaptation 11
2.3 Example of Case Study in Japan: The Ainu 16
2.3.1 Background 16
2.3.2 Ainu local knowledge of the environment 17
2.3.3 Ainu land and resource management 18

2.3.4 Ainu social networks and institutions 19
2.3.5 Ainu worldviews and belief systems 20
2.4 Summary 21
CHAPTER 3 22
RESEARCH METHODOLOGY 22
3.1 Introduction 22
3.2 Research Approach and Design 22
3.3 Selection of Study Area and Research Participants 23
3.4 Data Collection & Research Instrument 25
3.5 Data Analysis 25
CHAPTER 4 27
CASE STUDY 1: THE LUN BAWANG, BA'KELALAN 27
4.1 Background 27
4.2 Demographic profiles of the Lun Bawang 29
4.3 The Lun Bawang's TEK 30
4.3.1 Local knowledge of the environment 31
4.3.2 Land and resource management 33
4.3.3 Social networks and institutions 39
4.3.4 Worldviews and belief systems 41
4.3.5 Summary 43
CHAPTER 5 CASE STUDY 2: THE SA'BAN, LONG BANGA 45
5.1 Background 45
5.3 Demographic profiles of the Sa'ban 47
5.2 The Sa'ban's TEK 48
5.2.1 Local knowledge of the environment 49
5.2.2 Land and resource management 51
5.2.3 Social networks and institutions 55
5.2.4 Worldviews and belief systems 57
5.2.5 Summary 58
CHAPTER 6 CASE STUDY 3: THE PENAN, LONG LAMAI 60
6.1 Background 60
6.3 Demographic profiles of the Penan 62
6.2 The Penan's TEK 63

6.2.1 Local knowledge of the environment 64
6.2.2 Land and resource management 66
6.2.3 Social networks and institutions 70
6.2.4 Worldviews and belief systems 72
6.2.5 Summary 72
CHAPTER 7 COMPARISON OF ADAPTATION STRATEGIES AMONG THE LUN BAWANG, SA'BAN AND PENAN 74
7.1 Comparison of adaptation strategies 74
7.1.1 Local knowledge of environment 78
7.1.2 Land and resource management 79
7.1.3 Social networks and institutions 81
7.1.4 Worldviews and belief systems 83
7.2 Discussion 84
CHAPTER 8 IMPLICATIONS AND CONCLUSIONS 87
8.1 Introduction 87
8.2 Research Implications 87
8.2.1 Theoretical implications 87
8.2.2 Practical implications 91
8.3 Research Limitations 101
8.4 Future Research 102
8.5 Conclusion 103
REFERENCES 104
LIST OF PUBLICATIONS 113
Appendix A 114

LIST OF TABLES

Table 1: Emergence of TEK at the international level 8
Table 2: Comparison of perspectives on TEK framework 11
Table 3: Demographic profiles of the Lun Bawang 29
Table 4: Traditional strategies of the Lun Bawang for addressing climate change risks 30
Table 5: Demographic profiles of the Sa'ban 47
Table 6 Traditional strategies of the Sa'ban for addressing climate change risks 48
Table 7: Demographic profiles of the Penan 62
Table 8: Traditional strategies of the Penan for addressing climate change risks 63
Table 9: Comparison of adaptation strategies among three communities 75
Table 10: TEK, adaptation strategies and resilience 88
Table 11: Past studies on TEK in climate change context 90
Table 12: Proposed land use zoning for Ba'kelalan, Long Banga and Long Lamai 97
Table 13: Current zoning features and its considerations 98
Table 14: Proposed zoning features and its considerations 98

LIST OF FIGURES

Figure 1: Historical perspective of human knowledge 10
Figure 2: Conceptual framework 12
Figure 3: Location of study area and its natural areas 23
Figure 4: Ba'kelalan area 27
Figure 5: Ba'kelalan scenery 28
Figure 6: The *lati'ba'* (wet rice paddy) 34
Figure 7: Utilisation of buffaloes in the lati'ba' (wet rice paddy) 35
Figure 8: The kabun (home garden) 36
Figure 9: The sulap padi (paddy store) 37
Figure 10: Conservation of surrounding virgin forest 38
Figure 11: Community meeting at the Church 40
Figure 12: Community working together in the lati'ba' (wet rice paddy) 40
Figure 13: The tetel (fireplace) 43
Figure 14: Long Banga area 45
Figure 15: Long Banga scenery 46
Figure 16: Traditional calendar of Sa'ban 50
Figure 17: Shape of the bliin teng (first quarter moon) 50
Figure 18: The padi iraang (upland rice) 52
Figure 19: The paau padi (paddy store) 53
Figure 20: The éra (home garden) 54
Figure 21: Community pooling during rice harvesting 56
Figure 22: Long Lamai area 60
Figure 23: Long Lamai scenery 61
Figure 24: The inan parai (upland rice) 67
Figure 25: The pulah (home garden) 68
Figure 26: Conservation of the forest and natural resources 70
Figure 27: Bridging TEK, adaptation and resilience of socio-ecological systems 89
Figure 28: Percentage of land tenure in Sarawak 92
Figure 29: Proposed elements to be included in the Sarawak Zoning Plan 93
Figure 30: Proposed elements for identifying ICCA under the NCR land 93
Figure 31: Example of proposed zoning for Ba'kelalan 94
Figure 32: Example of proposed zoning for Long Banga Source: Author, 2020 95
Figure 33: Example of proposed zoning for Long Lamai 96
Figure 34: Elements of Cultural Heritage Tourism 100

LIST OF ABBREVIATIONS

TEK	-	Traditional Ecological Knowledge
IK	-	Indigenous Knowledge
TK	-	Traditional Knowledge
SDG	-	Sustainable Development Goal
IPCC	-	Intergovernmental Panel on Climate Change

CHAPTER 1

INTRODUCTION

1.1 Introduction

A global trend of climate warming is now clear and has been well documented in many research studies. Over the past few decades, the earth has experienced rapidly increased temperature change (New et al., 2009), with record high temperatures occurring in the past decade (Scripps Institution of Oceanography, 2017). Human activities are the primary drivers of climate change, contributing more than 95 percent of the rapid temperature rise (Cook, 2016), especially due to the burning of fossil fuels, deforestation and land-use changes that emit greenhouse gases. Worldwide, the impacts of global warming are evident and the trend is projected to become even more disruptive in the future (Bryndum-Buchholz et al., 2019; Jimenez & Takahashi, 2019). One response to such change is mitigation action to reduce the extent of warming; in addition, it is imperative to adapt to the climate change that already exists. Adaptation, however, has become more difficult in the face of uncertainties caused by the effects of climate change; therefore, developing adaptation will require further intervention in many directions (Kettle & Dow, 2014).

In response to this need, attention has increased to the efforts of Indigenous peoples with their traditional ecological knowledge (TEK), with a demonstrated capacity for addressing climate change at grassroots levels (Kupika et al., 2019). A growing body of research and global policy debates highlights how this knowledge system can contribute to climate action under Sustainable Development Goal (SDG) 13 and to life on land in SDG 15 by detecting climate change and responding and adapting to its impact, thereby supporting global adaptation actions.

TEK is an important expression of the Indigenous culture and is inextricably linked to Indigenous peoples' traditions. These peoples' knowledge and management reflect values that shape and facilitate their responses to the dimension of global climate change (Adger et al., 2013). Hence, despite Indigenous peoples being the worst affected by climate change, their TEK responses to local-level climate variations offer significant contributions to adaptation (McLean, 2012). TEK is the root of Indigenous peoples'

resilience and can foster their capacity to adapt to environmental change and uncertainties based on an in-depth understanding of the land (Scaddan, 2008). Although Indigenous peoples only represent 5 percent of the world's total population (Ramos-Castillo et al., 2017), Indigenous communities occupy roughly a quarter of the planet's land area, including many of the world's biodiversity hotspots (Schuster et al., 2019). This has challenged them to become ideal custodians of the landscapes and ecosystems in ways that are essential to climate change adaptation.

1.2 Problem Statement

Climate change is probably the greatest environmental risk of our time, and all sectors of society feel its impacts. Of these, rain-fed agriculture probably is the most directly affected (IPCC, 2007), so that Indigenous communities dependent on agricultural subsistence are in turn likely to be the most affected. While Indigenous peoples are now widely regarded as the most vulnerable to climate change impacts (Nakashima et al., 2012), their unique knowledge and experience are still relatively unappreciated when strategies are aimed at reducing vulnerability or developing adaptation to changing circumstances (Nalau et al., 2018). The Intergovernmental Panel on Climate Change (IPCC), for example, recognises the importance of Indigenous knowledge and attempts to incorporate such knowledge. However, in its latest reports (Assessment Report 4 and Assessment Report 5), Indigenous participation has often been overlooked or limited in scope. Since the interventions are intended for the most vulnerable, specifically the Indigenous communities, local knowledge holders and skills could instead be of great value.

There are several explanations for such omission. The most vulnerable groups have become the victims of institutional and social discrimination (Salick & Byg, 2007), hence diminishing their roles in development and political discourse, including climate change. In essence, they have been portrayed as victims of climate change impacts, rather than as agents of environmental protection (Etchart, 2017); this has also caused their culture and knowledge systems to be neglected as well. Indeed, there has been little discussion in Malaysia about the adaptation of Indigenous peoples to climate change.

Scholars have shown, however, that there is much to be learned from Indigenous and community-based practices that engage climate change adaptation, resilience and preparedness for disasters (Nakashima et al., 2012; Vinyeta & Lynn, 2013). This is because Indigenous peoples have often adapted to changes in the environment based on their long-term experience and exploration, which are passed from one generation to the next (McMillen et al., 2014). Through this process, a wide range of coping strategies has been developed or enhanced and is maintained locally or regionally (Gómez-Baggethun et al.,

2012; Leonard et al., 2013). Therefore, Indigenous peoples' knowledge and practices, specifically TEK, may provide a significant foundation for today's attempts to address even greater challenges of climate change.

1.3 Research Objectives

In view of the preceding arguments, the aim of this study is to investigate how some of the Indigenous peoples of Malaysia have been adapting to climate change by using TEK. There are three specific objectives of this study:

1. To describe the role of TEK in climate change adaptation context based on typologies of TEK.
2. To enhance understanding of Indigenous peoples' adaptation strategies to climate change based on three different case studies.
3. To provide important insights into the theoretical and practical implications.

1.4 Research Questions

This study responds to multiple questions according to the objectives of the study. The research questions for this study are as follows:

1. What does TEK mean?
2. Is TEK important in the climate change context?
3. Why is TEK important in the climate change context?
4. How do communities view climate change based on their local observations?
5. What are the adjustments that communities make in terms of land and resource management?
6. What are the interactions among the communities when facing disturbance?
7. What are the values and practices that the communities have retained to enable adaptation across generations?
8. Are there any differences or similarities between the different tribes in adapting to climate change?

1.5 Significance of Research

The purpose of this study is to intensively review the role of TEK in Indigenous peoples who are adapting to climate change. This research is expected to add to the body of knowledge in the field of climate change adaptation involving Indigenous peoples. TEK generates value that is actually not adequately understood and appreciated, and its holders have not been appropriately compensated when the existing system applies their knowledge. Therefore, this study may also serve as a catalyst for decision makers to formulate new strategies and initiatives to include these Indigenous communities in decision-making and protect their rights, including their use of TEK.

Analysing TEK in the context of climate change also reveals the value of TEK toward fulfilment of society's broader goals, such as conserving the environment, ensuring food security and developing sustainable agriculture, while protecting TEK encourages traditional practices and lifestyles to be maintained. This study provides a foundation for government and other stakeholders to collaborate with Indigenous peoples in developing appropriate and successful strategies to plan for and adapt to changing environmental conditions. This should include entities (government and non-government) defining and working towards what the communities want to accomplish, rather than relying solely on policy directives from the government.

1.6 Scope of Research

TEK is the central focus of the study to be conducted. There are four important components that are considered in the TEK:

1. Local knowledge of the environment—knowledge focused on careful observation of the local environment to direct their livelihood activities through time and space, including farming, hunting, fishing and gathering

2. Land and resource management—knowledge of the use of natural resources by Indigenous peoples and terrestrial and marine management strategies that have evolved through adaptive processes

3. Social networks and institutions—the social mechanisms of TEK, which describe the behaviour and role of individuals or communities when facing climate disturbance

4. Worldviews and belief systems—values which shape the behaviour of adaptation and how knowledge is accumulated across generations

The study involved three sub-ethnic groups of the Orang Ulu in Sarawak, namely, the Lun Bawang, Sa'ban and Penan. These were selected as participants in the research because most of the groups' members still reside in the remote interior of Sarawak and perform traditional practices in their daily activities.

1.7 Thesis Structure

This research process has been developed with careful planning, in order to address the research questions of this study and to attain its objectives. The thesis includes eight sections.

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Research Methodology

Chapter 4: Case Study 1 – The Lun Bawang

Chapter 5: Case Study 2 – The Sa'ban

Chapter 6: Case Study 3 – The Penan

Chapter 7: Comparison of adaptation strategies among the Lun Bawang, Sa'ban and Penan

Chapter 8: Implications and conclusions

CHAPTER 2

LITERATURE REVIEW

2.1 Traditional Ecological Knowledge (TEK)

2.1.1 Definition of TEK

Different cultures across the globe have different views of the natural world, which are not based on the fairly recent modern scientific outlook. These 'other ways of knowing' are often rooted in the traditional belief systems of indigenous people. They include sophisticated collections of interpretations and information that help societies interact with the natural environment for survival (e.g. hunting, fishing and gathering; agriculture and medicine and natural phenomena) as well as coping with any environmental changes (Nakashima *et al.*, 2012). Indigenous people consider their environmental management system as a vital part of their cultural identity and social integrity (Mazzocchi, 2006).

Many terms have been used to describe the body of indigenous people's knowledge, such as indigenous knowledge (IK), traditional knowledge and TEK. However, even though they sound a bit similar, these terms carry slightly different meanings. Magni (2016), for instance, described IK as the local knowledge of indigenous people or other particular cultural groups. This term is usually used in the development literature to describe local ways of knowing as opposed to the modern understanding of globalised culture or developmental science (Dudgeon & Berkes, 2003). Dudgeon and Berkes (2003) also argued that 'traditional knowledge' can be used as an alternative for IK. The term 'tradition' refers to cultural features, customs or thought processes handed down and thus preserved from generation to generation (Graburn, 2001). In this context, tradition is not static but cumulative and open to change (Nicholas-Figueroa, 2017). In other words, as their surroundings change, a cultural group will adapt to such change. TEK, on the contrary, has been defined as 'a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment' (Berkes, 1993: p. 4). Thus, TEK can be regarded as a 'more specific' subset within the larger body of IK literature.

Although both IK and TEK emphasise the social patterns of relationships within a cultural group and within the ecosystem (cultural aspect), TEK adds an ecological aspect; that is, it focuses on interaction patterns between human and nature as well as local ways of knowing and interacting with the ecosystem (Dudgeon & Berkes, 2003). This holistic approach derives from the definition of ecology itself, i.e. the relationship between living organisms and their biophysical environment (Friederichs, 1958). Since TEK is strongly connected to physical settings, every aspect of the local biosphere, including plants, animals, and landforms, can be considered as a part of the community and are therefore treated with respect and honour (Pierotti & Wildcat, 2000). This body of knowledge generally includes languages, systems of naming and classification, sustainable practices for the use of resources, rituals, indigenous worldviews and spirituality (Boven & Morohashi, 2002; Vinyeta & Lynn, 2013).

Essentially, TEK is cumulative, dynamic and adaptive. It is also grounded in the historical experiences of people and is the result of careful observations of ever-changing environmental, economic, social, spiritual and political conditions, reflecting the fact that knowledge of all these aspects is essential to survival (Berkes, 2017). Indigenous people express TEK as a "way of life"; rather than just knowledge about how to live, it is about the actual living of life (McGregor, 2004: p.78). As a self-management system, TEK is an environmental source of information that helps indigenous peoples protect and sustain their way of life. This is because it has become the basis for decision making, especially in matters related to agriculture, hunting and gathering, resource management, education, nutrition, health and food preparation (Nakashima et al., 2012).

2.1.2 Emergence of TEK at the international level

Western science originates in Europe and has become a common term referring to the dominant knowledge system in the western world. According to Hewson (2015), many great thinkers from the East (such as India, China, Japan, Korea, and Thailand), the Middle East and Africa have also contributed to Western Science. Before TEK was recognised, Western scientific knowledge, values, and skills, based on the works of Ptolemy, Copernicus, Newton, Aristotle, Einstein, Darwin, and others, had dominated those of indigenous people around the world (Hewson, 2015). The reason for this imbalance is rooted in the history of European Colonialism. In the 19th century, the colonial expansion involved a so-called mission aimed at making the less developed community more civilized (Aybar, 2014). Moreover, the dominant scientific ideas at that time have promoted the European vision of social evolution in which indigenous peoples were seen as 'savages' or 'barbarians' occupying the lowest levels of civilisation (Popova-Gosart, 2009). Consequently, the colonised people (i.e. indigenous people) were denied equal status within the legal system, and their cultures, knowledge an systems were

perceived as 'less civilised' and 'backward' in the globalised world (Latta & Wittman, 2012; Popova-Gosart, 2009).

However, after the World War II, the value of indigenous people and their knowledge systems began to be acknowledged at the global level due to the changes in the world economy and international political climate. The reasons for such recognition are fourfold: (1) information potential, (2) economic potential, (3) political potential and environmental potential of TEK (Berkes, 2017; Popova-Gosart, 2009). First, the transition of labour and capital into knowledge and technology intensive in the world economy during the 1970s has promoted the potential of TEK. Second, TEK is recognised as an intangible aspect of cultural/intellectual heritage that needs further protection and preservation which serves as an economic benefit of the state and/or humanity. Thirdly, the initial impetus of the human rights movement, that promotes "indigenous empowerment" which in turn helps indigenous peoples to restore their cultural/intellectual heritage within the global community. Finally, public frustration with modern practices in relation to resource management and conservation has triggered the inclusion of indigenous people and their TEK in this regard. Since the late 1970s, the credibility of TEK at the global level has been recognised by numerous international organisations, as shown in Table 1.

Table 1: Emergence of TEK at the international level

Year	Description
1971	Man and the Biosphere Program (MAB) is launched by UNESCO to conduct scientific investigations of traditional systems
1983	Programs under UNESCO have recognised traditional management systems in coastal marine areas
1984	Ecology Commission of the International Union for Conservation of Nature (IUCN) has established the Traditional Ecological Knowledge Working Group to promote the underrated TEK in natural resource conservation and management
1987	The Brundtland Commission Report recognised the role of indigenous groups to sustainable development
1991	The United Research Institute for Social Development (UNRISD) conducted a Program in Protected Areas to examine the role of indigenous knowledge in the context of participatory management
1992	The Convention on Biological Diversity (CBD) recognised the need to respect and preserve the knowledge and practices of indigenous and local

	communities especially their traditional way of life in relation to conservation and sustainable use of biological diversity
1993	Agenda 21, Chapter 26, Section 1 in the Earth Summit emphasised the recognition of indigenous values, traditional knowledge and resource management
1993	The Inter-Commission Task Force on Indigenous People of IUCN recognised indigenous people in strategies for sustainability
Early 2000s	The IUCN shows interest in indigenous and community conserved areas

Source: Berkes, (2017); Cordell (1995); IUCN (1993); Tsuji & Ho (2002); Vivian (1991)

2.1.3 TEK is traditional science

Science can be considered similar to TEK, thus, TEK is science (Hobson, 1992), i.e. the traditional science. In this regard, TEK is also driven by the 'curiosity' element that drives the Western scientific studies (Berkes, 2017). As Lévi-Strauss (1962) argued, the ancient people employed scientific curiosity (observation and experiments) to develop certain sophisticated technological skills (e.g. the making of water-tight pottery using unstable clay and fired under appropriate temperature, fuel and duration). In addition, indigenous people also conduct some type of science during their annual subsistence activities using their wealth knowledge of flora and fauna. In fact, they also have their own versions of Earth science, meteorology, physics, botany, chemistry, psychology and pharmacology (Barnhardt & Kawagley, 2005). Interestingly, TEK is as ancient as humankind whereby people across the world have develop a multitude of livelihoods before the emergence of modern science (Figure *1*). In fact, the origins of science are deeply embedded in traditional knowledge (Nakashima et al., 2012). In the Palaeolithic period for example, humans lived as hunter-gatherers and they have innovative hunting tools and various food-storage techniques (Thodengal & Kandiyil, 2014). In the Neolithic period, on the other hand, humans have developed important technology in agriculture, animal husbandry, food preparation/conservation, weaving and pottery (Lévi-Strauss, 1962).

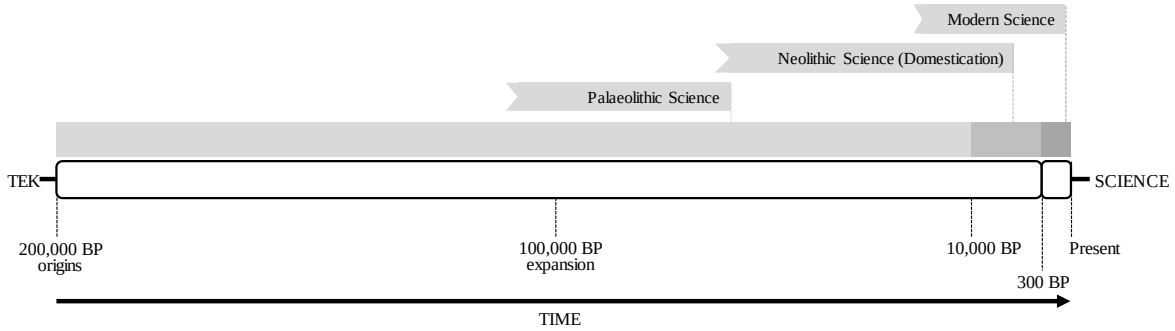


Figure 1: Historical perspective of human knowledge
Source: Adapted from Toledo & Barrera-Bassols (2009)

Therefore, TEK should not be neglected in the modern world because both Western science and TEK denote two different ways of perceiving the world. In other words, while Western science learns about the world by studying individual parts, TEK understands the world by observing the relationship between all parts (Mazzocchi, 2006). Currently, many disciplines embedded in Western science have recognised the value of TEK. Various forms of TEK are commonly accepted in disciplines such as the social sciences, medicine and public health, resource management, conservation of protected areas, biodiversity conservation, environmental monitoring and assessment, development and environmental ethics (e.g. Berkes, 2017; Biró et al., 2019; Khalafzai et al., 2019; Sundaram et al., 2019; Ulicsni et al., 2019). Due to its relevance, many climate researchers have also begun to embrace the practicality of applying TEK to contemporary climate change initiatives.

2.2 TEK in climate change adaptation

2.2.1 Climate change adaptation

Climate change adaptation has been an underappreciated topic across recent decades because mitigation action has seemed more urgent (Farber, 2007). Nonetheless, any mitigation measures that take place are expected to be insufficient to address all the impacts of climate change, resulting in an urgent need for adaptation. Adaptation is defined as 'the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects' (IPCC, 2014: 1758). However, climate change has instigated considerable environmental changes across the globe, which in turn necessitate adaptation strategies at multiple levels (i.e. global, regional and local levels) (Kettle & Dow, 2014). Because Indigenous peoples have amassed unique knowledge, practices and beliefs that connect them to the environment, they can be significant contributors to robust climate adaptation action.

2.2.2 TEK and climate change adaptation

When TEK complements scientific data through provision of site-specific precision and detail, valuable insights emerge (Vinyeta & Lynn, 2013). In essence, local explanations of observed climate changes are often more holistic and diverse when compared to the conventional climate model, which focuses largely on anthropogenic greenhouse gas emissions (Salick & Byg, 2007). The detection of environmental changes and development of strategies to adapt to these changes are important climate responses that can be informed by TEK (Parrotta & Agnoletti, 2012).

Essentially, TEK helps Indigenous peoples to track changes in their local surroundings through TEK-based observations and then to document their adaptation strategies responding to those changes. These abilities can be understood as emerging from the typologies of TEK. Using several interrelated levels of analysis, TEK can be structured as a knowledge–practice–belief complex (Berkes, 1999, 2017; Houde, 2007; McMillen et al., 2014). The first level is factual observation, followed by management practices at the second level, with social organisation at the third level. Finally, a fourth level underpins the other three levels of TEK, presenting the perceptions that govern relationships of humans and their environment (Berkes, 2017).

Berkes and other scholars (e.g. Davidson-Hunt & Berkes, 2003; Orlove & Brush, 1996) have studied the TEK framework from the perspectives of science of ecology, conservation of biodiversity and management of natural resources. The framework engages folk taxonomies, plant and animal ethnobotanical and ethnozoological classifications and perception of ecological processes, including human relationships to animals, plants and sometimes supernatural influences. Such information is usually used to target species and to develop methods that can protect habitats and natural resources. The present study, on the other hand, seeks to address TEK from a different perspective, that of climate change. Table 2 compares the TEK perspective in this study with previous studies.

Table 2: Comparison of perspectives on TEK framework

TEK elements	Previous studies by Berkes and others	This study
Local knowledge of lands, animals	Species identification	Forecast and track surrounding changes (e.g. weather, climate, seasons, etc.), including phenology of plant and animal species
Resource management systems	Species management	Managing land and resources so as to adjust to changes/disturbance

Social institutions	Social institution for management of species	Social relationship/ties, institutions and behaviour of the communities that foster social cohesion in the face of changes/disturbance
Worldviews	Values that shape management of species across generations	Values that shape management of land and resources, social relationship and behaviour; also, accumulation of values across generations

Based on a literature review, we developed a conceptual framework to describe and explore TEK in the context of climate change (Figure 2), using the TEK typologies of (1) local knowledge of the environment, (2) land and resource management, (3) social networks and institutions, and (4) worldviews and belief systems.

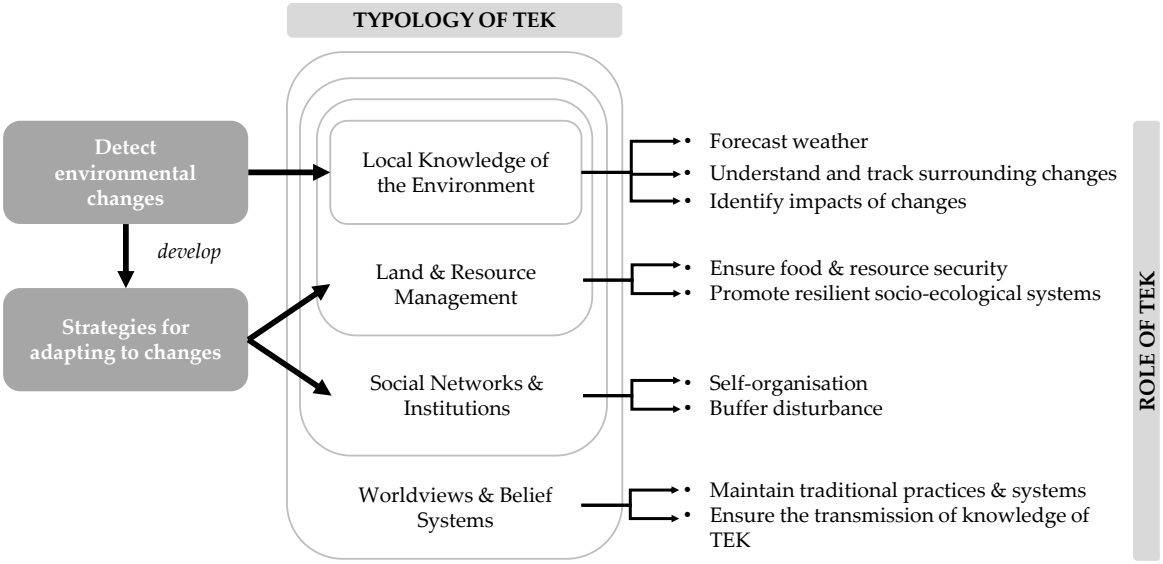


Figure 2: Conceptual framework

(a) Local knowledge of the environment

Local knowledge of the environment includes the knowledge of the flora, fauna, soil and landscapes as well as their classification, behaviour and distribution (Berkes, 2017; Houde, 2007; McMillen et al., 2017). This type of knowledge also encompasses understanding how the ecosystem works, the interactions of animals and plants within it and the role of biophysical parameters in influencing the entire community's behaviour (Freeman, 1992). In essence, indigenous people are able to understand the weather based on their understanding of animal behaviour, wind speed, sky coverage and length of precipitation (Garay-Barayazarra & Puri, 2011). For example, the Miriwoong community in East Kimberley, Australia observed the flowers on the Woolegalegeng (silver leaf paperbark tree) to predict the arrival of thunderstorms (Leonard et al., 2013). In the case

of Kenyah Badeng farmers on Borneo island, the behaviour of animals such as chickens and frogs, e.g. their noises, are the indicators of coming rains (Garay-Barayazarra & Puri, 2011). Seasonal changes or cycles can also be observed based on the development and reproduction of flora and fauna. For example, the harvesting seasons for certain plants are indicated by the appearance of certain insects, bird songs or blooming of flowers. These phenological events, i.e. the condition of the weather and cycles of seasons, are very important for indigenous people given their links to the timing of their subsistence activities such as hunting, gathering, agriculture and fishing.

In order to survive, indigenous people must be aware of even the smallest changes in their surroundings and must try to respond to those changes. For example, the Miriwoong people know that the flowering of the Gali-Galing (Fern-leaf grevillea) indicates the beginning of cold season and, thus, respond to this natural event by commencing their traditional burning practices. These practices are motivated by a desire to avoid late hot season fires that can have damaging impacts on the landscape (Leonard et al., 2013). In fact, many indigenous communities have their own traditional or seasonal calendar that they use to organise their relations to the surrounding land, sea and climate and that enables them to manage their activities across varying seasons (e.g. Garay-Barayazarra & Puri, 2011; Leonard et al., 2013; Prober et al., 2011). Generally, this local knowledge can offer very fundamental insights about climate change research. While scientific climate models detect environmental changes at bigger scales (i.e. melting of snow and ice, sea-level rise, high water temperature, etc.), local observations made by the non-industrial community offer information at smaller and more specific scales. Furthermore, indigenous persons' intrinsic knowledge of the environment helps these communities anticipate changing conditions and situations that could pose significant risks. Knowledge, experiences and approaches to dealing with changes in socio-ecological systems are strong assets that could inform climate change adaptation planning. They could help in understanding changes, impacts on local communities and their surrounding as well as coping strategies to adapt to those impacts.

(b) Land and resource management systems

Land and resource management systems contain indigenous people's knowledge about natural resources use and strategies of terrestrial and marine management that have evolved through adaptive processes (Leonard et al., 2013; McMillen et al., 2014). Possession of such systems allows indigenous communities to prepare for an anticipated hazard by modifying practices and developing appropriate technologies sustainably. In the context of climate change, land and resource management systems are fundamental in terms of building adaptive capacity that contributes to community resilience (McMillen et al., 2014; McMillen et al., 2017). In some cases, such as to avoid food depletion, indigenous people make an adaptive decision to ration resources that correspond to ecological

productivity. For example, a temporal restriction of harvest, including fishing, hunting, gathering and planting, could be imposed in response to common shortages as well as to allow renewal of surrounding ecosystems (Berkes et al., 2000; Gómez-Baggethun et al., 2012; Ingty, 2017; McMillen et al., 2014).

In addition, indigenous management systems often promote diversification that helps in spreading risks across spatio-temporal scales by providing a range of options, thus increasing resilience during shocks (Agrawal, 2008). These include swidden agriculture, integrated farming, agroforestry, farming and plantation of multipurpose tree species and crop varieties (Berkes et al., 2000; Hobson, 1992; Magni, 2016). Such mixing and selecting of different livestock and crop varieties in an integrated landscape of farming promotes bio-cultural diversity, which not only resilient to climate change but also has high rates of carbon sequestration in fighting against the change (Singh et al., 2011). Harvests are also spread across the seasons to ensure resources are available throughout the year (Gómez-Baggethun et al., 2012). Another important strategy is mobility which avoid risks across space (Agrawal & Perrin, 2008). For example, one of the most ancient system that the indigenous people still practice is shifting cultivation i.e. a cropland is left for a period without being cultivated to restore its fertility (Hillel, 2005). Fertility of land promotes growth of crops and produce surplus yield. Finally, storage of resources reduces risks experience over time especially in reducing food scarcity (Agrawal & Perrin, 2008; Gómez-Baggethun et al., 2012). Indigenous communities in Asia for instance, have improved the method for food preservation and storage such as using physical infrastructure to store crops and water, and drying food when food is abundance (AIPP, 2012).

(c) Social networks and institutions

Social networks and institutions are the social mechanisms of TEK that explain the social behaviour of actors in the community when facing disturbance. These structures strongly influence indigenous livelihoods and adaptation. In the climate change context, customary social institutions and networks promote adaptive capacity within social-ecological systems by buffering disturbances, promoting self-organisation and facilitating social learning (McMillen et al., 2014). For example, indigenous people of Ka'ūpūlehu in Hawaii and Dõnana, Spain both have practised community pooling during hard times. Such pooling entails sharing assets and resources (such as food, natural resources, labour and infrastructure) across households on a reciprocity basis during scarcity (Agrawal & Perrin, 2008; Gómez-Baggethun et al., 2012). Consequently, these community were able to increase food and resource availability and diversity across space and time, which gave them a buffer against difficulties, especially when resources were scarce e.g. during tsunami, drought and other disturbances (McMillen et al., 2017).

In addition, self-organisation is promoted through local leadership and institutions that provide the capacity to respond to shocks. Strong local leadership and institutions can encourage efficient allocation systems, support sustainability, promote social cohesion within community and store collective memory (Brown & Sonwa, 2015; Gómez-Baggethun et al., 2012; Ingty, 2017). Among community in alpine Himalaya, for instance, the traditional institution, namely the Dzumsa, which consists of 12 village representatives from Lachen valley, is very responsive to environmental stresses. It has played a vital role in preventing overuse of resources, maintaining resource buffers and providing social, environmental and economic security through resource partitioning (Ingty, 2017). Generally, social institutions and networks based on reciprocity and trust will influence the community resilience. In climate change adaptation planning, existing social institutions and networks should be incorporated and strengthened because they could disseminate and promote the exchange of needed resources and information more effectively (McMillen et al., 2014), especially when facing climate change impacts (drought, severity of storms and others).

(d) Worldview and belief systems

The worldview and belief systems of indigenous people underpin the first three elements of TEK, thus playing important roles in TEK as a whole. These systems are the basis for accumulation and transmission of local knowledge and resource management practices as well as the social networks and institutions. This transmission often occurs in the form of folklore, taboos, stories, ceremony and rituals and other related cultural tradition. In other words, worldview and belief systems are a mechanism for intergenerational transmission of knowledge in a form that is embedded in social systems (Berkes et al., 2000: 1257). One example of such transmission is the milpa script (related to milpa agroforestry system), which is passed from generation to generation and sustained by mythologies, cultural beliefs and yearly festivals (Folke & Berkes, 1998).

In practice, ceremonies, rituals and festivals help promote strong social networks and maintain relationships of reciprocity through sharing and exchanging information and resources. They can create and foster robust and enduring relationships among the exchange parties by creating trust and establishing a bond among community members (Ziegler, 2007). Consequently, during hard times, individuals can rely on these reciprocity relationships, thus helping to ensure resilience of resource access. Kula Ring in Papua New Guinea is an example of ritual exchange of gifts made from shells (McMillen et al., 2014). Indigenous peoples' worldviews often involve cultural and spiritual values that encourage sharing, reciprocity, respect and other values that are important for TEK to function. In essence, these values serve as the main factors maintaining traditional practices and systems (Swiderska et al., 2011). Generally, the worldview of indigenous people is fundamental to ensuring the continuity of TEK, especially in the globalised

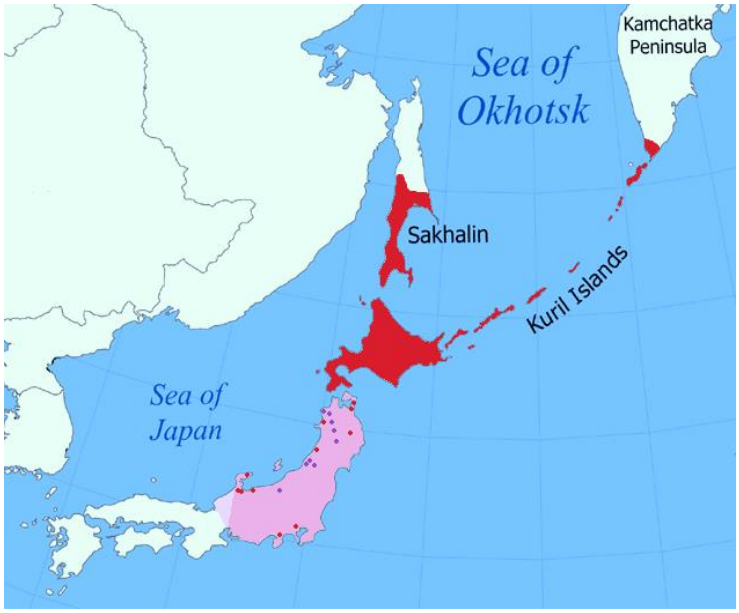
world. Thus, the loss of TEK means the loss of alternative ways of adapting to environmental changes, particularly in the face of climate change.

2.3 Example of Case Study in Japan: The Ainu

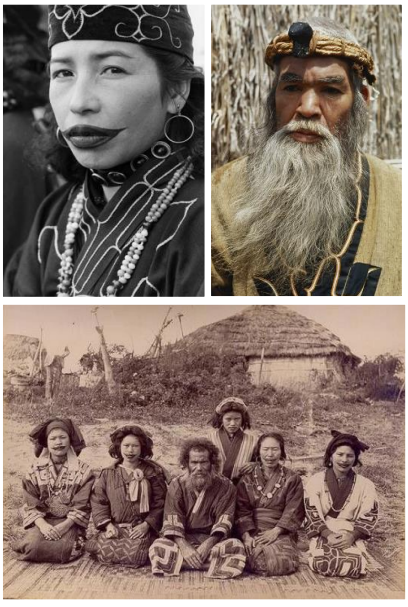
This section presents a description of TEK in Japan, particularly among the Ainu. This case study describes how the Ainu manage their livelihoods based on TEK components.

2.3.1 Background

Japan is home to numerous minority groups, and one of those groups is the Indigenous people of Japan, the Ainu. The word *Ainu* means human beings (Lie, 2004). These people were hunter-gatherers who worshipped nature and animals, spoke a language unlike those around them and had unusual customs such as tattooing their lips. Historical record asserts that by the 13th century, the Ainu people had settled on the northern part of Honshu (the main island of Japan), as well as on the northern island of Hokkaido, the southern part of Sakhalin (called Karafuto in Ainu and Japanese) and the Kuril Islands (Chishima in Japanese) (Sarah, 2013). Ainu settlements were traditionally situated near the ocean and were known as the Ainu Mosir, meaning 'the quiet earth where humans dwell' (Ito, 2008). This people's main subsistence activities are recorded as fishing and hunting (Okada, 2012).



Location of the Ainu
Source: Okada, 2012



The Ainu
Source: Kiriko Made, 2018

2.3.2 Ainu local knowledge of the environment

For the sake of survival, the Ainu noted any slight changes in their environment and scheduled their livelihood practices according to the demands of different seasons. Ohnuki-Tierney (1973) explains that the Ainu year is divided into two main seasons, the cold season and the warm season, which are reflected in their subsistence economy, pattern of settlement and religious activities. These two seasons were further broken down into four shorter seasons: *paykari* (spring) (mid-February to May); *sakiita* (summer) (June to August); *čukiita* (autumn) (September to mid-October) and *matayta* (winter) (between mid-October and mid-February). *Kamačuh* (October) is the month of marten trapping, during the winter, while *hahrah* (April) is the month of the herring run, during spring. The Ainu developed a calendar system that can forecast their activities, because both the peak time of the marten pelt and the herring run are natural phenomena that occur independently of human actions. Ohnuki-Tierney (1973) explains the phenomena that mark the cold and warm seasons as follows.

For the Ainu, the cold season begins at the time of first snow in October with marten trapping. During the trapping period, the men build huts and live in the mountains. Meanwhile, the women gather nettles to weave their clothes and candlestick lilies for food and finish other necessary tasks of preparation for the cold season. As the men return from the marten-trapping, a bear ritual called *iyomante* is held on a supra-community scale. The Ainu then travel further inland to their winter settlement, where the men continue to hunt, except when the snow is too deep. Animals captured during this period include squirrel, fox, musk deer, reindeer and bear. Sea-mammal hunting, which takes place intermittently throughout the year, does not break up the period, although the most plentiful capture is expected at the end of the cold season when seals are born on the ice. The Aimu also fish through the ice, when the ice is not too thick. Long winter nights are often spent reciting myths and tales. In addition to the *iyomante*, most other Ainu rituals often take place during the winter.

Herring migration marks the beginning of the warm season. During the waxing moon of April, the Ainu head toward the coastal area, where they form their summer settlement. The main activities throughout the summer for the men consist of fishing in rivers, lakes and the sea, while women gather plants. From these harvests during this season, many fish are dried and smoked and plants are dried. This busy fishing season ends when the Ainu go upstream for salmon fishing. More significantly, throughout this season hunting for land mammals is minimised. Spring and autumn seem to mark the beginning and end of the warm season, respectively, in terms of Ainu seasonal activities. During the cold season, Ainu activities engage their deities, so the cold season can be regarded as sacred, while activities in the warm season are profane.

2.3.3 Ainu land and resource management

The ability to predict the seasons is critical how the Ainu establish their livelihood across time (Kayano & Hane, 2018).. As predominantly hunter-gatherers with limited agricultural practice and no food trade, for their sustenance the Ainu have relied entirely on the natural world around them. Ainu culture, language and religion evolved in support of a comfortable and autonomous standard of subsistence, so that each Ainu could live 'not needing food,' *kupoutar yayperepoka*, the culture's state of greatest happiness (Moody, 2014: p.4). Over generations, the Ainu have been both resourceful and imaginative in establishing ways to survive with what was available to them. Ainu people have specific traditional protocols for using natural resources, and these protocols have played a large part in protecting their environment as well.

The Ainu culture can be seen to revolve around hunting, fishing and the selection of edible plants on which the people depended for subsistence. However, agriculture has at times made up an essential component of the Ainu ecosystem. Kohara (1999) pointed out historical evidence indicating that the Ainu practiced limited farming during the Edo period (1615–1868), using the harvest to supplement their diet. Later, agriculture became fully established in the late nineteenth and early twentieth centuries when the foods raised became staples in the diet (Kohara, 1999). Dublin and Tanaka (2015) clarified that the Ainu practiced small-scale agriculture, growing modest grain crops of wheat, millet and barley and more recently cultivating beans and other vegetables, including daikon, pumpkins, potatoes, tomatoes and onions. In addition, they gathered native plants for food consumption, including wild garlic, wild grapes, lily bulbs and even skunk cabbage, which was dried after being collected. The Ainu also gathered berries and nuts, acorns and chestnuts—the chestnuts are buried to keep them fresh throughout the winter. As an agricultural preference, the Ainu chose fields with fewer grasses and trees, in order to avoid clearing vegetation and chopping trees and often these were on riparian land. Based in their religious beliefs regarding their gods, the Ainu neither fertilised the fields nor vigorously weeded them (Morris-suzuki, 1994).

Crop and harvest storage has also been essential to the Ainu. For everyday needs they cooked the food they obtained from hunting, fishing, gathering and farming; they also stored a large portion of the food supplies for winter and potential famine (Hayashi, 1970). As one example of such famine, it is estimated that when the salmon run on the Ishikari River collapsed in 1725, several hundred Ainu died of starvation that winter and spring (Irish, 2009). The stored food is prepared using different techniques. The Ainu have preserved fish, meat and some vegetables by drying. Hayashi (1970) reported that meat and fish were dried and smoked and then were piled them up in a storehouse. This kind of processing and storage allowed meat to be kept for many years and prevented spoilage. It also protected these supplies from infestation by flies and other insects. For trout, the Ainu use a different technique, as this fish did not dry or smoke well the way salmon did. Irish (2009) clarified that the Ainu captured the trout that swam upriver during the springtime and held them in a natural spring of flowing fresh water. The

spring was covered with small stones, allowing the fish to be kept for up to a month. The Ainu stored dried wild plants and vegetables, either in the storehouse or on a board in a basket called saranip or shintoko (a lacquered ware). Grains were placed in straw bags. The Ainu prepared a hole in the ground near each home to store turnips and potatoes, which protected such crops from freezing during the winter.

Use of land for the Ainu is closely aligned with the use of the surrounding areas. Dublin and Tanaka (2015) outlined the relevant rules designed to be practiced by everyone, with these authors pointing out sustainable use of natural resources within the concept of carrying capacity. The Ainu have had guaranteed access to both hunting and fishing grounds, allocating vertical portions of land to various *kotan* (hamlets). Such divisions were conducted on the basis of the availability of deer, salmon and some main plants. For the Ainu, this system of assessing carrying capacity was crucial to preventing over-hunting and overfishing. They will agree to split a *kotan* into two separate ones whenever a *kotan* is found to be too large, due to an increase in family size. More importantly, various *kotan* always came together for hunting and fishing expeditions. Permission to hunt, fish, or gather in another *kotan*'s territory could be sought and acquired from the headman. He would hold a special ceremony to award the permission to a person. This is important since there is a religious cultural aspect to allowing access to an area. Entry to the territory of another *kotan* without consent is considered a serious crime and a death penalty may be imposed. Anyone who entered the territory of another *kotan* did so also at high personal risk from traps that the Ainu set up catch animals in their territory, making it extremely dangerous to enter an area without knowing where such traps were located. The locations of the traps would be revealed to a person when permission was granted by the headman.

2.3.4 Ainu social networks and institutions

The Ainu live in close contact not just with their fellow Ainu but also with vast numbers of beings of the universe. They believe their wellbeing depends on their good relations with the owners of the soul, deities, spirits and demons (Ohnuki-Tierney, 1973). The Ainu mainly lived in *kotan* (small villages or hamlets) close to the rivers where the people fished (Pham, 2011). Irish (2009) described the *kotan* as having a headman who could be in charge of more than one village. He would oversee religious ceremonies, ensure that all families in his region have food to eat and become a representative of the *kotan* in relations with outsiders, as well as taking on other leadership duties. In general, different *kotans* were three to five miles apart, with as few as three or as many as 20 homes in a *kotan*; each dwelling sheltered one nuclear family (Irish, 2009).

More significantly, the Ainu have a concept of mutual ownership of land, as opposed to single ownership. Watanabe (1973) wrote that the Ainu people was defined by ethnologists as a river-centred community in which groups of a few households cooperated in subsistence activities such as fishing and gathering. For example, Dublin

and Tanaka (2015) explained that the Ainu practice four types of communal hunting: (1) *sunoyama* (communal hunting by Matagi hunters targeting the Japanese serow, *Capricornis crispus*); (2) *tateshi* (two or three hunters catch a sleeping bear in its den); (3) *muratate* (similar to *sunoyama* communal hunting but with community rules) and (4) *denjishsi* (no community rules, with the only beneficiaries the people taking part in the hunt).

Furthermore, sharing is fundamental in the culture of the Ainu. They often shared food and drink with their neighbours, although it might be just a cup of wine (Kayano & Hane, 2018). In addition, the first salmon captured in early autumn each year was a special item to be shared with neighbours (Selden, 2018). Selden (2018) also reported that whenever there is a disagreement among community members, they apply *ukocaranke*, a practice of settling disputes by debating rather than fighting. In such a case, the people involved in the conflict will sit down and debate for hours or even days, before one of them has been defeated and decides to compensate the other.

2.3.5 Ainu worldviews and belief systems

Moody (2014) wrote that the Ainu believed that the world in which they lived was inhabited by a number of gods, or *kamui*, who protected human beings and gave them food in exchange for ritual offerings. According to their traditional views, the Ainu viewed the plants and, in particular, the animals as the bodily representation of divine spirits that provided them with food and should be respected in order to maintain a reciprocal relationship between man and the gods. Such religious views taught strict food collection and patterns of consumption and inspired Ainu practices.

All of these early Ainu beliefs are reflected in the *kamui yukar*, the oldest and most sacred manifestation of oral Ainu culture. Roche et al. (2018: p. 70) explained that Ainu people often remember a cautionary guideline of 'do not collect wild plants exhaustively. They need to be protected for future generations and for wild animals'. According to Dublin and Tanaka (2015), in the doctrine of Ainu, when a plant or animal was to be harvested or killed, *kamui* was invited to a ceremony to ensure success. This ritual further strengthens the strong sociocultural bond between the people and their surroundings. For example, the Ainu people celebrate the Asircep-Nomi festival, a symbol of continued support from their ancestors for annual salmon cultivation.

Strong (2011) stated that the most prominent religious ceremony in the culture of Ainu was the *iyomante* (bear ceremony). Preparation for the *iyomante* begins in the spring. At this time, the men will go to the mountain to catch a cub and bring it home. The host family raises the cub inside the house and then moves it to a bear cage when its claws become too dangerous for them. Just before the Ainu move into their winter settlement, they slay the bear in a long-planned ritual. Many outsiders might consider this practice to be a cruel act, but this is not so for the Ainu people. In accordance with their religious views, the bear is properly slaughtered and its carcass is also properly treated to ensure proper transition of its life to the realm of deities. Such an act means that the bear will

return carrying meat and fur as presents in a gesture of goodwill, just as human visitors would. Importantly, several friends and relatives, including those who live very far away, will come together to take part in the ceremony, which lasts for several days. However, in the early 1960s the Japanese government officially banned the Ainu bear ceremony. The Ainu continue to worship and honour bears today but they no longer kill them ritually.

2.4 Summary

For centuries, Indigenous people have lived in harsh natural environments where they have coped with and adapted to environmental changes in order to survive. As highlighted in this paper, TEK is an 'other way of knowing' that helps Indigenous people track changes in their local surroundings by providing a knowledge base with which to compare current observations, as well as by offering a method for documenting adaptation practices. Generally, local knowledge of the environment, land and resource management, social networks and institutions and worldviews and belief systems are all very important and need to be considered when documenting TEK, in order to generate and understand an overall picture of the impacts of climate change along with local adaptation. TEK systems can be particularly valuable in fostering adaptation and resilience during times of environmental and climate change. Such systems can fortify community capacity to deal with any disruption and maintain ecosystems under uncertain conditions because the body of knowledge coevolves with ecological and social systems.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This section discusses the approach that guided conduct of this study. It includes description of the research design, selection of study area, data collection and research instrument and data analysis. This research is a qualitative case study.

3.2 Research Approach and Design

The research approach includes the method and procedure used for conducting the study. This work falls within the category of discovering, comprehending and interpreting the role of TEK in helping Indigenous people understand and adapt to climate change. According to Yin (2009), qualitative case study is a highly relevant method when a study is intended to clarify an in-depth process based on the issues of how and why. This is because the approach to case study allows the researcher to understand those processes or phenomena that are especially difficult to quantify. Through a case study approach, the researcher gathers first-hand and comprehensive data from the participants in the study, as well as from other information sources, such as the researcher's own observations and experience when doing fieldwork.

Stake (1995) describes two benefits of using a case study approach: First, it is concise, straightforward and easy to understand and second, it is more descriptive. The richness, depth and variety of information gained through case studies make it valuable and very important to understanding a phenomenon or an occurrence (Yazan, 2015). In addition, the case study is highly versatile and flexible because it engages a variety of methods in the data collection process (Yin, 2009).

Another thing to note in qualitative studies is that the design of the study is not static rather is built according to the purpose of the research that prompts exploration (Stake, 1995). The interpretation of qualitative research data is therefore inductive, based on the themes proposed (Braun & Clarke, 2006). Specifically, the emphasis of a qualitative

research is not on hypothesising but rather on understanding the true meaning and nature of the study area (Yazan, 2015).

3.3 Selection of Study Area and Research Participants

Field sites and communities were chosen based on the following criteria: (1) communities that still maintained traditional practices or economies, (2) resource-based livelihoods and (3) location of homes in a vulnerable environment (Ingty, 2017; Vinyeta & Lynn, 2013). Therefore, this research was conducted in Sarawak, Malaysia, where most of the Indigenous communities meet these criteria.

Sarawak is a Malaysian state located in northwest Borneo Island, bordered by Sabah to the northeast, Brunei to the north and Kalimantan to the south (Figure 3). With an equatorial climate, the temperature of Sarawak is relatively uniform throughout the year, 23 °C early in the morning to 32 °C during the day (Sarawak Government, 2019). Sarawak, as in other parts of Malaysia, experiences two monsoon seasons; the northeast monsoon brings heavy rain between November and February, while the southwest monsoon from June to October is usually milder. The average annual rainfall is between 3300 and 4600 millimetres, which may vary according to locality (Sarawak Government, 2019).

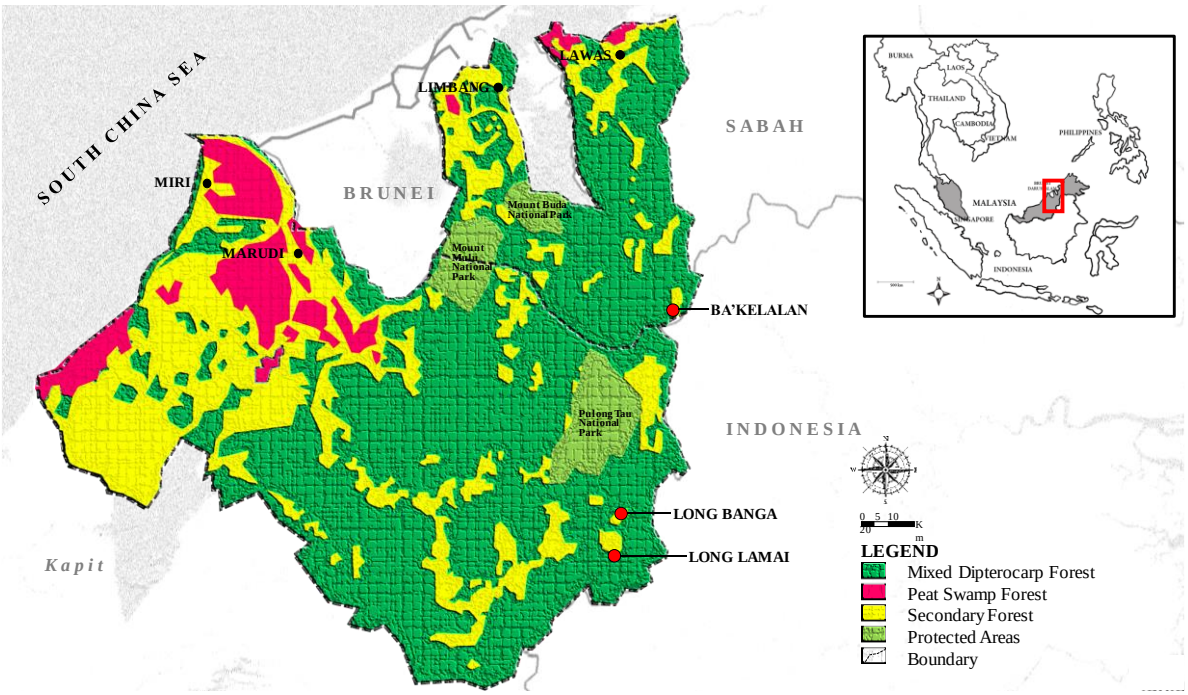


Figure 3: Location of study area and its natural areas

With a total population of 2.5 million people, Sarawak has 25 ethnic groups that can be categorised into seven major ethnicities, namely, Iban, Chinese, Malay, Bidayuh,

Orang Ulu, Melanau and others (Kheung & Zaidi Adruce, 2018). Orang Ulu was chosen as the main research target because the majority of them still live in the remote interior of Sarawak and perform traditional practices in their daily activities. The Orang Ulu, who are also known as the "people of the interior", are made up of a few tribal groups in north-eastern Sarawak and their population ranges from 300 to over 25,000 people (Besar et al., 2014). Three sub-ethnic groups of Orang Ulu were chosen, namely, the Lun Bawang, Sa'ban and Penan. Lun Bawang are wet rice agriculturalists who live in the highlands, the Sa'ban are upland rice agronomists living in the low land, while the Penan are the legendary hunter-gatherers of Sarawak who previously lived in the rainforest.

With a population of 1500 people, the Lun Bawang people are indigenous to the Ba'kelalan highlands, an isolated region located in the Limbang Division of Sarawak at an altitude of 3000 feet above the sea level. In the native language, Ba' means paddy field, whereas Kelalan means river. The Lun Bawang were one of the earlier settlers in the mountainous regions of central Borneo (Runciman, 1960) and many of their traditional economical activities are related to rice cultivation, especially the *lati'ba'*. *Lati'ba'* refers to a traditional system of wet rice cultivation that is still maintained by the Lun Bawang people, where they incorporate water buffaloes into the farming system. The Lun Bawang are also known as hunters and fishermen and, at the same time, practice animal husbandry such as rearing poultry, pigs and buffaloes.

The Sa'ban, on the other hand, are often referred to as a sub-ethnic group of Kenyah or Kelabit (Harisson, 1949). They comprise small communities in Long Banga, which settled in the most isolated area of the Baram River in the Marudi Division. Originally, the Sa'ban came from the Bahau watershed in East Kalimantan. They migrated to Sarawak around 1900 and continued until the late 1960s. The total number of the Sa'ban people is around 1100, which makes them one of the smallest sub-ethnic groups in Sarawak. Their increasing outmigration into the urban areas has reduced the number to about 500 people in Long Banga. All of these households are involved in diverse agricultural activities, but most are upland rice cultivators. Fishing and hunting for wild game is also a common activity for some individuals in the village.

Finally, the Penan are the renowned hunter-gatherers who used to live in the rainforests of the Sarawak interior. They are expert hunters who use silent blowpipes and poison darts for hunting. Their traditional staple food is sago, which comes from the core of a small palm tree. The majority of Penan communities were nomadic up until the 1950s. The transition in lifestyle was due to programmes promoted by the state government and foreign Christian missionaries to settle them into villages. One of the earliest Penan settlements is Long Lamai, with a population of approximately 580 people. Due to their isolation and sedentary lives, they have started to focus on an agrarian

lifestyle where they cultivate rice and plant garden vegetables. However, they still rely on sago as their main staple as well as jungle fruits and hunting game.

3.4 Data Collection & Research Instrument

The TEK of indigenous groups was sampled during three fieldwork visits conducted in three villages between January and February 2019. In-depth interviews with local informants (Guion et al., 2011) and field observations were conducted. Since the focus was on TEK, the targeted informants were those with direct experience in traditional practices including farming, hunting, gathering and forestry. The first person approached in each village was the headman to get background information about the study area, including population size, economic activity, history of the communities and other basic information. Snowball sampling technique (Naderifar et al., 2017) was used to identify further key informants. Overall, 31 face-to-face semi-structured interviews were conducted with local informants. Some of the answers were documented using a field notebook because there were a few informants who were unwilling to be tape-recorded due to unresolved disputes with the state government. The interviews took between 1 to 2 hours and were stopped if they drifted into repetitive information.

The questionnaire was structured into four main parts. Part One was designed to gather data on climate risks and threats affecting the livelihoods within the study area, environmental changes and understanding their weather forecasting and bioclimatic indicators. Part Two was related to their traditional strategies on land and natural resource management when they experience disturbances. Part Three was aimed at capturing the role of their social networks and institutions when a calamity strikes. The final part was used to understand their worldviews and belief systems related to their practices. The majority of respondents could speak and understand the Malay language (the official language of Malaysia) and only a few used English. Interviews were therefore conducted mostly in Malay. We also asked informants to translate a few words in their native language which represented the real expression of their communities rather than the official language.

3.5 Data Analysis

There are different ways in which qualitative data can be analysed. For qualitative research, there is no single best or most accurate way to analyse data (Bogdan & Biklen, 2003). Lincoln and Guba (1985) confirmed that there is no consensus or uniformity in qualitative studies regarding data analysis. This means the qualitative data analytics process will be subjective. The most important thing, however, is that the purpose

remains the same, namely, to make the data collected relevant in a research context. Thematic analysis (Braun & Clarke, 2006) was used in this study to analyse qualitative data and identify themes in each of the research components. The global theme was built around a TEK framework. According to Braun and Clarke (2006) the method of thematic analysis should span several phases, including data transcription, encoding, theme creation and preparation of a report.

Data collected during fieldwork are transmitted within a text document. The process of incorporating data in this way is called transcription. For this study, repeated reading of data from interview transcripts supported the formation of key ideas (categories). The data were then encoded based on the transcripts produced. Joffe and Yardley (2004) describe encoding as the process of identifying and compiling into transcripts texts that have similarities, differences, patterns, or related structures, which subsequently generate or convey certain themes. Every related code is assembled to shape one main idea or theme. Thus, any frequent, unique, interesting code that has enough evidence to support the research findings is can effectively produce a theme. At this point the data need to be interpreted carefully so that the themes generated can provide appropriate meaning in the context of the study. The results of the study obtained through these mentioned methods and processes are reported in the next section.

CHAPTER 4

CASE STUDY 1: THE LUN BAWANG, BA'KELALAN

4.1 Background

Ba'kelalan is an isolated highland with an altitude of 3,000 feet situated in the Sarawak Limbang Division. The closest town is Lawas, which is connected to 150 km of the former unpaved and bumpy logging road that can only be reached by four-wheel drive vehicles. It takes about six hours to get from Ba'kelalan to the town. Nevertheless, the trip can take up to 24 hours during a bad day particularly when it rains. They also have a STOLport that uses 19-seater DHT aircraft with twice-a-week flights to Lawas and Bario.

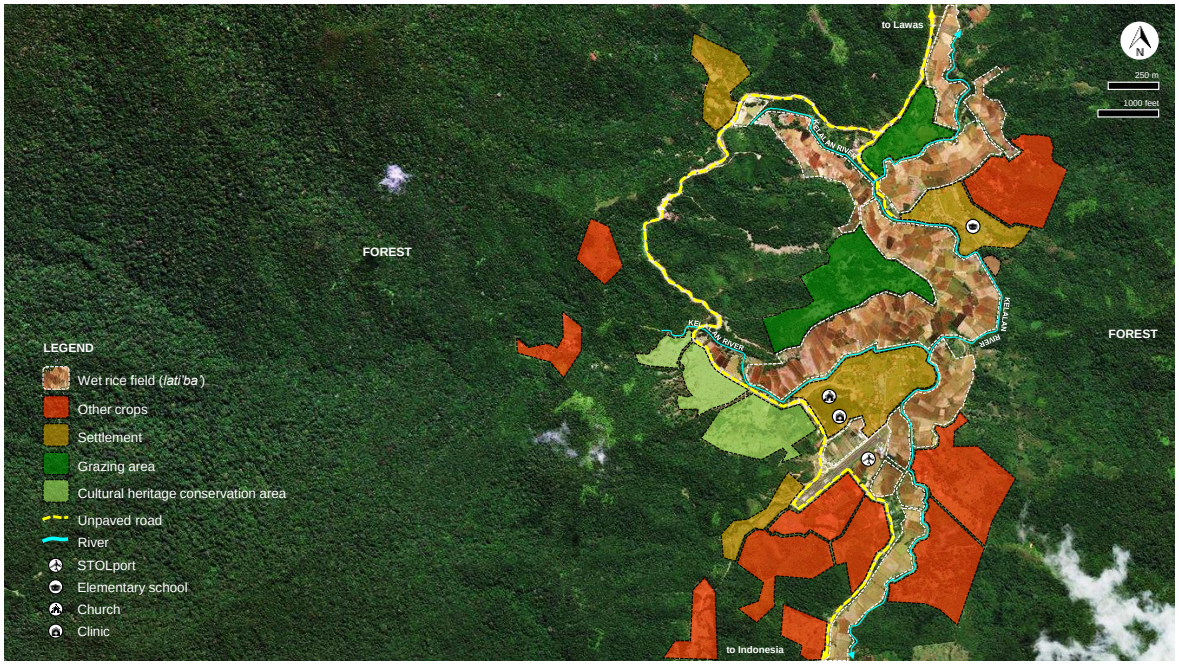


Figure 4: Ba'kelalan area
Source of aerial photo: Bing Maps, 2020

Ba'kelalan has a tropical climate with an average annual rainfall range of 2800 to 3150 mm and temperatures ranging from 18 to 29 C (Kuok & Chan, 2012). This picturesque highland is inhabited by the Lun Bawang tribe, a deeply religious group with a population of around 1500 people. Agriculture was the dominant industry of the region for hundreds of years ago. But the economy today is more diverse, with some of them

forming small businesses. Many roads are not paved, and the energy supply on the highlands is primarily from micro-hydro dams, solar power and generators. Villagers have access to small village clinics, primary school and kindergarten.

Figure 5: Ba'kelalan scenery
Source: Field survey, 2019

4.2 Demographic profiles of the Lun Bawang

Below are demographic profiles of the respondents.

Table 3: Demographic profiles of the Lun Bawang

Demographic Profile	Key Informant
Total Sample	10
Sex:	
Male	8
Female	2
Age group:	
18-30 year	1
31-45 year	2
46-65 year	3
65+	4
Education	
Primary	1
Secondary	7
Tertiary	2
Main Income	
Farming	7
Small business	2
Salaried work	1

Source: Field survey, 2019

4.3 The Lun Bawang's TEK

The traditional strategies for addressing climate change risks as identified by the Lun Bawang are shown in Table 4 and explained as follows:

Table 4: Traditional strategies of the Lun Bawang for addressing climate change risks

TEK component	Types of adaptation strategies	Description	Example

Local knowledge of environment	Forecasting	▪ Observing bioclimatic indicators to predict weather changes and availability of games
		▪ Observing changes in local surroundings
		▪ Identifying impacts of changes
			▪ Bioclimatic indicators:
			  ▪ Observation of sky colour to predict daily rainfall. Formation of mist in the morning believed to be informative of temperature changes
			  ▪ Sightings of fruits to forecast the abundance of game
			▪ Observed changes:
			  ▪ Temperature of the environment has significantly increased.
			  ▪ The weather and seasons have become uncertain.
			▪ Identified impacts of changes:
			  ▪ Warmer temperatures cause frequent drought events which dry up the *lati'ba'* (wet rice paddy)
			  ▪ Erratic rainfall causes flash flooding that erodes the *lati'ba'*

Land and resource management	Diversification	▪ Diversification and creation of resource redundancy to spread risk through time and space	▪ Integrated crop-animal farming is maintained through traditional *lati'ba'* system ▪ Intercropping of *kabun* (home garden) promotes heterogeneity ▪ Diversified resource base through *kabun* and forest produce
	Storage	▪ Physical infrastructures for storage	▪ Storage of resources in the *sulap padi* (paddy store) promotes food security
	Rationing	▪ Seasonal restrictions on harvesting	▪ Enforcement of *'tagang'* systems to avoid fish depletion

	Conservation	▪ Maintaining and restoring habitats, and protecting biological diversity	▪ Conservation of forest area under local customary law
Social networks and institutions	Pooling	▪ Sharing of resources, labour and infrastructure among community	▪ Practising community pooling during a crisis for example *ngeruyung, musang, ngumum, gotong-royong* ▪ Preservation of family tree to promote social cohesion ▪ Headman and church institutions enhance community engagement
Worldviews and belief systems	Storytelling Cultural festivals	▪ Knowledge and cultural transmission across generations	▪ Community value 'kill only enough for food' as conservation principle ▪ Value of uncertainty encourages disaster preparedness across generations through legendary folktales called *'beras dan harta'* ▪ Cultural festivals *'Pesta Beras Adan'* encourage knowledge and cultural transmission

Source: Field survey, 2019

4.3.1 Local knowledge of the environment

Forecasting: During the ancient times, the Lun Bawang relied heavily on traditional forecasts to manage daily lives. Since the weather conditions affect their livelihood activities, weather prediction is essential to make daily business more manageable particularly during the harvesting season that needs dry weather. According to the community, one of the bioclimatic indicators they used to forecast the weather is the sky colour. The villagers noted the following:

> *"…weather forecasting was very easy last time. It was built upon general observation. If we look at the sky and it turns red, that is a sign that it is almost dry. Dry weather…"*

> *"…if it's raining, it's hard to harvest. During harvesting season, we need dry weather. Rain will cause damage to the harvested paddy. So if it rains, then we need to do more work. We need to dry the paddy. If we keep wet paddy, it will grow. Therefore we need to make sure that all of them are dry before we store the paddy…"*

Furthermore, during the shedding of ripe fruits, many of the Lun Bawang would go into the forest, as it indicates abundance of wild bearded pigs (Sus barbatus) in the area especially in January. Everyone in the village also fished for meat in early January during the cold night, as it signifies the fish spawning in Ba'kelalan.

> *"…the bearded pigs usually come seasonally when the fruits drop in the forest. And that event occurred during the harvest season. So man will go hunting when the pigs come…"*

> *"…it's cool tonight, because the fish come out. They will come out to lay eggs when the weather is cold. We predict based on the weather and date, like tonight, the fish will come out..."*

Nonetheless, the majority of respondents described that most of the bioclimatic indicators used to predict weather and seasons are now less reliable. This then corresponds to the climate change issue. The Lun Bawang were unaware of the precise dimension of climate change when asked about the perception of climate change, but everyone was of the view that the local climate had changed. Both men and women of all ages were able to provide knowledge about potential climate change and the effects it had created. They reported significantly higher temperatures in their atmosphere. One of the bioclimatic indicators that they used to indicate whether or not the weather is cold is by morning mist formation. When the mist is formed it indicates that the area is cold. Yet in the morning, the mist is no longer formed. The villager in Ba'kelalan noted, for instance, the following:

> *"…it was always misty morning here. Very misty. If it's misty, it means that the weather is cold. Now it's hard to get it. No more. It's a sign that the temperature is not quite cool. So normally in the dry season, the mist is forming because of cool temperature. If not, it's not cold then…"*

According to them, their main crops, the *lati'ba'* or wet rice field, are affected by high temperature. For most of its growth, the rice must be kept flooded in the *lati'ba'* system (Jok, 2012) because it will produce the best yield when enough water is in place. If water supply is not adequate, yields will decrease. Therefore, if the local temperature is high for a long time, it triggers drought. The river is usually the primary source of water for the *lati'ba'*. Thus, if droughts last a long time, the river's water level drops. Low water levels in the river prevent water from flowing into the *lati'ba'*, leaving it dry. Rice planting is not possible, thus reducing the production of food. According to the villagers, a prolonged drought had previously occurred that had seriously affected yield during that season. As noted by the villagers:

> *"…if drought happened, it will be totally dry. Our river becomes dry. It happened previously. Now our river is almost dry within these two to three months. The problem with a dry river is that the water does not flow into the paddy field. So, the paddy field also*

becomes dry. If no water in the field, that causes us the problem. We cannot plant the rice…"

"…it happened previously. Totally dry. The paddy field cracked…"

Another important change they found is the uncertain weather pattern. Weather forecasting is no longer practical because of the irregular climate. Indeed, according to the community, the pattern of rainfall these days is also highly unpredictable. This situation is noted by the villagers as follow:

"…last time it was easy to predict the weather. Easy to organise and manage. Now it is very hard…"

"...for rain, it depends; now we cannot predict the rain anymore. It becomes uncertain. Sometimes there is a lot of rain in a year. Sometimes, there is less..."

According to the Lun Bawang, erratic rainfall is impacting them in many ways. For example, heavy rainfall in a short period of time causes flash floods. Such floods erode their paddy fields, damaging their livelihood assets. In 2017 for instance, there was a huge flood in which all paddy fields were destroyed, particularly those near the banks of the river, and it caused a huge loss.

"...there were floods. Floods occur at least once a year. 2017 was the biggest flood in history that hit our village..."

"...2 years ago there was a big flood. All the crops near the river banks were affected..."

"...It will be raining at the end of the year but the rain is unpredictable. Heavy rain triggers flash flooding..."

Although climate change seems to affect their food resources, the villagers coped with it through their practices in land and resource management. The next segment discusses these practices.

4.3.2 Land and resource management

Diversification: Diversification practices have been considered important for the Lun Bawang in their traditional management of the land and resources. First, diversification refers to the agricultural techniques used to adapt to climate conditions. Integrated crop-animal farming has been the tool used to secure food supplies and make farming more resilient to climate change. The rice-buffalo co-culture system in Ba'kelalan is an age-old farming practice. The *lati'ba'* system is a wet rice farming technique used for generations

by the Lun Bawang, which represents a close connection between humans, buffaloes and the environment. For hundreds of years, the Lun Bawang worldviews have revolved around the *lati'ba'* that they cultivate and consume. It is not surprising that the Lun Bawang call themselves "the people of the wet rice fields" as they depend on the *lati'ba'* for livelihood and cultural significance. An individual without the *lati'ba'* will not actually be recognised as part of the Lun Bawang. As noted by the villagers:

> *"…if a family does not have a paddy field, it means they are not from Ba'kelalan. Every family in Ba'kelalan must have a paddy field…"*

Figure 6: The *lati'ba'* (wet rice paddy)
Source: Field survey, 2019

Basically, the *lati'ba'* is permanent terraced fields that surround the communities' settlements and a great example of efficient agricultural systems. In this primitive method, they crafted the valley between the mountains in blocks of rice fields and used the stream flow from the mountain to irrigate their *lati'ba'*. Canals were built for directing the flow of water into each block. The *lati'ba'* is then filled with flowing (not stagnant) fresh water and flooded throughout the year. Water buffaloes will be released into the *lati'ba'* after the harvest season to clear all remaining paddy straws. The buffaloes will live in the field during that period until the next paddy season. Consequently, because of their movement in the rice field, the buffaloes soften the soil while their waste becomes organic fertilisers which increase soil fertility. The Lun Bawang explained that this technique helped them maintain the rice yield of each plot for centuries, despite environmental stressors. This is noted by the villagers as follow:

"…so, until now, we stick to traditional. Our ancestors were brilliant because they knew if we overused the land, it would lose fertility, so they give it time to rest. Single cropping a year. With this method for hundreds of years, we have not lost the yield of every plot. Year in year out, the yield is almost the same. No changes from ancient times. And no application of fertilisers. Zero fertiliser. We use buffaloes. Buffaloes, paddy and river cannot be separated. If there are no buffaloes, it affects the paddy field. If there is no paddy field, the buffaloes cannot live. After harvesting there are new plants. The paddy shoots. It becomes the buffaloes' food. So, when they eat it, they become as if they are ploughing machine and their waste becomes the fertiliser. Secondly, they clean the paddy field. So, the farmer doesn't have much problem with weeding…"

Figure 7: Utilisation of buffaloes in the *lati'ba'* (wet rice paddy)
Source: Field survey, 2019

Using this technique, one harvesting season will produce a yield which can be consumed for up to several years. Diversification can also be found in their home garden by intercropping crops and integrating livestock and crops. The former refers to the simultaneous cultivation of more than one crop species within the same field (Hauggaard-Nielsen et al., 2008), whereas the latter applies to a combination of different livestock and crop mixtures. Each family in the Lun Bawang has a *kabun*; a garden consists of fruit trees, vegetables and other surplus crops such as bananas, pineapple, yam, and etc. Sometimes, their home garden also holds other food varieties such as poultry, livestock and fish. They will work on their *kabun* after the harvest season to ensure continuous supply of food throughout the year. This diversification of the agroecosystem ultimately helps them adapt to severe climatic conditions such as drought

and floods, because if one part of the area is affected, there will still be food supply in the other region.

> *"…we have home garden. We plant fruits. After harvesting we will work on our home garden. Food is always available. Sometimes some people breed fish, if he has a pond. Like him, he plants pineapple…"*

> *"…near the hills we raise buffaloes, make home garden, plant fruits, yam and others…"*

Figure 8: The *kabun* (home garden)
Source: Field survey, 2019

Storage: The one-year harvesting season crop surpluses are kept in the paddy store or the *sulap padi* in the local language. Storing the resources ensures a constant flow of food over the years. The storage action also ensures that emergency supplies are available when a disaster occurs. The villagers remember this when they suffered a tragedy years ago:

> *"…there was a prolonged drought in 1997. For seven months. The crops failed. The land cracked that it grew mushrooms. Luckily, we had old stocks. We always have stocks. Every year we will keep the stock. It will not finish. Like for this year, paddy from 2017 and 2018, half of them are still available. We were taught by our ancestors to keep a stock…"*

> *"…source of food still available because we have stock. Paddy, we stock for one or two years. Harvest from last year still available to consume. We have a store, the paddy store. In case if anything happens, we always have stock. It never decreases…"*

Figure 9: The *sulap padi* (paddy store)
Source: Field survey, 2019

Conservation: With regard to the *lati'ba'* systems, water management is important to ensure that the water source for inundating the paddy field is always sufficient. So one of the methods they used to ensure enough water in the river even in the dry season is by conserving the water catchment area, which is the forest. According to their traditional laws, no human activities other than hunting are allowed, in particular cutting and logging within their virgin forest. The following was explained by the villagers:

> *"…water management, we conserve the area, we conserve the water catchment area, we do not destroy. If we cut the trees, the water, the ground becomes dry. Because the trees help to retain water, if we clear the jungle, there is not enough water in the ground, so there will be little water in the river. So naturally, we leave it so that we have enough water even in the dry season. The area must be conserved. No human activities except for hunting. Cutting and logging are not allowed…"*

Figure 10: Conservation of surrounding virgin forest
Source: Field survey, 2019

Forest conservation not only helps communities adapt to climate change but it also promotes resilient ecosystem services by preserving their biodiversity. In addition, the community acknowledged the practice of specific restrictions on certain resources, in particular for hunting and fishing, to ensure the recovery of stocks in the face of any climate disasters. For instance, they will only take for their own consumption during hunting, because they are not allowed to over-exploit. The principle of "kill only enough for food" underpins this behaviour. The villagers note it:

> *"…because we did not hunt for business. There are some who sell but not for commercial purpose. He only sells one or two animals. Enough for all. Like me, I do not go for hunt anymore. I buy. But its equivalent for you going also. I take the short cut by not going. Instead of going, I use money. Take just for food, no overhunting. Outsiders are not allowed to hunt. If our community went for hunting, if they get one, it is more than enough. It is only for that season that they need to hunt. For example, during Christmas, my nephew caught one deer. That was enough. After that, we do not hunt anymore. He said there are a lot of deer in the forest. It means they are not overhunted. Resources are still abundance…"*

Rationing: They have a *tagang* system for the fish, which literally means 'to stop'. It is a basic traditional method of ensuring that fish stocks are not exhausted. The river is divided into three zones in this system – red, yellow, and green. The red zone is the area where fishing is completely prohibited. The yellow zone is the area where people are permitted for fishing occasionally. Finally, the green zone is where people are allowed to

fish. The local community operates the *tagang* system on this river, and those found in breach of the law will be fined. The villagers note this:

> *"…in the tagang system, the fish are controlled in terms of harvesting. Nobody is allowed to fish without permission. The penalty is quite heavy. If somebody gets caught, they will be fined around RM500 or RM1000…"*

4.3.3 Social networks and institutions

Pooling: Coping with climate stresses is more effective when communities can get together and respond collectively to the challenges presented (Risco et al., 2015). During difficult times the Lun Bawang practice community pooling. *Musang, ngeruyung, ngumum* and *gotong-royong* are some forms of cooperation or mutual aid. The spirit of cooperation has existed since ancient times, bringing people closer to each other. This cooperation includes exchanging resources, food and infrastructure that provide them with a buffer against difficulties. Indeed, they will do everything together in every work, and if there are any problems, they will sit down together and discuss. The villager noted this as:

> *"…because of the collaboration and cooperation within the community, until now, we will do everything together. Problems are discussed together in the hall or the respective villages. If it involves the whole village, we will call everyone…"*

Even in the farming, they will plant the paddy together. According to the Lun Bawang, they will choose one date, and the chosen date will be announced during Sunday prayer in the Church hall. Everybody will go to the paddy field during the event and plant the paddy at the same time, and no one will be left behind.

> *"…the date will be announced through Church especially during Sunday prayer. Church has a lot of function for announcement because there is a lot people there…"*

Figure 11: Community meeting at the Church
Source: Field survey, 2019

Figure 12: Community working together in the *lati'ba'* (wet rice paddy)
Source: Field survey, 2019

Community pooling became possible with strong and well-knitted ties to the community which began from the family line. The family tree is always maintained in the Lun Bawang culture, and everyone must know each other. These mutual ties are strengthened and sustained during festivals and by regular visits between them. Through these strong bonds, they will connect and support one another in times of crisis. This is mentioned by the villagers as follow:

"…the community bond is very strong. It is difficult to be separated. Indeed, it is our tradition to preserve the family line. Until today, we will inform our children and grandsons about the family tree. They must know their siblings. That is why I told you, these are my cousins. It can be the third, fourth, fifth cousins but they are my cousins. Because we come from one source, then we spread out. So, we must memorise and protect it. At any times we need one another, we always come and communicate. We help. They must know their uncle, aunt and cousins. And then during the big day, we will gather and let them know. We must reinforce. The elder will inform about families…"

Interestingly, the community leader is also the one that brings the community together in the first place. The strong social networks between the communities indicate a strong local leadership. Among Ba'kelalan communities, the headman and the Village Development and Security Committee (JKKK) are the traditional institution. The headman manages a conflict within a village, whilst the JKKK is a committee directed by the headman. Leaders provide advice and encouragement while communities provide support and assistance.

4.3.4 Worldviews and belief systems

The worldview and belief systems are the root of the entire TEK. They act as mechanisms for the transmission of knowledge between generations, maintain the traditional practices and ensure that the culture is passed from one generation to another. Human beings are deeply connected with nature within the Lun Bawang culture. Their traditions and beliefs often mean that they take a deep respect for nature. Therefore, as discussed earlier, the importance of 'kill only enough for food' encourages them not to over-hunt, over-harvest or over-fish that will protect their resources for future use. The value of uncertainty also underpins their adaptation strategies. The Lun Bawang, for example, expressed the need to plan for tahun jahat, a season that has to do with bad harvest due to droughts or other disasters. The villagers noted the following:

"...but we always have food supplies. We keep stock to prepare for that tahun jahat (bad year). It happened previously during our ancestors' times, no food. It was so difficult..."

The fear of this occurrence is installed within the community and transmitted through oral traditions over generations. Interestingly, one of the folktales of Lun Bawang is related to this event that reminded them to prepare for the uncertainty or disaster. The title of the story is *'Beras dan Harta'* or 'Rice and Possessions'. According to the story, the community should prepare for the *'iru'* season or drought. They have been taught to take care of the paddy field and plant as many paddies as they can each year and make a stock so they will still have the resources to survive in the event of a disaster. This is explained by the villagers as follow:

"…why rice and paddy are of value compared to other properties? Let me tell you a story. Once, the beads were a symbol of wealth and prestige. Those who own beads are deemed rich. Once upon a time there was, a rich man who owns many beads. He wanted to keep as many beads as possible. So, for the sake of prestige he sold all his rice and paddy to buy the beads. And then unexpectedly next year came the unforeseen tragedy, a prolonged drought, it was the 'iru' season. All crops failed. Nothing can be planted. This is why people were planting a lot of paddies. We do not know what is coming next year. This year we usually plant a lot of paddies for next year's consumption. We do not know what will happen. So, everybody has their paddy when this disaster happened. Even the poor have their paddy. The rich man, instead, was left with nothing. He had neither rice nor paddy. So, to get some rice he decided to sell all his beads but nobody wanted to buy them. The moral of the story, that is why you see the people of the Ba'kelalan, everybody has more than one paddy field. And the paddy is very important to us, the Lun Bawang, and we value paddy more than anything else …"

According to the villagers, this story was passed from a generation to another generation. Currently, they are trying to make it a published story and print it in books so it will not be lost. They wanted the young generation to learn from it as well. As noted by the villagers:

"…both school students and the younger generation need to know this. Because we do not know what lies ahead of us. We have planned it beautifully today, but nobody knows what will happen next year …"

The story-telling was usually done when they were sitting and gathering around the Lun Bawang's *'tetel'*, a traditional fireplace. *Tetel* was traditionally used for cooking and heating. Since they live in the highlands, the temperature is pretty low, and *tetel* is therefore very important for this purpose. Each family in the village owns a *tetel* and it was often the place where the children get their lessons from the elderly in the tradition of Lun Bawang. The villagers noted this as:

"...The tradition of Lun Bawang is that when we have dinner, we will sit near the tetel because it's cold, so we will have the chance to talk to our kids...."

"...tetel is used for cooking. It's the spot where the whole family lies and tells a story during the cold season. Story about our ancestors, their lives and their convictions. The story usually has to do with self-development. The fireplace is very important to us..."

Figure 13: The *tetel* (fireplace)
Source: Owl Homestay Ba'kelalan, 2019

In addition, cultural traditions and knowledge are passed from one generation to the next during social functions such as a festival. Apart from celebrating the Christmas, the Lun Bawang celebrates the after harvest festival, the *Pesta Beras Adan* in the local language. This festival is held each year to honour the rice harvested and as a sign of gratitude. Before Christianity, This festival was historically a popular Lun Bawang custom since ancient times to honour the spirit of rice. The Lun Bawang will meet and learn during this festival, and will maintain their special culture and identity. In addition to passing on all the information, this festival has helped the community build strong social networks and maintain a relationship of reciprocity. This is because the festival is the location where information and resources are shared and exchanged. Consequently, individuals may rely on this reciprocity relationship during difficult times, thus helping to ensure resilience of access to resources. As noted by the villagers:

> *"…it is by this festival that we develop closer ties with each other…"*

4.3.5 Summary

It is clear from the findings that TEK plays an important role in helping indigenous people adapt to climate change. The first facet of TEK has helped them to understand and track surrounding changes which is an important aspect in climate change adaptation actions. Even though the notion of climate change is still quite abstract among the Lun Bawang, they are aware that the weather has changed. The findings addressed in the previous section showed that the primary concerns in Ba'kelalan are drought,

unpredictable weather and flash flood. The most disruptive disturbance in the study area, though, is the prolonged drought. In essence, most of the coping strategies recognised were directly or indirectly related to drought management. The explanation for these changes is commonly perceived to be associated with the destruction of the forest caused by the logging company and the opening of a new road connecting Ba'kelalan with the town of Lawas. None of the views correlated those changes with increased greenhouse gas emissions.

More importantly, the Ba'kelalan communities have been dealing with and adjusting to weather and environmental changes for decades, demonstrating adaptive capacity to environmental stress through the use of the TEK's second facet, that is, customary land and resource management. An exceptional traditional wet rice cultivation that has been sustained since ancient times has completely fostered sustainable soil, water and forest management, thereby leading to a socio-ecological system that is resilient. The practice of planning for the anticipated threat by stockpiling, diversifying and resource rationing helps them to cope with resource shortages that are necessary when a disaster strikes suddenly. In the third facet of TEK, strong social cohesion among the community built on the basis of kinship relations and strong leadership enables them to respond collectively to environmental challenges, thus reducing their vulnerability. In addition, all of these elements are held and strengthened by the last facet of TEK, their worldview and belief systems, which are still being practiced and passed on to young generations until now.

The communities have, however, shared some concerns. One of those is youth migration. In Ba'kelalan, more young people are moving out to the city center due to modernisation, better education and lifestyle change. Although TEK is theoretically passed on to the youth, in practice, the older folks are afraid that their children will no longer be able to do so. Therefore, ways to ensure TEK use in the future need to be identified. Finally, as climate change is becoming serious, the adaptation scale effort must also be increased, thereby making it necessary to complement TEK with science-based information and to put together modern technologies for adaptation.

CHAPTER 5

CASE STUDY 2: THE SA'BAN, LONG BANGA

5.1 Background

Long Banga is located in the Marudi Division of Sarawak. It is one of the most remote villages in the upper Baram River, about 373 km from the nearest town of Marudi. Long banga is linked to an unpaved logging road and is accessible only by four-wheeled vehicles. There is a small airport, Long Banga STOLport, which offers flights to Miri and Marudi twice a week using DHC-6 Twin Otter. The population of the village is around 500 and is dominated by the people of Sa'ban.

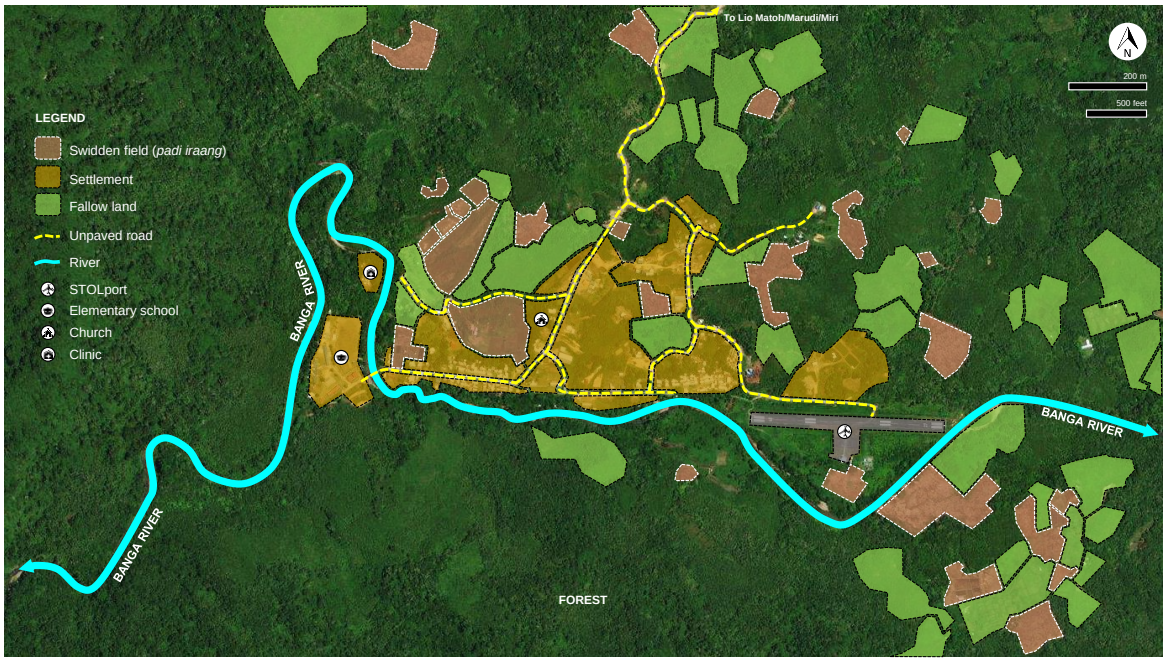


Figure 14: Long Banga area
Source of aerial photo: Bing Maps, 2020

Agriculture is the main economic activity, and some of the villagers run small businesses. Electricity supply comes mainly from micro-hydroelectric dam while water supply comes from the mountain stream. There is currently one elementary school (SK Long Banga), a STOLport, a church, and a public clinic.

Figure 15: Long Banga scenery
Source: Field survey, 2019

5.3 Demographic profiles of the Sa'ban

Below are demographic profiles of the respondents.

Table 5: Demographic profiles of the Sa'ban

Demographic Profile	Key Informant
Total Sample	10
Sex:	
Male	6
Female	4
Age group:	
18-30 year	0
31-45 year	2
46-65 year	2
65+	6
Education	
None	6
Primary	1
Secondary	3
Tertiary	0
Main Income	
Farming	8
Small business	2
Salaried work	0

Source: Field survey, 2019

5.2 The Sa'ban's TEK

The traditional strategies for addressing climate change risks as identified by the Lun Bawang are shown in Table 6 and explained as follows:

Table 6 Traditional strategies of the Sa'ban for addressing climate change risks

TEK component	Types of adaptation strategies	Description	Example
Local knowledge of environment	Forecasting	▪ Observing bioclimatic indicators to predict weather changes and availability of games ▪ Observing changes in local surroundings ▪ Identifying impacts of changes	▪ Division of the year into two seasons based on climatic patterns ▪ Shape of the moon known as *"bliin teng"* was used as an indicator to plant seeds ▪ Observed changes: ▪ Temperature of the environment has significantly increased. ▪ The weather and seasons have become uncertain. ▪ Identified impacts of changes: ▪ Droughts cause the land to dry up and inhibit the growth of the *padi iraang* (upland rice) ▪ Wildfire events due to prolonged droughts ▪ Uncertain weather and seasons makes rice farming difficult
Land and resource management	Diversification	▪ Diversification and creation of resource redundancy to spread risk through time and space	▪ The shifting cultivation of *padi iraang* allows the land to rest in 4–5 year cycles and maintains soil fertility ▪ Intercropping of *éra* (home garden) promotes heterogeneity ▪ Diversified resource base through *éra* and forest produce
	Storage	▪ Physical infrastructures for storage	▪ Storage of resources in paau padi (paddy store) ensures constant flow of food over the years
	Conservation	▪ Maintaining and restoring habitats, and protecting biological diversity	▪ Conservation of forest area

Social networks and institutions	Pooling	▪ Sharing of resources, labour and infrastructure among community	▪ *"Si'sawai, Si'hnau, Si'lawai"* (one heart, one mind and one goal) is a socio-cultural philosophy that strengthens community kinship ▪ Practice of *ledu'* to help those who have suffered from disaster ▪ Church owns a rice farm called *mah maa' tempún* to help those who run out of food
Worldviews and belief systems	Storytelling Cultural festivals	▪ Knowledge and cultural transmission across generations	▪ Value of uncertainty encourages disaster preparedness across generations through *madei'* (advice from elders) ▪ Knowledge and cultural transmission occurs through *'Ngkui'* festival

Source: Field survey, 2019

5.2.1 Local knowledge of the environment

Forecasting: Understanding change in the local surroundings is essential for the Sa'ban to manage their subsistence activities, especially rain-fed agriculture, hunting, and fishing. Careful observation of the climatic factors such as rainfall and dry day is essential as they affect local livelihoods. Traditionally, their annual planting calendar consists of two seasons; the 'wet season' which is from October to February characterised by heavy precipitation and the 'dry season' from March to September with drier and higher temperature. According to the interview with the Sa'ban, they observed significant changes in the weather and seasonal patterns. The community noted as follows:

> *"...what we observe these days, the weather is uncertain. In the previous time, it was fixed. From March to September it is the dry season, less rain. The month of October and above, there is a lot of rain. But now, it is uncertain..."*

These changes consequently affect the Sa'ban staple food, '*padi iraang'*, a Sa'banese word that translates as 'upland rice'. The agronomic practice of the *'padi iraang'* is different than that of the wet rice farming whereby its cultivation is heavily dependent on both seasons. For *'padi iraang'*, the dry season is the best time for land preparation for the next planting season whereas the wet season with heavy rain provides perfect conditions for the rice to grow. In the dry season, land clearance, which involves cutting down the trees and grass, is carried out. The area is then left to dry for about a month before burning events are performed to clear the entire place. Therefore, the best time for this practice is during the dry season. Towards the end of the dry season in August, the local community will start

to dibble the land for seed sowing. The seeds will then get continuous water supply from the rain during the wet season for growth.

One of the bioclimatic indicators that are utilised to indicate the right time to start the dibble sowing is by observing the lunar cycle or the phases of the moon. According to the villagers, when they see the *''bliin teng'*, or the 'first quarter moon' during the night in August, they will start the dibble sowing the next day. The villagers noted this:

> *"…we will search for the moon, the bliin teng. If we see the teng, we can start to plant the rice. For example, if we see the teng tonight, tomorrow we will start the dibble sowing within one week until we finish. The rice will grow very well…"*

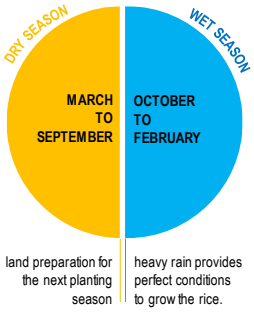


Figure 16: Traditional calendar of Sa'ban


Figure 17: Shape of the *bliin teng* (first quarter moon)

However, this indicator is no longer reliable due to the shifting weather and seasons. Thus, this affects their food production and supply. There are abrupt variations to the rainfall; sometimes it is plentiful at an unexpected time, sometimes it is very low for an extended period. This unpredictable rainfall pattern not only disturbs the rice but other activities such as fishing. For instance, the villager noted the following:

> *"…nowadays, the uncertain weather and season conditions affect us in some ways. If it is too hot, our crops will not grow well because they need water. They grow but not much. On the other hand, if there is too much rain, people cannot go to work on the farm. If we want to go fish in the river, also it is difficult due to the rapid flow of the water…"*

Another significant change that the community observed is the increase in the surrounding temperature. According to the community, the weather is much warmer than it used to be. One of the villagers noted the following:

> *"…the temperature of this area has changed. A lot of changes compared to the previous time. Last time it was not as hot as this. Now it is scorching. It is weird because we live near the jungle, it was supposed to be cooler because we have many trees…"*

The warmer and drier season consequently led to droughts. Unfortunately, prolonged droughts have caused a bigger disaster in the form of wildfires. During the tragedy, the fire burnt the surrounding virgin forest in Long Banga and spread as far as 17km within the soil to Lio Matoh. Due to the prolonged dry spell, the wildfire event lasted for two to three months. Almost all the crops and resources in the forest that the community depended heavily upon were burnt away, causing significant loss to the villagers. The villager noted as follow:

> *"…we are afraid that the droughts will cause the wildfires like what happened previously. Last time, there was a long dry spell. The wildfire spread from Long Banga to Lio Matoh. First, the Long Banga area and then to Baram River and then to Lio Matoh. It lasted for months, almost two to three months…"*

> *"…during the wildfires, all the crops of the villagers were burnt. It was hard to control the fire. All the fruits were burnt. The virgin jungle was also burnt. The fire was caused by drought…"*

Uncertain weather and seasonal patterns, increase in surrounding temperature, drought and wildfire events in the past have resulted in a significant impact on the livelihood of the community. These factors also undermined food security. Therefore, the community members have learned from the disasters and are now better in managing their resources to ensure that food is always available all year round. The next section explains these practices.

5.2.2 Land and resource management

Mobility: Mobility is seen in the shifting cultivation of the *padi iraang*, or the upland rice. For hundreds of years, rice has been the staple food for the Sa'ban. The cultivation of *'padi iraang'* is a Sa'ban farming tradition that is passed from generations to maintain sufficient rice production every year. Compared to the wet rice farming, the *'padi iraang'* only grows on dry soil and upland terrain. The basic concept of the shifting cultivation technique is the rotation of a long season of fallow followed by a short season of farming. It also involves a repeated shift of fields and the use of fire to remove natural vegetation (Erni, 2008). The method begins with *'temaraa''* (cutting down trees and other woody plants) and *'lemdiek'* (slashing the undergrowth). The area will then be left to dry before *'ntueng'*; the burning of dried vegetation takes place. This process helps to create nutrient-rich ashes that improve the soil fertility and to eliminate weed and pest temporarily from the area. The community will start the seed sowing right before the wet season arrives. Once the rice is matured, it will be harvested. In the next planting season, the same cycle is repeated in other fields. The empty field, on the other hand, is left to rest for four to five

years, allowing for regeneration of vegetation that will become trees. The villagers noted this:

> *"…we do not use any fertiliser. Everything is natural. To ensure that the soil is fertile and the rice grows well, we will shift the field from one place to another every planting season. We only use the same field for a maximum of two times in a row. Because for the 'padi iraang', if you cultivate it at the same place continuously, the yield is not much. That is why we shift from one place to another…"*

> *"…for the 'padi iraang', we burn the dried vegetation, and the ashes become the fertiliser. The 'padi iraang' plantation will shift from one place to another. For example, this year we do it over here, next year we change to another place. We wait until the trees grow for a few years. After about five years, we will do it again there. Every year the plantation site of 'padi iraang' will shift place. We can only cultivate the same land for two times. If we do it three or four times, the soil will not fertile anymore…"*

The Sa'ban claimed that through this method, the soil fertility is maintained persistently for years, and the rice will grow well and produce surplus yield.

Figure 18: The *padi iraang* (upland rice)
Source: Field survey, 2019

Storage: Storage is important to keep the surplus yield from the *padi iraang* plantation. The community keep the surplus yield in the *'paau padi'*, or the paddy store, to ensure that they will have a continuous supply of food even when disaster strikes. Thus, this relieves any food scarcity during times of crises. The villagers noted as follows:

"…we have a paddy store, 'paau padi'. The 'paau padi' is full of harvested rice. I have a lot of rice inside the 'pauu padi'. It was from three years back. Also, two years back. And the latest was last year harvest which is still available. We keep the stock. If the harvest is not good, we still have the stock. For example, this year, our harvest was quite poor due to drought. But we still have the harvest from the last few years which were very good. Our 'paau padi' is full during those seasons…"

Figure 19: The *paau padi* (paddy store)
Source: Field survey, 2019

Diversification: Diversification is another strategy that is evident in their land and resource management. Apart from *'padi iraang'*, every family establishes an *'éra'*. It is an integrated home garden characterised by a traditional land use system where they grow numerous species of plants as their secondary crop using intercropping farming technique. Some examples of crops in their backyards are bananas, sweet potato, other vegetables, and fruits. Most of these crops are fairly resistant to drought. Sometimes, the home garden also holds other food varieties such as poultry, livestock, and fish. Occasionally, the villagers use the old fallow field as their era to plant other secondary crops such as maize and pumpkin to maximise their food security. The villagers noted as follow:

"…sometimes, we plant pumpkin, corn, and other crops on the fallow fields. But if you do not want to use the land for other things, just let it be. It will become bushes. For example, small trees have grown now. In the next four to five years, the trees will mature. Then we will repeat the process…"

Diversified agroecosystems help the community to adapt to climate extremes such as droughts and wildfires. If other resources are damaged, there is still other food supply available. This was proven when the largest wildfires happened in the 1990s and burned all the *'padi iraang'* and resources in the forests such as wild fruits and vegetables. Luckily their *'éra'* and *'paau padi'* were not affected; thus, the food resources were secured. The villager noted this:

> *"…last time during the wildfires, all our crops, the 'padi iraang' were burnt down. It was hard to control the fire. All the fruits in the jungle were burnt. Luckily our 'éra' in our backyard did not burn during the incidence. The ones that were burnt were the 'plueng raal' (primary forest) and 'amuep' (secondary forest) …"*

> *"…fortunately our 'paau padi' did not burn. Because we protect them from fire. If they were burnt during the incidence, it means disaster to us. What are we going to eat then?…"*

Figure 20: The *éra* (home garden)
Source: Field survey, 2019

Conservation: Like the Lun Bawang, conservation is one of the adaptation strategies practice by the Sa'ban. The Sa'ban has a community forest reserve that is conserved and protected from any logging activities. The conservation effort helps to maintain the ecosystem integrity, which allows the buffering local climate to reduce the risks and impacts from extreme events. Moreover, the community forest reserve also supports other essential ecosystem supplies which provide them with water, wild meat, fish, and traditional medicine. The villager notes this:

"…in the Long Banga area, we have a reserve forest that nobody can disturb. We reserve and conserve the area to avoid the loss of our forest. We are afraid that if all the trees are cut, we do not have any place for hunting anymore. Our water supply will be depleted. In fact, we depend on the forest for traditional medicine. If we do not protect it, it will be hard for us…"

5.2.3 Social networks and institutions

Pooling: Communal pooling is found in the Sa'ban adaptation response which pools risks across households. For example, they work together to protect their village when wildfires hit them a few years ago. The villager recalled the experience as follow:

"…because people love the trees, the forest, and the village, we fight the wildfires together. We brought the fire extinguishers, the whole village. Some put out the fire over here, and some did it over there. Some protected our 'paau padi'. The village keeper beat the gong to inform the villagers about the hazard…"

They also perform collective action during the planting season because the cultivation of *'padi iraang'* is strenuous work, and it needs a significant workforce. They will decide the dates to work on the field together. It includes the times to cut down the trees, to do the harvesting and other activities related to the *'padi iraang'*. Moreover, the Sa'ban practises *'ledu''*, a type of community pooling action meant to help one in needs during crises. According to them, the whole community will help those who experience food shortages due to drought or other disasters by sharing resources and labour. The community member mentioned the following:

"…if, one of us in the Sa'ban community is in trouble; we will help him. For example, everybody is working on the farm, but then someone's farm gets hit by disaster, no food for him, we will help. We call this practice as ledu'. It also happens when somebody passed away in the village. We will visit the family. We will bring food to the family…"

The Sa'ban also pool their labour on the *mah maa' tempún*, a rice farm owns by the Church institutions. The aim of the farm is to help those who run out of rice due to a bad harvest year in a form of loan. The affected person will repay the rice once he manages to produce his own rice. Through this farm, the community will work together on the field in all respects, and the yield produced from the farm is given to those in need as a loan. This cooperation enhances unity within the community and provides insurance against food crises. The community noted the following:

"…during Sunday prayer in the Church, they will announce, for example, during this date we will do some work in the church farm for this person. So, everybody will go to the farm and work together…"

Figure 21: Community pooling during rice harvesting
Source: Field survey, 2019

Community pooling in the community is driven by the Sa'ban philosophy, the '*Si'sawai, Si'hnau, Si'lawai'*, which has become the root of their social strategies in building adaptive capacity to face environmental challenges. Carrying the meaning of "one heart, one mind, and one goal", this philosophy unites and strengthens the kinship of the community. The community noted that it enables collective action and reciprocity wherever they are, especially during hard times. The villager stated the following:

"… 'si'sawai, si'hnau, si'lawai'. It means one heart, one mind, and one goal. As an identity and philosophy of the Sa'ban, it should be in everyone's heart so that it will be practised wherever they are. Because it unites us and also strengthens our kinship. We are grateful to have the local wisdom…"

Additionally, the *lún rah lem awéeng* or the headman is the respected community chief, and he is the point of reference before they make any decision. He also leads the implementation of the values discussed above, besides driving collective actions and managing conflicts. The villager noted this:

"…to strengthen our community ties, our chief, the lún rah lem awéeng does that. He is the one who will gather everyone to do everything together…"

5.2.4 Worldviews and belief systems

One of the principles found underpinning the Sa'ban adaptation approach is to plan for uncertainty. Similar to the Lun Bawang, the fear of a bad harvest makes them more conscious about their resource management.

> *'…when drought occurs, rice yield will be lower. So if there is less food, we will keep it in the paddy store. That is why people have their paddy store…"*

> *"…if the harvest is poor, then we still have stock. The yield, like this year, is not so good compared to the previous year..."*

The awareness of this occurrence is built within the community and transmitted through oral traditions through centuries. For the Sa'ban, the transfer of knowledge starts from the family unit through *madei*, a session to advise and to demonstrate in a practical sense. In this practice, the older folks will give counsel to the youngster about the importance of their traditions. *Madei* can take place in different locations, either during dinner or lunchtime, when everyone in the family gathers. It can also take place on the farm when they bring along their children to teach them about traditional farming and how to secure food resources. The villager noted this as follow:

> *"…for the Sa'ban, parents and older folks hold the responsibility to advise and teach the children about our tradition. It can take place during our family gathering, lunch, or dinner time. For example, our children, our grandchildren, must know and learn about 'padi iraang'. In the past, we brought the children to the farm. We do not want to lose our tradition…"*

> *"…when I was small I followed my parents to the farm and into the jungle for hunting. That is why until now, I can do the farming and hunting myself. I also learned from my parents to prepare for food shortages, especially using the 'paau padi'. It was taught by our ancestors that everyone who does farming must have the 'paau padi'. The structure of the 'paau padi' is high, about 7 to 8 feet above the ground. The body of the 'pauu padi' is made from wood and covered by a layer of zinc or plastic. This design could prevent rats and other unexpected hazards. With this 'paau padi' we will secure our food resources for years…"*

Moreover, social functions such as ceremonies and festivals play essential roles in the knowledge transmission and establishment of strong social cohesion within the community. Before the seed sowing, they will perform the '*Sembayaang'* ceremony in the church to request for good harvest and avoidance of hazards. After the harvest, they will celebrate *'Ngkui'*, a Sa'ban after-harvest festival to commemorate the harvested rice and also to express their gratitude for the excellent harvest. In both events, the community

gathers and learns about their culture as well as share information and resources. Consequently, it strengthens the reciprocity relationship that they can rely on when disaster strikes. The community noted the following:

> *"…usually the ceremonies and festivals are our tradition to build relationships among us. Our culture is not the same as urban dwellers. We have ceremonies before we start planting and also festivals after the harvesting. During these events, we can meet and talk to our friends and relatives. We eat, we drink, we do 'ngajat' (traditional dance), we do everything together. And during this time, the young will get advice from the older folks…"*

5.2.5 Summary

The results revealed the application of TEK in the Sa'ban way of life. The first facet of TEK helps the community to detect changes in their surroundings. Significant changes that they experienced include the shifting in weather and seasons with more erratic rainfall and an increase in the temperature in recent times. It also exposes the vulnerability of the community to droughts and wildfire events. A significant finding is that the bioclimatic indicators that were used formerly to manage their daily lives are now out of sync. In response to these climatic challenges, the community manages their land and resources using the second facet of the TEK. They practice traditional long-fallow shifting cultivation for their upland rice, which benefits both the community and biodiversity system. Their agricultural lands are highly diverse; characterised by a mosaic of vegetation including home gardens, fallow land, annual crops, natural forest, and community forest. This diversity has now become the central element in their adaptation strategies to climate change, which helps to spread risks across space and time. The method of storing stocks has also made them more resilient to climate stresses.

In the third facet of TEK, the community philosophy becomes the basis of their social network that promotes social cohesion. More notably, the headman and the Church institution oil the wheels for the foundation of the reciprocity network among the community, which is vital to promote collective actions in response to climate difficulties. This is vital to reduce vulnerabilities. Finally, the last facet of TEK holds the three elements together and shows how knowledge transmission from generations to generations occurs through ceremonies and festivals. Older folks are vital knowledge holders that command a high level of respect from the community.

However, the community expresses their concerns regarding losing the TEK. Many young people have migrated to urban areas for studying and working, thus leaving their parents to work in traditional farming on their own. Due to the changes in lifestyle and modernisation, not many young people are interested in living in an isolated village,

though they will come back for festivals annually. Furthermore, the community is also worried about the continuous deforestation by the logging company which may impact the forest resources they depend on. Deforestation also decreases the number of trees that helps to reduce carbon dioxide levels, thus increasing the severity of the impact of climate change on the local community.

CHAPTER 6

CASE STUDY 3: THE PENAN, LONG LAMAI

6.1 Background

Long Lamai is a village of Penan in upper Baram, in northern Sarawak. To reach it requires an eight-hour ride from the town nearest to the settlement, on unpaved logging tracks, followed by an hour's walk through thick rainforest. Alternatively, it can be reached by a one-hour flight from Miri to Long Banga via a 19-seater Twin Otter, followed by a one-and-a-half hour boat trip to Long Lamai. Long Lamai is a very vibrant village with a population of around 580 people and 116 households. Long Lamai has achieved significant infrastructural milestones, demonstrated by the construction of new homes, rice farming and hydropower and solar-generated electricity.

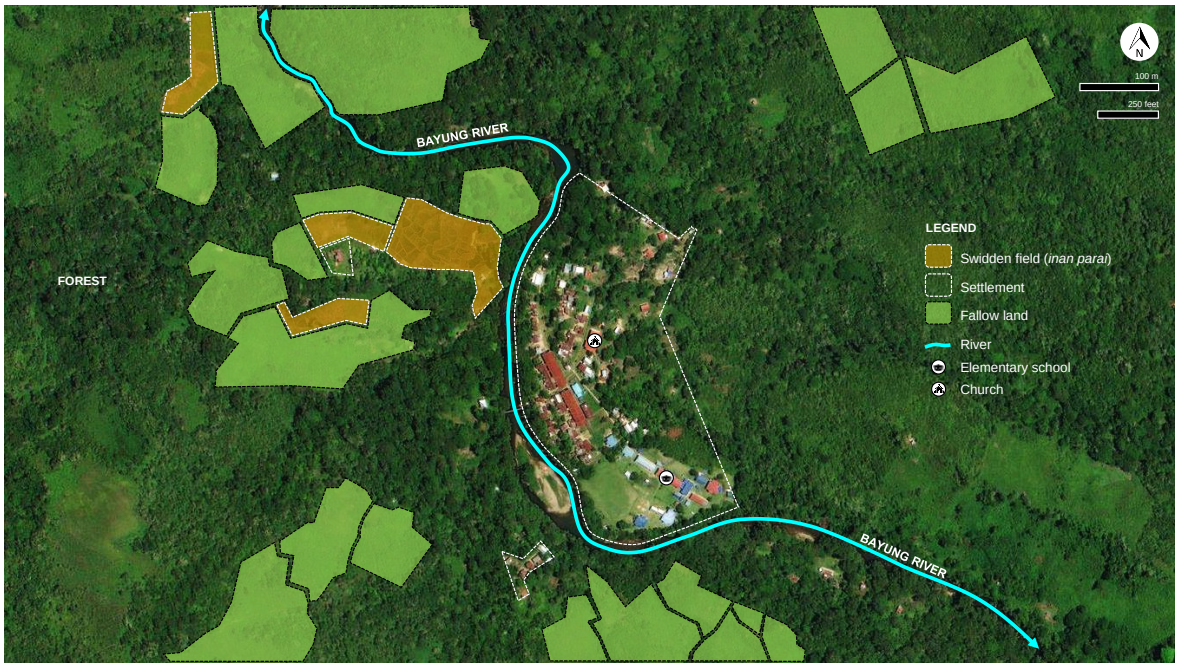


Figure 22: Long Lamai area
Source of aerial photo: Bing Maps, 2020

Figure 23: Long Lamai scenery
Source: Field survey, 2019

6.3 Demographic profiles of the Penan

Below are demographic profiles of the respondents.

Table 7: Demographic profiles of the Penan

Demographic Profile	Key Informant
Total Sample	11
Sex:	
Male	8
Female	3
Age group:	
18-30 year	1
31-45 year	3
46-65 year	6
65+	1
Education	
None	4
Primary	3
Secondary	4
Main Income	
Farming	9
Small business	2

Source: Field survey, 2019

6.2 The Penan's TEK

The traditional strategies for addressing climate change risks as identified by the Penan are explained compiled in Table 8:

Table 8: Traditional strategies of the Penan for addressing climate change risks

TEK component	Types of adaptation strategies	Description	Example
Local knowledge of environment	Forecasting	▪ Observing bioclimatic indicators to predict weather changes and availability of game ▪ Observing changes in local surroundings ▪ Identifying impacts of changes	▪ Bioclimatic indicators: ▪ Division of the year into two seasons based on climatic patterns ▪ Observations of fruits and animals predict the coming of different seasons and forecast the abundance of game ▪ Observed changes: ▪ Temperature of the environment has significantly increased ▪ The weather and seasons have become uncertain ▪ Identified impacts of changes: ▪ Drought events inhibit the growth of *inan parai* (rice plant) ▪ Wildfire events due to prolonged droughts ▪ Uncertain weather and seasons make farming and hunting difficult
Land and resource management	Diversification	▪ Diversification and creation of resource redundancy to spread risk through time and space	▪ The practice of shifting cultivation of *inan parai* in cycles of 4–5 years allows vegetation to regenerate and maintains soil fertility ▪ Intercropping of *pulah* (home garden) promotes heterogeneity ▪ Diversified resource base through *pulah* and forest produce
	Conservation	▪ Maintaining and restoring habitats and protecting biological diversity	▪ Conservation of forest and resources through a set of customs known as *molong* encourages the community to preserve resources for future generations

Social networks and institutions	Pooling	▪ Sharing of resources, labour and infrastructure among community	▪ Community principle is to maintain good relationships with each other and remember obligations to each community member ▪ Practice of *petulat* encourages resource sharing, especially during hard times ▪ *Pengepemung* remains central for collective problem solving and decision-making
Worldviews and belief systems	Storytelling Cultural festivals	▪ Knowledge and cultural transmission across generations	▪ Principle of 'take only what you need' promotes resource preservation ▪ Awareness of uncertainty encourages disaster preparedness across generations through *tesok* (advice from elders) ▪ *'Dau Adet Penan'* is a cultural festival celebrated annually to transfer knowledge and tradition

Source: Field survey, 2019

6.2.1 Local knowledge of the environment

Forecasting: The Penan divide the year based on rainfall, into the rainy season (October to February) and dry season (March to September). They identify significant variations in daily weather conditions, such as hot and dry at midday, as awareness of these changes is essential for planning subsistence activities. For example, the *inan parai* (swidden upland rice) is always burned at high noon, the hottest time of the day. The fires that are lit at the bottom burn hot and race up the hills and within an hour the swidden has turned to ash. The Penan often track the presence or absence of pigs and fruits to denote these seasons when dividing up the year and to forecast abundance of game animals. Apparently, in June and July, the Penan observe the massive migration of *babui* or Bornean wild bearded pigs (*Sus barbatus*) and the migration indicates the approach of the fruit season. The fruiting of forest trees after this occurrence marks the beginning of the wet season and when fruiting ends, the dry season is imminent. The villagers noted the following:

> *'…we usually went to the forest in the sixth or seventh month of the year during the pig season. Normally during the migration of the pigs, it means a good fruit season is coming. The fruit season usually takes place after the ninth month of the year…'*

'…when the trees are fruiting, that means we are in the rainy season. Fruits of any kind. And when the fruiting stops, we are in the dry season. We forecast the weather and season that way…'

However, most respondents explained that many of the established
weather forecasting bioclimatic indicators had become unreliable due to climatic changes. When the Penan were asked about climate change, all respondents acknowledged that the environment has changed over the decades, impacting them in different ways. First, they reported that their environment is getting warmer:

'…the weather had changed quite a bit. It has been cold here, but it is hot now…'

'…after all, the weather is now too hot, and it was too hot during the dry season, which triggers droughts…'

For the Penan, warmer temperatures have caused prolonged droughts, which have affected their *inan parai* and caused forest fires. The fires burned for months, consuming a hundred hectares of land, killing potentially thousands of animals and plants and destroying their ancestral burial grounds. They also said hunting was difficult because they could hardly detect traces of the animals. In addition, fishing has become problematic because the rivers are drying out.

'…the wildfire has happened three times in a row in our village. Once in a decade. First, it was in the '70s and then in the '80s and '90s. We could not do anything. All, our forests and our crops were burned away…'

'…fires destroyed my ancestral burial grounds in the 1980s and 1990s…'

'…it was a severe drought; even the paddy could not grow during the wildfire…'

'…during the drought searching for animals was so difficult for us. When we go into the forest, we generally look for the footprint of the animals. When dry, there were no signs we could see, just dust. If it was raining, we might see it. We still use this approach even in the modern days. If it rained last night, for example, 2 in the morning. And when you go into the forest the next day to check for the thing, that means it was there at 2 o'clock. If there is no sign, you will never catch anything even if you are waiting so long…'

'…it is better to hunt in the rain because the leaves are damp. You will not make any noise when you walk. If it is dry, you are going to make a noise as you walk. We might see the animal footprint and we know that the animal is there. It was so hard the last time we were hunting during the drought…'

'…during the drought, it was difficult to find food because the river was dried…'

The Penan also stated that their weather and seasonal trends had become unpredictable. Weather forecasting had been much clearer in recent decades because the Penan seasonal planting calendar was based on fixed climate patterns. This calendar is no longer reliable today because of the changes in rainfall and temperature regimes. Recently, the weather has changed every few weeks during the year; heavy downpours and floods could occur during the dry season and prolonged dry weather stretches took place when everyone expected rain. Sometimes the planting season was delayed by several weeks due to unceasing rain. As the Penan depend on this traditional calendar, these changes affect food production and supply accordingly.

> *'…we are not certain about the weather, because it is unpredictable now. Sometimes it rains when it should be the dry season. That is the weather we could see shifting. For instance, it should be the dry season during the season we want to burn the field, but it was raining. So, we have to wait until it dries out. It was fixed last time, but the weather has been uncertain in the last 10 to 15 years…'*

> *'…today, weather and season are so different. Far different. What I can see is that weather forecasts are not the same as they were before…'*

> *'…if it is raining it is going to flood. Now we can no longer predict this. Last time we knew when the dry season is coming, so we would know in what month the rain would fall. Every year, it was fixed. Now it is no longer predictable…'*

6.2.2 Land and resource management

***Mobility*:** The Penan utilise a mobility strategy by shifting where they cultivate *inan parai*. Their agricultural system for this plant engages rotating use of the land as dry soil and upland terrain. Once rice harvesting has been completed, the land where it was cultivated is left to rest for four to five years, allowing vegetation to regenerate in the area. The Penan noted that with this approach, soil fertility is persistently preserved across the years.

'…normally, the place to plant our paddy will be moved. It will be in the other place next year. If it was good during the first year, it would be less good the second time and it was not good the third time, we need to move to another place. If the trees in the old place have grown tall, we will return to that place while we wait for other places to regenerate as well. This technique preserves soil fertility…'

Figure 24: The *inan parai* (upland rice)
Source: Field survey, 2019

Diversification: In the Penan resource management strategy, the second most important principle is diversification. For example, food safety is maintained through the *pulah* or home garden, which also raises other food sources such as poultry. The forests also are a source for animals, fish, vegetables and fruits. Such variety mitigates risks, because if one food resource is destroyed, a food supply remains available in another area:

> *'…We have a home garden other than the paddy. We grow cassava, long beans, pineapple and sour eggplant. I have chicken too…'*

> *'…If our crops are not growing well, then we must find wild vegetables. We will go to the forest for hunting and fishing…'*

Figure 25: The *pulah* (home garden)
Source: Field survey, 2019

Conservation: Conservation takes part in the Penan strategy for climate change adaptation. The forest provides the Penan community with alternative resources and is therefore regarded by customary law as a protected conservation area. The villagers note this:

> *'…in our village people are protecting the forest, we are not going to cut down the trees, no large scale burning because it is going to destroy the forest. For us, the Penan, the forest is very important…'*

> *'…our forest is protected because the Penan relies heavily on it. Because from the forest we get whatever we need. It is our food source and everything you need for hunting, fishing and others…'*

> *'…from the forest, we get our life…'*

The most important aspect of Penan management of these resources is the traditional action of *molong,* meaning preserving. Penan *molong* several types of trees, including as blowpipes, house-building trees, fruit trees and *tajem* trees for their poisonous arrows, as well as rattan strands and sago. Some will *molong* animals they have found, including monkeys, chickens and others. The resources can be *molong* individually or communally:

> *'…molong means taking care of the animals, trees, or anything else. When we catch a monkey, for example, we like it and we will take care of it…'*

> *'…For instance, molong is when I see that tree and I like it, so I'm going to molong that tree. I will clean the tree area and preserve it, as proof that this is my molong. I will*

molong the tree. That is a case in point for a tree. For instance, if chicken, I will give it a label, I will tie a plastic on its feet. The trees in the forest that we are going to take care of, we will also molong it…'

The community value of 'take only what you need' is the basis for conservation behaviour that avoids over-hunting and overharvesting, ensuring an abundant supply of food for the future. For example, the Penan will only chop down a few trunks when harvesting palm trees for sago, leaving the remaining structure to allow the palm to grow new sprouts. They never cut the whole plant down, as this would destroy it. Likewise, rattan harvesting is selective, to ensure that young rattan plants mature for future collection.

'…the forest produce, we will just take what we need …'

'…we just cannot cut the tree down. It is going to grow. If we want to build a house, we are going to look for a tree that is particularly suitable for making wooden boards. We are not allowed to cut other trees. If we want to make sago out of the palm tree, we are not going to cut the entire tree…'

'…I will only take the mature ones when I take the rattan…'

'…we the Penan do not cut down the tree. We look after the forest…'

In general, forest conservation both supports how people adapt to climate change and encourages healthy habitats through the protection of biodiversity.

Figure 26: Conservation of the forest and natural resources
Source: Field survey, 2019

6.2.3 Social networks and institutions

Pooling: Evidence supports the presence of communal pooling within the Penan community. To the Penan, life in the rainforests as nomads was difficult and handling the related problems forced them to support each other through the practice of *petulat*, a word that translates roughly as sharing. The villagers note this:

> *'…. whenever we catch an animal in a game, it was shared…'*

> *'…the Penan enjoy sharing. When that person gives, the other also gives. The Penan love each other…'*

In addition, when any community members are in need, particularly if a disaster strikes them, they will get support from the villagers. Announcements are provided to keep the entire village updated.

> *'…if a tragedy has hit one of our members, we shall help him in any way…'*

> *'…if a member has problems, the Penan will support each other…'*

> *'…announcement will be made about the affected member and everyone will come and help…'*

Pengepemung is another Penan collective action that means 'to gather'. The Penan assemble once a month for community work such as *gotong-royong*, meetings and other events, including collaborative problem solving and decision-making.

> *'…normally, we will have a meeting in this village first so we can do everything together. For example, we will clear the land together for paddy cultivation. We are planting the paddy together, too. Therefore, no one is left behind …'*

> *'another for gotong-royong …'*

> *'…pengepemung is an action. For example, they will decide on a date in a month for gotong-royong. Cooperation is important in our community. In a big group, that is pengepemung…'*

'…there is also pengepemung during festivals, which means gathering in a group. There is a lot that can be done in pengepemung. We can organise a meeting in pengepemung, where we can decide things together. Pengepemung makes our work easier…'

Community pooling can be readily achieved because maintaining good relationships between the communities has been a Penan principle for generations and appreciating their community as a whole is fundamental to the Penan. These mutual bonds facilitate communication and provide relief during disasters and the bonds are reinforced and maintained through festivals and regular visits. Despite modernisation, this principle still applies in Penan communities to this day.

> *'…our ancestors taught us about one important thing. We remember their advice about our family, brothers and sisters that we should remember and we should not forget. We have to maintain a good relationship with our families and even with the neighbours…'*

Local leadership was also identified as an essential element in driving collective action and managing disputes. Based on the previous chieftaincy system, headmen are formally appointed by the government and possess extensive knowledge of the culture and customs of their communities. The respondents highlighted that when hazards do occur, the first person they consult with is the headman.

> *'…normally, we will get advice from the headman and he will make the decision based on the joint discussion…'*

Similarly, church institutions have been significant within the community. During the rice season, for example, the church is the platform that informs the community members of the dates when they will begin planting rice together. Sunday Mass also brings the community together, strengthening their unity.

'…each Sunday, after Christianity, we assemble in the Church for mass prayer. At the Church they'll announce anything…'

6.2.4 Worldviews and belief systems

The relationship of Penan cultures to the natural world is holistic. The Penan have been guardians of their lands for millennia and have deep interactions with the ecosystems where they live. As previously mentioned, the importance of 'taking only what you need' encourages people not to over-exploit their resources and to protect these resources, particularly during a disturbance. Uncertainty also underpins their coping methods, a condition that prompts them to plan for the worst. This emphasis is reinforced by *tesok* relating to the advice received from the elders and from storytelling. The villagers explained this:

'…my late father, for example, advised the villagers to plant anything they could grow, including cassava, fruits and others. They must have other crops other than paddy. There is at least another option if the paddy does not grow well. The Penan have to take care of their yield after harvesting…'

'…the Penan tradition is to tell our children and grandchildren stories. After the festivals or any event, we will have that one time for storytelling. The elders will give advice and tell a story about our past during that time…'

In addition to celebrating Christmas, the Penan engage in traditional beliefs-based cultural events and festivals, particularly the *Dau Adet Penan*, promoting reverence for nature, strengthening identity and linking the community together. The villagers explained these:

'…here we have the time to tell stories about our roots, our culture. Once a year, we will pick a day to tell the story of our ancestors, our village's story. So we can pass the knowledge on to new generations. We have a cultural festival, the Dau Adet Penan. On this date, all our '…once a year, we will spend a day with all the Penan telling them about history and culture. Because without that, we will lose everything. It gives us strength…'

'…the headman will give us advice during the gathering…'

6.2.5 Summary

These findings demonstrate the major roles TEK plays in supporting Penan adaptation to climate change. First, TEK assists the community in detecting changes in its environment. The substantial changes the Penan has observed in recent times include a shift in weather

and seasons, with more irregular rainfall and increases in temperature. The Penan also highlight the community's vulnerability to droughts and wildfire events. An important finding of this study is that the bioclimatic indicators that were once used to arrange the everyday lives for the Penan no longer function this way.

In response to these climate threats, the community uses the second dimension of the TEK in managing the Penan land and resources. Diversification of resources has been an effective adaptation option under climate stress, as it protects natural biodiversity, enhances the agroecosystem's ability to respond to stresses, reduces the risk of total crop failure and secures alternative opportunities for food supply. An enduring sense of preservation and responsibility to the forest is embedded in the Penan principle of *molong*. This supports the critical role that nature plays in supporting the ability of people to adapt to the impacts of climate change. As a third facet of TEK, the Penan has been able to maintain good relationships with each other, which has enabled them to collectively respond to environmental challenges. Finally, TEK ties these three elements together and shows how knowledge transfer from generation to generation takes place through festivals and guidance from older folks.

Beyond these effects, other concerns have been expressed by the Penan. Surprisingly, the Penan was more alarmed by the destruction of natural resources on their land, especially the forest, than by climate change itself. They have been working for decades toward halting the destruction of the Sarawak rainforest. Despite national and international laws that protect Indigenous land rights, the Sarawak state government does not recognise the rights of the Penan to the rainforest. To the Penan, the connection to their land is an important source of resilience.

CHAPTER 7

COMPARISON OF ADAPTATION STRATEGIES AMONG THE LUN BAWANG, SA'BAN AND PENAN

7.1 Comparison of adaptation strategies

The comparison of traditional strategies for addressing climate change risks as identified by the Lun Bawang, Sa'ban and Penan are outlined in Table 9.

Table 9: Comparison of adaptation strategies among three communities

TEK components	Adaptation strategies	Example in case studies		
		Lun Bawang	**Sa'ban**	**Penan**
Local knowledge of environment	Forecasting	Bioclimatic indicators: • Observation of sky colour to predict daily rainfall. Formation of mist in the morning believed to be informative of temperature changes • Sightings of fruits to forecast the abundance of game Changes observed: • The temperature of the environment has significantly increased. • The weather and seasons have become uncertain. Identified impacts of changes: • Warmer temperatures cause frequent drought events which dry up the *lati'ba* (wet rice paddy) • Erratic rainfall causes flash flooding that erodes the *lati'ba*	Bioclimatic indicators: • Division of the year into two seasons based on climatic patterns • The shape of the moon known as "bliin teng" was used as an indicator to plant seeds Changes observed: • The temperature of the environment has significantly increased. • The weather and seasons have become uncertain. Identified impacts of changes: • Droughts cause the land to dry up and inhibit the growth of the *padi iraang* (upland rice) • Wildfire events due to prolonged droughts • Uncertain weather and seasons makes rice farming difficult	Bioclimatic indicators: • Division of the year into two seasons based on climatic patterns • Sightings of fruits and animals predict the coming of different seasons and forecast the abundance of game Changes observed: • The temperature of the environment has significantly increased. • The weather and seasons have become uncertain. Identified impacts of changes: • Drought events inhibit the growth of *inan parai* (rice plant) • Wildfire events due to prolonged droughts • Uncertain weather and seasons makes farming and hunting game difficult
Land and resource management	Diversification	• Integrated crop-animal farming is maintained through traditional *lati'ba'* system which promotes agrobiodiversity, food	• Intercropping of *éra* (home garden) promotes heterogeneity • Diversified resource base through *éra* and forest	• Intercropping of *pulah* (home garden) promotes heterogeneity • Diversified resource base through *pulah* and forest

		diversity and land resource management. • Intercropping of *kabun* (home garden) promotes heterogeneity • Diversified resource base through *kabun* and forest produce	produce	produce
	Mobility	N/A	• The shifting cultivation of *padi iraang* allows the land to rest in 4–5 year cycles and maintains soil fertility	• The practice of shifting cultivation of inan parai in 4–5-year cycles allows vegetation to regenerate and maintains soil fertility
	Storage	• Storage of resources in the *sulap padi* (paddy store) promotes food security	• Storage of resources in *paau padi* (paddy store) ensures constant flow of food over the years	N/A
	Rationing	• Enforcement of 'tagang' systems to avoid fish depletion	N/A	N/A
	Conservation	• Conservation of forest area under local customary law	• Conservation of forest area	• Conservation of forest and resources through a set of customs known as *molong*
Social networks and institutions	Pooling	• Practising community pooling during a crisis for example *ngeruyung, gotong-royong, ngumum, musang* • Preservation of family tree to promote social cohesion • Headman and church institutions enhance community engagement	• Practice of *ledu'* to help those who have suffered from disaster • Church owns a rice farm called *mah maa' tempún* to help those who run out of food • *"Si'sawai, Si'hnau, Si'lawai"* (one heart, one mind and one goal) is a socio-cultural philosophy that strengthens	• Practice of *petulat* encourages resource sharing especially during hard times • *Pengepemung* remain central for collective problem solving and decision making • Community principle is to maintain good relationships with each

		community kinship	other and remember obligations to each community member
Worldviews and belief systems	• Community value "kill only enough for food" as preservation principle • Value of uncertainty encourages disaster preparedness across generations through legendary folktales called "beras dan harta" • Cultural festivals "Pesta Beras Adan" encourage knowledge and cultural transmission	• Value of uncertainty encourages disaster preparedness across generations through *madei'* (advice from elders) • Knowledge and cultural transmission occurs through '*Ngkui'* festival and *Sembaayang* ceremony	• Principle of "take only what you need" promotes resource preservation • Value of uncertainty encourages disaster preparedness across generations through *tesok* (advice from elders) • *"Dau Adet Penan"* is the cultural festival celebrated annually to transfer knowledge and tradition

Source: Field survey, 2019

7.1.1 Local knowledge of environment

The communities managed their subsistence activities such as agriculture, hunting and fishing by observing and predicting the variability of their climate and local surroundings. Traditional forecasts included observation of sky colour, temperature, moon phases, fruiting of fruit trees and the migration of animals. For example, the Lun Bawang reported that a reddish evening sky signals good weather the next day, characterised by a dry atmosphere with no precipitation. This condition is ideal for harvesting their *lati'ba'* because harvesting it during the rain will damage crops, thus reducing their yield.

The Sa'ban and Penan, who cultivate upland rice, divided the year into two seasons based on climatic patterns; the "wet season" from October to February is characterised by heavy precipitation and the "dry season" from March to September is drier with higher temperatures. The agronomic cultivation of upland rice is heavily dependent on both seasons. The dry season is perfect for land preparation, whereas the wet season with heavy rains provides optimum conditions for the crop to grow. The Sa'ban reported that they observed lunar phases to guide seed sowing. During the night in August, they look for the *"bliin teng"* or the "first quarter moon" as it indicates the perfect time to plant seed. Scientifically, the first quarter moon is considered fertile and wet due to the effects of tides on groundwater tables (Harris & Summer, 2002) exhibited during the moon's phases.

The Penan monitor the presence and absence of fruits and pigs to predict the coming of different seasons and forecast the abundance of game. Apparently, the Penan monitor the massive migration of *"babui"* or Bornean bearded pigs (Sus Barbatus) in June and July which indicates that the fruit season is approaching. Following this event, the fruiting of forest trees signifies the beginning of the wet season, and when it stops, it means that the dry season is imminent. The Lun Bawang also explained that the shedding of ripe fruits during the harvest season in January indicates an abundance of bearded pigs in the jungle. The cold night temperatures in January also signal the spawning of fish in Ba'kelalan.

The majority of respondents, however, described that most of the bioclimatic indicators used to forecast weather and seasons were no longer reliable and were falling into disuse in the last 10 to 15 years due to changes in climate conditions. These indicators and adaptations all point to climate change issues directly impacting these indigenous groups. When they were asked about their perceptions of climate change, all respondents noted shifts in the climate and were aware of the impact these variations had caused. First, they reported that temperature of their environment has significantly increased. The Lun Bawang, for example, noted that the disappearance of the "misty morning" is a sign

that the temperature is no longer cool. Apart from being vital for moisturising fields and gardens, mists make morning activities preferable during that time (Ellen, 2011). Disastrously, warmer temperatures cause frequent droughts and affect the wet rice fields.

In the *lati'ba'* system, the rice must be kept flooded for most of its growth (Jok, 2012). Therefore, prolonged droughts cause the river to dry up and prevent water from flowing into the *lati'ba'*, causing it to dry too. Planting rice is then difficult, which reduces food production. For the Sa'ban and Penan, prolonged droughts affected their upland rice and caused forest fires that lasted for months. During the event, all the crops and resources in the forest that they depend upon greatly were burned away, causing significant losses. The fires had destroyed the places where they get their food and damaged the rivers where they get the water supply. Since the communities live in isolated areas, market access is very limited. The nearest town that they can get the food supply is Marudi, which is located 230 km away from their home and can only be accessed by four-wheeled-drive (4WD) or Twin Otter plane. For the Penan, the forest has been their home for thousands of years, which holds food, water, traditional medicine and other resources. Most importantly, it holds their ancestral burial grounds, which create a link between past and present generations. Thereby, forest loss is impacting the cultural and spiritual life of its people. The Penan also stated that game was difficult to hunt during droughts as they could hardly detect any traces of the animals.

In addition, the communities consistently reported that the weather and seasonal patterns had become uncertain. In the past few decades, the prediction of weather was much easier when their seasonal planting calendar was based on fixed climatic patterns. Nowadays, this calendar was no longer reliable due to the shifts in rainfall and temperature regimes. There are abrupt variations to the rainfall; sometimes it is very low for an extended period, sometimes it is plentiful at an unexpected time. Accordingly, it affects food production and supply, especially among the Sa'ban and Penan who depend on this traditional calendar. The Lun Bawang also reported that heavy rainfall that occurs in a short period causes flash flooding, which erodes their paddy fields and thus destroys their livelihoods.

7.1.2 Land and resource management

Climate change poses threats to those communities that are heavily dependent on natural resources and the monsoon climate for their agricultural practices. A few strategies were recorded that are used to respond to variations in climate and ensure an abundance of food and resource supplies throughout the year.

First, diversification strategies were found common across all three communities. Diversification helps to spread risks across spatial and temporal scales, thus increase food

and resource security (Agrawal, 2008). In these case studies, diversification refers to the agricultural techniques and also the variety of resource based used to adapt to climate stresses. For example, the integration of animal husbandry with crop cultivation technique by the Lun Bawang promotes agrobiodiversity, food diversity and resource management that strengthens the resilience of the agroecosystem to climate change (Singh & Singh, 2017). The intercropping method was another agricultural technique that promotes diversification. It involves the concurrent cultivation of more than one crop species on the same field (Hauggaard-Nielsen et al., 2008). Practically, this type of technique is applied in their integrated home gardens. They use different terms to refer to the garden. The Lun Bawang refer to it as "kabun", the Sa'ban call it "*éra*" and the Penan use the term "pulah". These home gardens occasionally included taro, cassava, sweet potato or yam. Some families also had papaya and banana trees and other vegetables. This farming system is very productive (Hu et al., 2017) because it reduces climate-driven crop failure as diverse crops have different climatic adaptability (Shava et al., 2009). In addition, food security is also upheld through their home gardens which host other food varieties such as poultry, livestock and fish. The forests are also an option for obtaining wild animals, fish, vegetables and fruits. These options minimise risks, because if one food resource is damaged, the food supply in another region remains available.

Second strategy is mobility, which is seen in the shifting cultivation of the *padi iraang* (Sa'ban) and *inan parai* (Penan). Mobility pools risk across space and is the most common natural responses to environmental risks. The Sa'ban and Penan cultivate upland rice, which only grows on dry soil and upland terrain using this agricultural system. Shifting cultivation is the most ancient agricultural system for maintaining soil fertility (Hillel, 2005). The basic concept of this method is the rotation of a long season of fallow, followed by a short season of farming. It involves the repeated shift of fields and the use of fire to remove natural vegetation (Erni, 2008). With this method, both Sa'ban and Penan noted that the soil fertility is maintained persistently for years which promotes the growth of rice and produces a surplus yield.

Third strategy is storage, which is found in the Lun Bawang and Sa'ban resource management strategy. Storage strategy refers to physical infrastructure used for storing the resources. In these case studies, paddy store is used to house the surplus from each harvesting season. This paddy store is specially designed to avoid external threats such floods, rat attacks and others. It is a hut-like store made of wood, seven to eight feet above the ground which can only be climbed with a portable staircase, to prevent rats from getting inside the store. The body of the store is covered with zinc or plastics, while the pillars are coated with a slippery surface to inhibit rats climbing up. Storing resources is very important for these communities as it ensures a constant flow of food over the years and provides an emergency stock when disaster strikes, or if there is a poor harvest. Storing resources is very important for these communities as it ensures a constant flow of

food over the years and provides an emergency stock when disaster strikes, or if there is a poor harvest.

Fourth strategy is rationing, which is only found significant in the Lun Bawang communities. Rationing is an important strategy to control the distribution of scarce resources. In this case, rationing will limit the individual use of natural resource in order to cope with scarcity especially in the case of disaster-related shortages.

Finally, this research has found conservation to be another coping technique that is not addressed in other studies on adaptation to climate change. Conservation of the forests across all communities was found to be important. Forests act as a buffer to protect paddy fields and provide alternative resources for the community, thus, they are maintained as a conservation area by customary law, with penalties imposed for violations. No human activities other than hunting are allowed within the forest, especially cutting and logging. The community applied value practices of "kill only enough for food" and "take only what you need", which have also become the basis of conservation behaviour to avoid over-hunting, over-harvest and over-fish, thus ensuring an abundant food supply in the future. In general, conservation of the forest not only helps communities to adapt to climate change, but it also promotes resilient ecosystems by maintaining biodiversity.

7.1.3 Social networks and institutions

Local institutions and networks play an important role in managing disturbances caused by climate and environmental stressors. In essence, coping with calamities is more effective when the communities respond collectively (Adger, 2003). It requires everyone to know each other and care for one another in times of need. These communities are bonded by the cohesive forces of their family and kinship structure. Customarily, a family is shaped by a clans' relationships, which comprise father, mother, brother, sister, uncle, aunties, cousins and so on, which are also known as the extended family (Pascoe, 2018). The Lun Bawang reported that the preservation of the family tree is their tradition which ensures everybody knows each other. The Sa'ban highlighted their socio-cultural philosophy, "Si'sawai, Si'hnau, Si'lawai" (one heart, one mind and one goal) which unites and strengthens community kinship. Similarly, maintaining a good relationship between the communities has been a Penan principle for generations, and remembering their community as a whole is fundamental. These mutual bonds facilitate communication and provide relief during disasters, which are reinforced and maintained through festivals and regular visits. Despite modernisation, this principle still applies in all three communities to this day.

Communal pooling during hard times remains central in all three communities. For the Lun Bawang and Sa'ban, joining forces originated from rice culture. Farming either wet or dry rice is a strenuous task which requires the communities to pool their labour. Since the rice is planted on the same day, people rely heavily upon each other. A labour pool is needed for the heavy farming tasks like clearing/burning, planting and harvesting. Ngeruyung, musang, gotong-royong and ngumum are some forms of cooperation in the Lun Bawang community among those who need help on their farm. On some occasions, food is prepared as a reward once the work is over. "Ledu" is a term practised by the Sa'ban that refers to the help that is offered to those who have suffered from disasters (i.e., food shortages due to poor harvest). For the Penan people, living as nomads in the rainforests was a struggle and managing the uncertainties required them to support each other through the practice of "petulant", a term that translates roughly as sharing. Even today, failure to share is the greatest offence in their society. "Pengepemung" is another collective action practised by the Penan which means "to gather". Once a month, they gather for communal work such as gotong-royong, meeting and other activities that require collective problem solving and decision making.

Local leadership was also identified as an important element for driving collective action and managing disputes. Headmen, village councils and the church institutions provide direction, and carry and transmit knowledge in all three communities. The headmen are formally appointed by the government based on the previous chieftaincy system and possess extensive knowledge of culture and customs of their communities. The respondents highlighted that, when hazards do occur, the first person they refer to is the headman. Accordingly, church institutions were significant within the community. The Orang Ulu are Christians, predominantly of the Sidang Injil Borneo or Borneo Evangelical Church (SIB). Even though professing Christianity has led to the elimination of some rituals (i.e., improper disposal of dead bodies and headhunting), some old practices have been maintained and infused with current religious teaching. For example, before Christianity, the communities will gather to perform a ritual to worship the spirit of the rice before they started to plant the paddy. However, today, this practice is replaced with Sunday Mass, and it becomes the platform that informs the community of the dates they will collectively begin the rice planting. It brings the community together, thus strengthening their unity. These practices are common across all three communities. Interestingly in the Sa'ban culture, the church owns a mah maa' tempún, a rice farm cultivated by the community collectively, and the yield produced from the farm is given to those who run out of rice as a loan. This cooperation provides insurance against food crises and enhances their relationship by supporting their capacity to manage climatic and environmental change.

7.1.4 Worldviews and belief systems

Worldview and belief systems are at the root to the whole TEK system which shapes resource management and social relationships within the communities when they face a disturbance. From their traditional worldview, the natural world is one aspect of their lives and this interconnectedness creates a moral responsibility to live in harmony, respect and care for the environment. As mentioned, the value "kill only enough for food" and "take only what you need" remind them not to over-exploit resources. Hence, species depletion is reduced, thus securing their resources in times of need.

Their adaptation strategies are also underpinned by the value of uncertainty, such that preparing for the worst is an obligation in their community. For example, the Lun Bawang expressed concern about "tahun jahat", which is related to a bad harvest due to droughts or other disaster, causing reduced food supplies. The same concern was also found in the Sa'ban and Penan communities. The fear of this event is installed within each community and passed across generations through oral traditions. The Lun Bawang, for instance, have created a legendary folktale named "beras dan harta" or "rice and possessions". It explains the importance of protecting the rice field or the *lati'ba'*, which surpasses anything to be seen in Ba'kelalan. The need to prepare for an iru season (drought) encourages them to plant as many paddies as they can each year and make emergency stock, so that in the event of disaster, their food is secured. As for the Sa'ban and Penan, this knowledge is accumulated through *"madei"* (Sa'ban) and *"tesok"* (Penan), which refers to the advice obtained from their elders.

Communities also take part in cultural festivals based on traditional beliefs, which encourage respect for nature, reinforce identity and connect the community. For the Lun Bawang and Sa'ban, rice is central to their culture. Before Christianity, the Lun Bawang and Sa'ban perform rituals to summon the spirits of the rice after harvesting season to make the next harvest bountiful. The communities believe that the spirits will preserve the *lati'ba'* and padi iraang that support their livelihoods. For these communities, the rice is important that it must be nurtured for the next generations. Today, the rituals are replaced with annual thanksgiving festivals, the Pesta Beras Adan (Lun Bawang) and Ngkui festival (Sa'ban). Even though the rituals were no longer practice, the importance of preserving the rice is passed across generations during these events. The Penan, on the other hand, celebrate Dau Adet Penan. It is an annual festival that becomes the platform for the community to reinforce their history of being nomadic who rely a lot on the forests. The Penan feels that the history of their community will give them the strength to face today's challenges, especially in protecting the forests. In general, these cultural festivals are essential for communities to learn and preserve their culture. Apart from knowledge transmission, the festivals become places for sharing and exchanging information and resources, which strengthened social networks and maintained

reciprocal relationships. Therefore, during hard times individuals then rely on these reciprocal relationships, thus ensuring the resilience of resource access, which is a fundamental need in the face of climate and environmental extremes.

7.2 Discussion

The intimate knowledge the Orang Ulu have of their local ecosystems revealed broad changes in the climate. The warming temperature perceived by these communities is consistent with the increasing temperatures recorded over the past decades, which have indicated a mean temperature increase per decade of approximately 0.14 °C for Sarawak (NRE, 2015). The temperature increased sharply in the years 1972, 1991, 1997–1998 and 2015–2016 due to a strong El Niño, with the 2015–2016 event being the worst (Tang, 2019). In addition to rising temperatures, droughts were the primary concerns of these communities more than other disasters. Most of their coping strategies, including the fear of tahun jahat (a bad year), were related to drought management. Following this, the World Meteorological Organization reported that droughts have hit Sarawak numerous times since the 1970s due to a great decrease in rainfall associated with El Niño events (World Meteorological Organization, 2017). It has also been predicted that droughts will hit Sarawak harder and for more prolonged periods in the future (Bong & Richard, 2019) with an expected increase temperature of 3.8 °C (Malaysian Meteorological Department, 2009). Judging from future climate change projections, the capacity of these communities to adapt to future climate stressors will be further challenged. Consequently, it requires advance intervention to manage risk in the face of climate change, especially long-term management to deal with significant uncertainties (Lebel et al., 2015).

Our work also revealed that traditional strategies for managing the land and resources were the results of attempts to adapt to environmental stressors and uncertainties. Interestingly, this management system is consistent with the concept of adaptive management (Berkes et al., 2000; Holling, 1978; Walters, 1986), an approach used to manage natural resources in the face of uncertainty (Winterhalder, 1983). An important aspect of ecosystem management for resilience is adaptive management to minimise uncertainty, which is the best approach for dealing with external shocks, given the complex non-linear dynamics of interconnected socio-ecological systems (Allen et al., 2011). As mentioned above, these communities use practices that conserve ecosystem resilience, such as shifting cultivation systems to maintain forest cover, intercropping two or more crops in proximity to increase plant diversity, thus promoting resilience. This management system has subsequently created a vibrant mosaic of land use patterns within indigenous territory comprising patches of natural forest, managed forest, rotating fallow and permanent fields. It is a productive mosaic of habitats where the harmonious interaction of people and nature sustains biodiversity and provides humans with an

ecosystem that supports various livelihoods and well-being (Cocks, 2006; Watson et al., 2019). This bio-cultural diversity is a major source of change response capacity which is strongly linked to community resilience (Bridgewater & Rotherham, 2019; Calvet-Mir et al., 2016) and needs to be further enhanced and promoted.

Furthermore, our findings indicate that the connections between these communities and their lands and forests are an important source of adaptation. When disaster strikes, for example, the lands and forests within the indigenous realm provide emergency resources such as wild animals, fruits, vegetables and other resources. Therefore, it is important for these communities to have access to these territories to obtain these resources. In this regard, the recognition of the collective rights to indigenous lands, territories and resources will support well-being of the indigenous communities and tackle climate change (Hedden-Nicely & Caldwell, 2019). Our results corroborate previous research findings suggesting that secured land ownership, along with the rights to access, manage and extract natural resources from that land, are a pre-requisite of community resilience.

Anthropological scholars have provided important insights into how crisis and famine weaken social relations and reciprocity in traditional communities (Sahlins, 1972). Our research, however, suggests that food scarcity and crisis promote collective action by pooling resources and labour. This action is based upon the community culture, where the failure to retain this tradition is the greatest offence. Consequently, the social cohesion necessary for community resilience is maintained. In addition to social networks, the resilience of these communities is ascribed to indigenous institutions based on their own principles in response to the mutual support needed during disasters. This self-help approach has a strong influence on the community, which should be recognised by the government so that the marginalisation of these institutions can be avoided.

Another important result of our work relates to the role of worldview and belief systems in creating long-term community resilience by maintaining the culture of indigenous communities. Culture is essential as it shapes a community's values and how each community perceives the world and behaves accordingly (Adger et al., 2013). Previous research has shown that folk beliefs support the sustainable use of natural resources which contribute to enormous increases in the pristine highland forest (Hakim, 2011). Our findings not only prove that their cultural values, which are sustained through oral traditions and traditional festivals, have shaped the way the community governs their resources, but they also promote and maintain social cohesion among the communities. Therefore, the traditional way of life of these communities must be recognised and sustained to support resilient socio-ecological systems. Furthermore, unlike previous research which focused only on the role of religious ceremonies in supporting resilience to environmental extremes (Gómez-Baggethun et al., 2012;

Hiwasaki et al., 2014), our study found folktales and advice were other mediums of shared-belief systems that nurture community resilience. Folktales may have increased resilience by installing the value of "uncertainty" in an interesting and fun way within the community, especially among younger generations. Cultural festivals on the other hand, imitate the function of religious ceremonies, which enhance social cohesion.

CHAPTER 8

IMPLICATIONS AND CONCLUSIONS

8.1 Introduction

This section examines the implications of this study, including implications for both theory and practice. This section also reviews the limitations of the research presented here and of future research and concludes the study.

8.2 Research Implications

The results of this study have both theoretical and practical implications, which are probed in the following.

8.2.1 Theoretical implications

Exploring the effects of TEK in the context of climate change that involves Indigenous peoples offers a major contribution to the field of climate change adaptation. This is reinforced by TEK being addressed in many other studies in relation to natural resource management (Mao et al., 2019; Popp et al., 2019; Yager et al., 2019). Such research has thus further improved the understanding of how the TEK system functions in the context of climate change.

In the present study, we have documented that the TEK system provides a holistic approach that helps Indigenous people respond to the changing climate. Several adaptation approaches were developed based on considering TEK's major components. Such practices function importantly in the promotion of resilience, which in turn plays a role in social and ecological processes that sustain the wellbeing of the social–ecological system. Table 10 demonstrates how all of these components interrelate and contribute to socio-ecological resilience.

Table 10: TEK, adaptation strategies and resilience

Elements of TEK	Adaptation Strategies		Resilient Attributes	
Local knowledge of the environment	Forecasting	Local observation helps develop strategies to cope and adapt	Ecological diversity Ecosystem services	The protection and enhancement of natural ecosystems and biodiversity will enhance resilience. Diverse ecosystems recover rapidly as they have more options for coping with different forms of disturbance (Dunn & Velez, 2018)
Land and resource management	Rationing	Temporal restriction of harvest in response to common shortages allow the renewal of surrounding ecosystems		
	Diversification	A mixture and selection of various livestock, crop varieties and other resources promotes biocultural diversity		
	Mobility	An area of land that has been left for years to rest encourages the regeneration of vegetation		
	Storage	Stockpiling emergency food supplies contribute to food security and creates a resilient food system		
	Conservation	Protects healthy habitat that sustains a broad range of biodiversity under changing conditions		
Social networks and institutions	Pooling	Community shares assets and resources (e.g. food, natural resources, labour and infrastructure) across households on a reciprocity basis. Local leadership and institutions build social cohesion within the community	Social capital and self-organisation	Social capital comprising qualities such as collective action, reciprocity and participation is an asset for resilience (Ledogar & Fleming, 2008)
Worldviews and belief systems	Knowledge and cultural transmission	Transmitting knowledge and values across generations promote collective long-term memory of adaptations	Continuous learning	The ability to learn and share information from past experiences is key to resilience (Duchek, 2019)

Source: Author, 2020

Based on the TEK components, a conceptual framework can be built that links TEK, climate change adaptation and socio-ecological resilience, as shown in Figure 27.

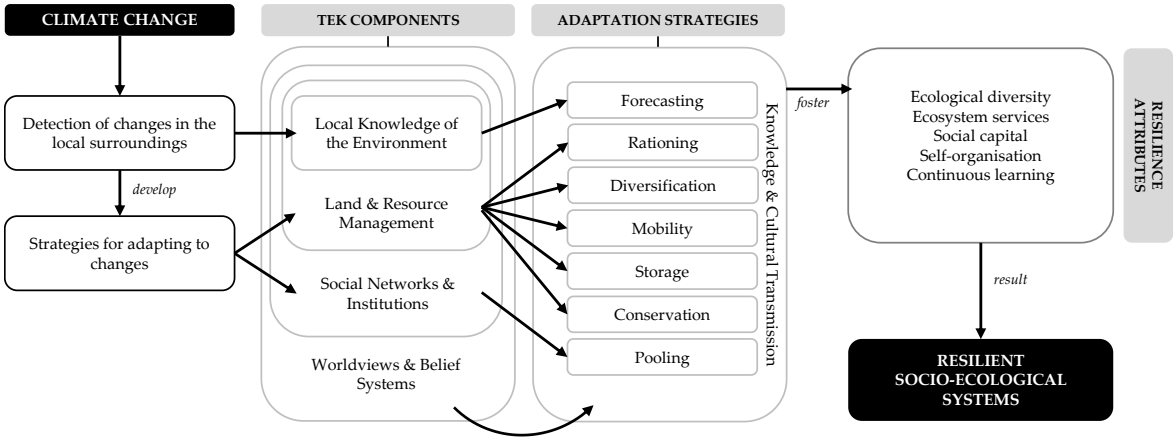


Figure 27: Bridging TEK, adaptation and resilience of socio-ecological systems
Source: Author, 2020

Figure 27 includes the most important components of TEK that reinforce the adaptation practices of Indigenous communities, namely, forecasting, rationing, diversification, mobility, storage, pooling and exchange. These adaptation practices are consistent with the local adaptation classification already provided by Agrawal (2008), Prasad et al. (2009) and Gómez-Baggethun et al. (2012). Figure 27 also includes conservation, a strategy that was not emphasised in previous research. These practices are fundamental to fostering resilience attributes that in turn function in the social and ecological processes that support the wellbeing of social–ecological systems. In this regard, socio-ecological systems include interplay between humans and their biophysical environment, an interaction increasingly recognised for its value in conceptualising human-environment systems and the way these systems can be tuned toward resilience (Berkes et al., 2003; Stokols et al., 2013). In the context of social–ecological systems, resilience denotes the following: (1) the ability of a system to retain its identity, structure and feedback after encountering a set of changes (Walker et al., 2004) and (2) the ability of the system to reconstruct after it has crossed a threshold (Folke, 2016).

In the sense of this study, therefore, resilience refers to the capacity of local communities to react to, withstand and recover from the adverse effects of climate change through the use of available resources and social support within communities, which in turn are sustained through traditional practices. The important attributes of these abilities are (1) ecological diversity, (2) ecosystem services, (3) social capital inclusive of social connections and participation in community groups, (4) self-organisation and (5) continuous learning in response to environmental change (Folke et al., 2002; Gómez-Baggethun et al., 2012; Walker & Salt, 2006). As discussed, when adaptation practices are rooted in TEK, they significantly encourage the development of these attributes. Therefore, this concept is applicable to other place-based research that regards TEK in climate change studies. Unlike previous studies that only emphasised the importance of a few components of TEK (See Table 11), our work suggests that each component of TEK has a special function that should be awarded equal weight and importance.

Table 11: Past studies on TEK in climate change context

Related studies on TEK in climate change adaptation	TEK components considered in the study	Region
Yang et al. (2019)	Local knowledge on environment Land and resource management	China
Zin et al. (2019)	Local knowledge on environment Land and resource management	Myanmar
Khalafzai et al. (2019)	Local knowledge on environment Land and resource management	Canada
Leonard et al. (2013)	Local knowledge on environment Land and resource management Worldviews and belief systems	Australia
Lefale (2010)	Local knowledge on environment	New Zealand
Soriano (2017)	Local knowledge on environment Land and resource management	Phillipines
Gyampoh (2009)	Local knowledge on environment Land and resource management	Africa
Leidler (2006)	Local knowledge on environment	Canada
Riedlinger (1999)	Local knowledge on environment	Canada
Makondo & Thomas (2018)	Local knowledge on environment Land and resource management Worldviews and belief systems	Africa
Nyong et al. (2007)	Local knowledge on environment Land and resource management	Africa
Pearce et al. (2015)	Local knowledge on environment Land and resource management	Canada
Pareek & Trivedi (2011)	Local knowledge on environment Land and resource management	Rajasthan, India
Egeru (2012)	Local knowledge on environment Land and resource management	Uganda
Burkett (2013)	Local knowledge on environment Land and resource management	Hawaii
Riseth et al. (2010)	Local knowledge on environment Land and resource management	Norway, Sweden
Naess (2013)	Local knowledge on environment Land and resource management Social institutions and networks	Tanzania
Tremblay (2006)	Local knowledge on environment	Canada
Lynn et al. (2013)	Local knowledge on environment Land and resource management Social institutions and networks	United States
This study	Local knowledge on environment Land and resource management Social institutions and networks Worldviews and belief systems	Malaysia

Furthermore, each component interrelates with all the others. This forms the belief systems into a foundation for culture, concerning all of the ways people perceive and manage the environment and their social relationship. This aspect is often ignored in many place-based climate change adaptation practices; however, we argue that it is important to incorporate worldview and belief systems to capture the essence of adaptation behaviour within the community in depth. These systems related to the nature of TEK, which is not a 'one-size-fits-all' concept. TEK is developed through a continuous process that also includes spiritual and cultural elements of knowledge holders, in addition to their multigenerational observations and skills. These aspects are more localised and specific to certain communities, formed around their social, economic and cultural needs. Hence, an adaptation plan without these elements would be inoperative and in turn would lead to maladaptation to climate change (Barnett & O'Neill, 2010).

8.2.2 Practical implications

(a) Maintaining Indigenous territorial integrity using Zoning Plan

Consideration of the findings of this study suggests that Indigenous peoples can be ideal environmental stewards. By compiling and making use of TEK, they have maintained sustainable traditional agricultural practices, traditional forest management and conservation practices and traditional livelihoods within their territories. These practices contribute to maintaining biodiversity and ecosystem services that in turn enable people to adapt to and mitigate climate change (Gonzalez-Redin et al., 2018). In this way, the areas under an Indigenous community's control are effectively conserved and can be considered Indigenous and community conserved areas (ICCAs) (Borrini-feyerabend et al., 2004). ICCAs are 'natural and/or modified ecosystems containing significant biodiversity values, ecological services and cultural values, voluntarily conserved by Indigenous peoples and local communities, both sedentary and mobile, through customary laws or other effective means' (IUCN, 2010). Not all areas under community control are effectively conserved, so these ICCAs should be recognised in national policies and practices, including land-use planning (e.g. zoning plan) and conservation policies. Legal recognition by the country's government can be followed by recognition or respect from private entities, such as logging and concession companies that sometimes encroach on Indigenous territories. A prevalent problem that Indigenous people experience is the abuse of their rights to territories, lands and natural resources. In many countries, including Sarawak, the collective rights of Indigenous peoples have received little recognition (Nelson et al., 2016). Moreover, even where there are the legally protected native customary rights (NCR) over land in Sarawak, Indigenous rights have been denied in the absence of law enforcement (Bian, 2007). Such abuses of legal rights to land and resources, including its use and management, have led to biodiversity loss for the lands of

Indigenous peoples. Therefore, it is crucial for Sarawak to institute a zoning plan as a tool to demarcate Indigenous territory and protect its status legally.

Sarawak currently does not have a proper zoning plan for the state. In practice, the zoning system is essential if further development is to avoid overlapping the existing uses and in order to preserve some areas including, Indigenous land and their territorial rights within the state or country. The Planning Department under the Land Survey Department of Sarawak is the body that oversees all development of Sarawak. There are six categories of land tenure in Sarawak: (1) Registered Title Land, (2) Registered State Land, (3) Planted Forest, (4) Permanent Forest, (5) Protected Areas and (6) Native Customary Rights Land (NCR). However, the Planning Department only handles the first two types of land, involving a number of land uses, such as agricultural, residential, commercial, industrial, governmental institutions and mineral extraction. Other land uses fall under the Sarawak Forestry Department (SFD) and the Land Department. In addition, although as much as 13 percent of Sarawak's land is classified as NCR land (Figure 28), only 2 percent of that land is surveyed and titled.

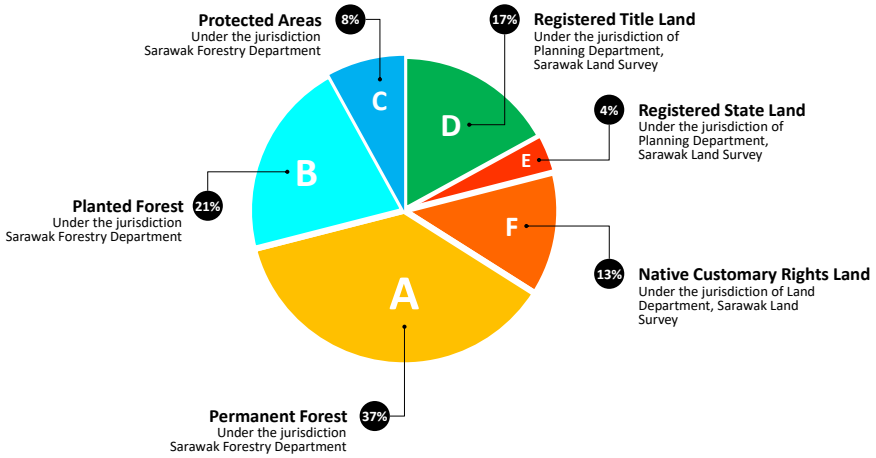


Figure 28: Percentage of land tenure in Sarawak
Source: Adapted from Osman & Kueh, 2010

Many of the Indigenous tribes of Sarawak have tended their land for generations and had automatically developed NCR land but received no official document or title recognising them as legal landowners. The SFD holds few official records that differentiate between NCR land and the timber land category (Planted Forest). Nonetheless, when the department established boundaries, it consistently fails to conduct thorough investigations and allows logging concessions even where there is NCR land. Therefore, creating and enforcing a comprehensive zoning plan is crucial to protecting the territorial rights of the Indigenous people. More importantly, ICCAs can be recognised within the NCR land (see Figure 29).

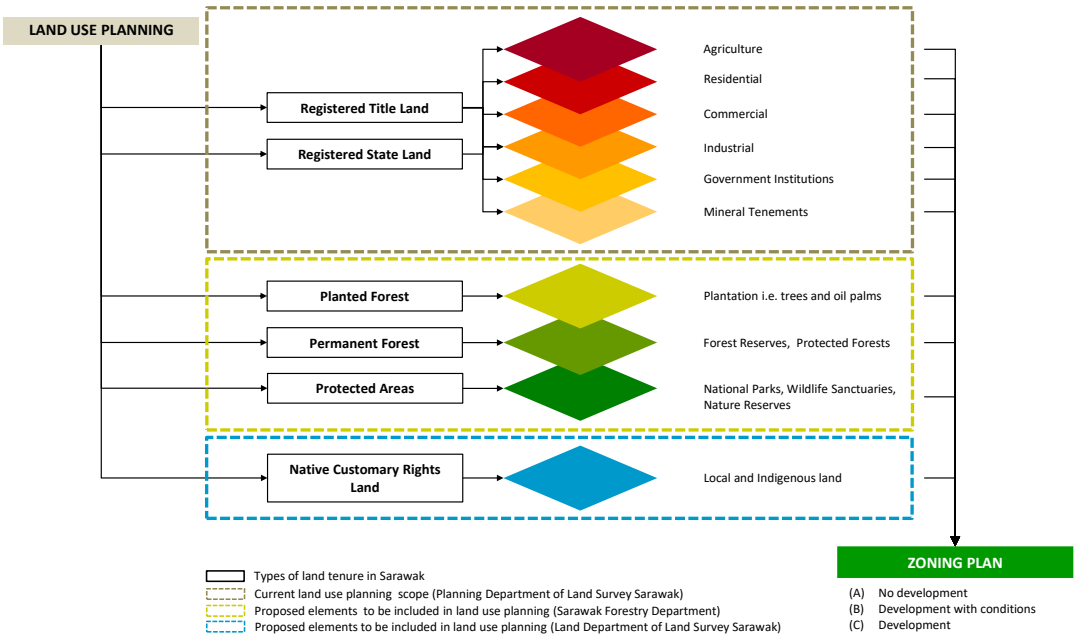


Figure 29: Proposed elements to be included in the Sarawak Zoning Plan
Source: Author, 2020

This study also suggests specific elements for defining an ICCA within NCR land, in a way that is more inclusive compared to the previous NCR land components based on the NCR land definition. The 'never-ending situation' conflict between the Indigenous people and the government of Sarawak is due to fundamental differences in how the meaning and recognition of NCR territory are perceived and enacted. The area that the Indigenous people claim as NCR land is not the same as the NCR area that the Sarawak Land Code defines and recognises. While this conflict requires further study in the future, the present work can propose some components for identifying the ICCA territory, based on the study's results (see Figure 30). Figure 31, Figure 32 and Figure 33 show examples for each case study area on developing a zoning proposal.

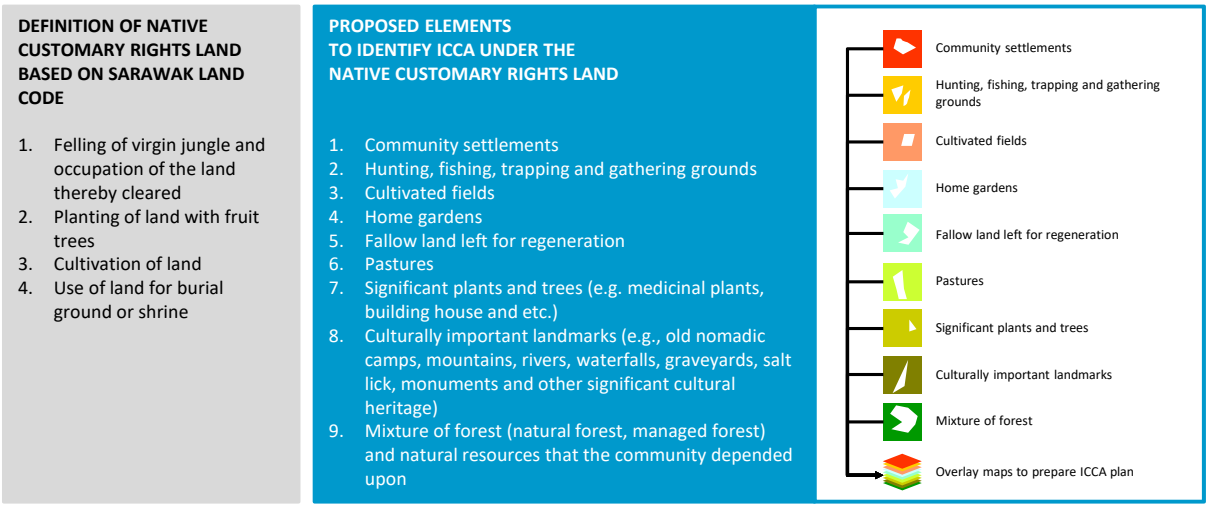


Figure 30: Proposed elements for identifying ICCA under the NCR land
Source: Author, 2020

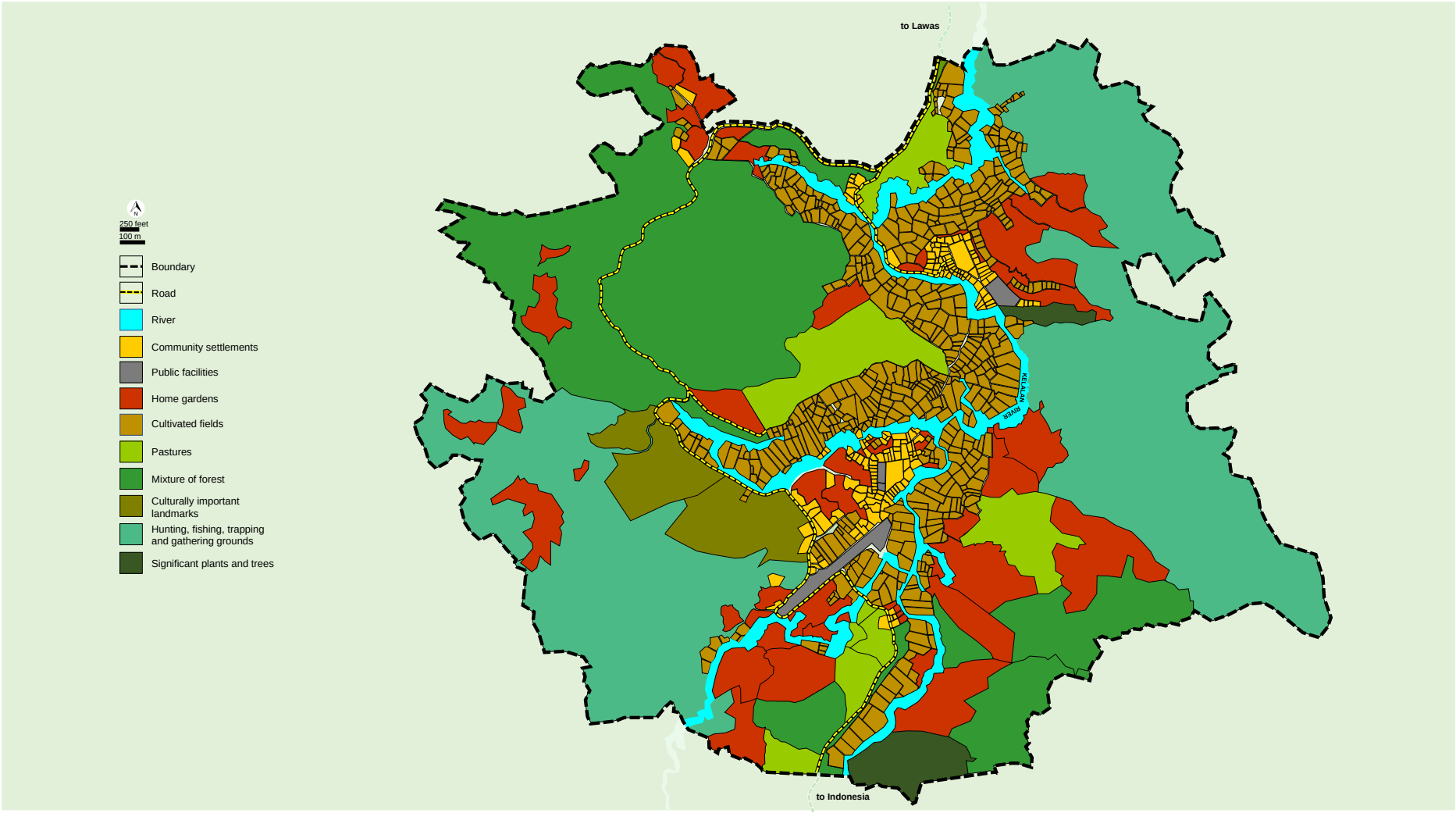


Figure 31: Example of proposed zoning for Ba'kelalan
Source: Author, 2020

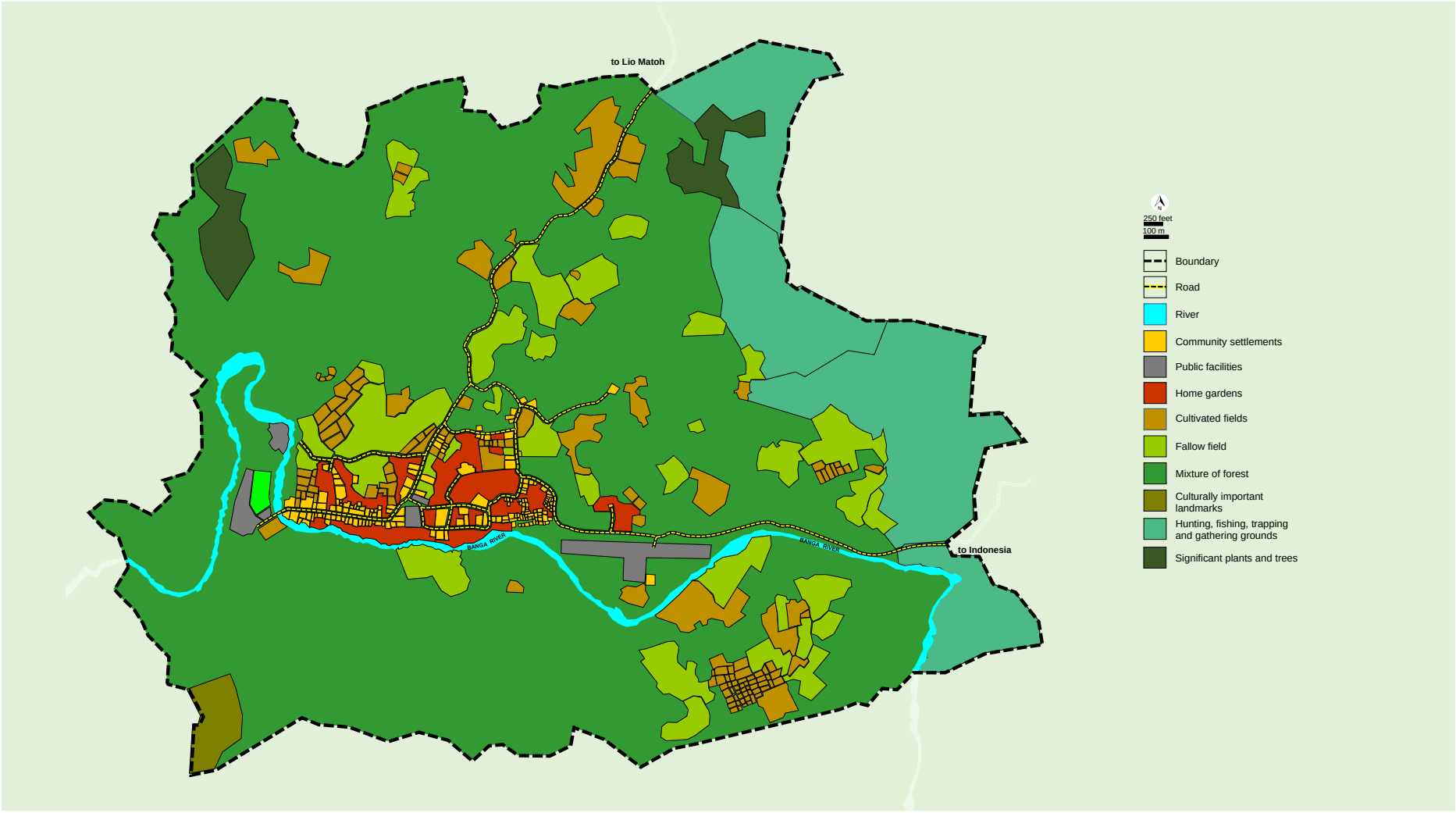


Figure 32: Example of proposed zoning for Long Banga
Source: Author, 2020

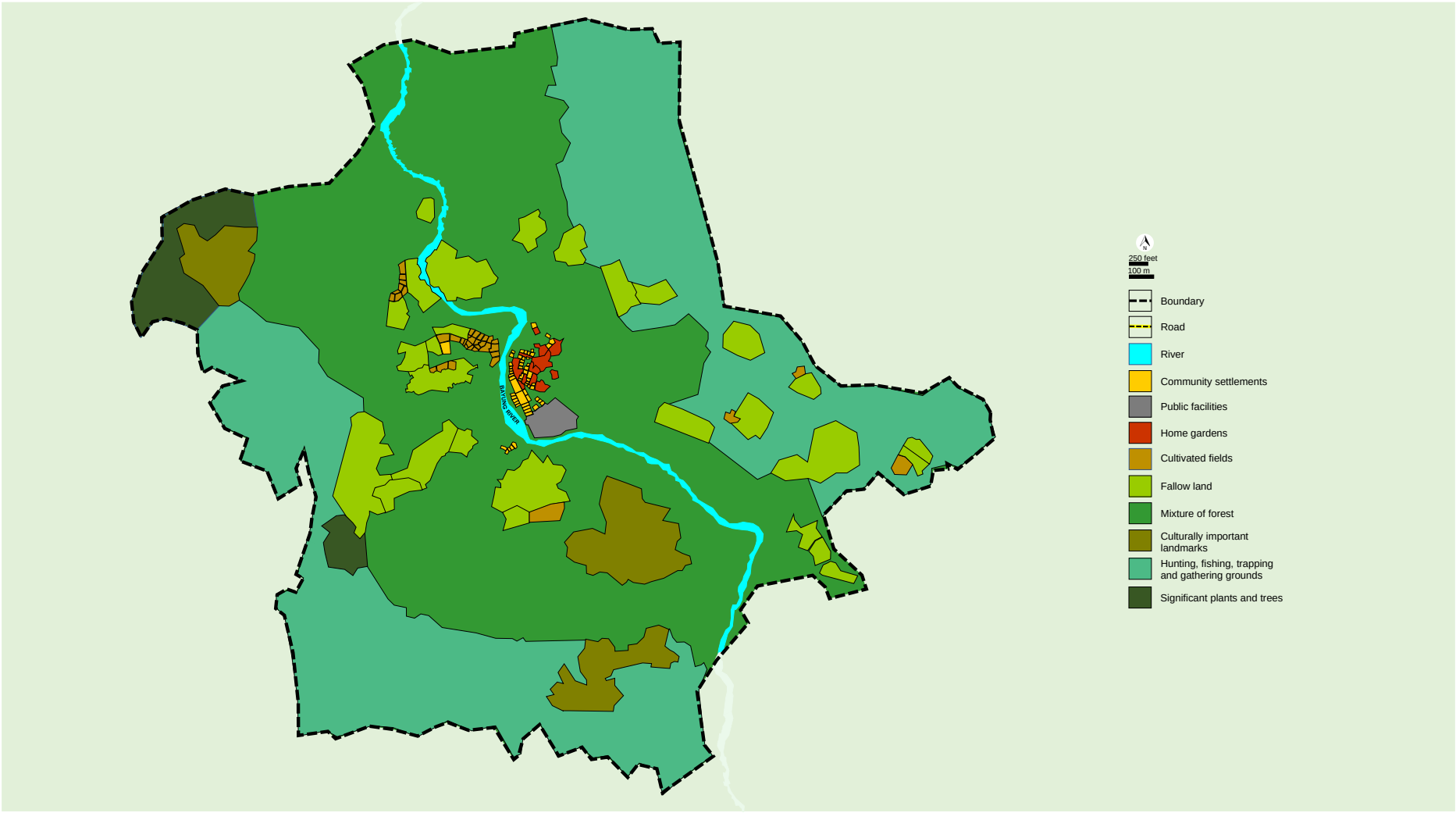


Figure 33: Example of proposed zoning for Long Lamai
Source: Author, 2020

Table 12: Proposed land use zoning for Ba'kelalan, Long Banga and Long Lamai

Present land use	Area (Ha)	Proposed Land Use	Area (Ha)	%
A. Ba'kelalan				
Community settlement	50	Community settlement	50	3.1
River	10	River	10	0.6
Public facilities	8	Public facilities	8	0.5
Home gardens	180	Home gardens	180	11.1
Cultivated field	210	Cultivated field	210	13.0
		*Pasture land	130	8.0
		*Mixture of forest	379	23.4
		*Hunting, fishing, trapping and gathering grounds	462	28.5
		*Significant plants and trees	90	5.6
		*Culturally important landmarks	101	6.2
TOTAL	**458 Ha**	**TOTAL**	**1,620 Ha**	100.0
B. Long Banga				
Community settlement	**17**	Community settlement	17	1.9
River	**9**	River	9	1.0
Public facilities	**8**	Public facilities	8	0.9
Home gardens	**27**	Home gardens	27	3.0
Cultivated field	**63**	Cultivated field	63	7.0
		*Fallow field	64	7.1
		*Mixture of forest	542	60.4
		*Hunting, fishing, trapping and gathering grounds	153	17.0
		*Significant plants and trees	10	1.1
		*Culturally important landmarks	5	0.6
TOTAL	**124 Ha**	**TOTAL**	**898 Ha**	100.0
C. Long Lamai				
Community settlement	18	Community settlement	18	2.0
River	8	River	8	0.9
Public facilities	13	Public facilities	13	1.4
Home gardens	18	Home gardens	18	2.0
Cultivated field	55	Cultivated field	55	6.1
		*Fallow field	83	9.2
		*Mixture of forest	314	34.9
		*Hunting, fishing, trapping and gathering grounds	295	32.8
		*Significant plants and trees	21	2.3
		*Culturally important landmarks	74	8.2
TOTAL	**112 Ha**	**TOTAL**	**899 Ha**	100.0

*Proposed land use types to be included in the zoning plan

Source: Author, 2020

The current land uses reflect the decision of the Sarawak government to define Indigenous territories that are not broad enough to cover what the communities need. Table 13 provides a description of current land-use categories.

Table 13: Current zoning features and its considerations

Types of land use	Description
(A) Community settlement	Community settlement refers to land-use in which residences or housing predominate, in contrast to industrial and commercial areas. The land-use category may also be used for residential, administrative or commercial, educational, or other welfare purposes.
(B) River	A river is an environmentally sensitive area that needs to be preserved, restored and controlled over the long term in the best possible way. This zone, which functionally, aesthetically and economically contributes to the rural ecosystem, is considered to be an area of public use with recreational purposes only.
(C) Public facilities	Zones of public facilities include property currently owned or managed by public bodies or private organisations. Public facilities area uses include but are not limited to educational facilities, utilities and other institutional uses.
(D) Home gardens	Home gardens are land-use areas for crops other than rice plantations. In this area, the combination of plant crops and livestock is highly recommended. Commercial monocrop planting in this zone is not permitted.
(E) Cultivated fields	Cultivated fields are dedicated as rice plantations. Therefore, other types of plantations are not allowed in this zone.

Source: Author, 2020

Based on this study, other land uses were selected for the proposed zoning plan in terms of the plan's role in helping Indigenous communities respond to environmental and climate change. More importantly, the zoning plan protects Indigenous people's territory from activities that could have an adverse impact on their livelihood and the settlement's landscape. Descriptions of these other proposed zoning features and aspects that need to be considered for each area are provided in Table 14.

Table 14: Proposed zoning features and its considerations

Types of land use	Description
(A) Pasture Land	Pasture or buffalo grazing land is specifically important for the Lun Bawang as part of the traditional wet rice farming cycle. Therefore, this area requires protection in the zoning plan. The period of grazing each year will follow the seasonal harvesting

	of the wet rice farming, as this allows plants to become well established before heavy grazing. The system thus encourages rotational grazing, which can help ensure proper management of pasture land. To prevent overgrazing, the amount of livestock per acre should be limited to only one buffalo per acre.
(B) Fallow Land	This land is usually used for farming but is held without crops for a season, to allow it to regain its fertility. Land-use is limited to the growth of secondary polyculture crops and no further development within this region is permitted. If not planted with crops, then the land should be left to rest for at least 5 years before it is used again to grow hill rice.
(C) Mixture of forest	Natural forest or natural resources that the community depended upon and that are preserved by customary law. Activities in the area are limited to gatherings and hunting. Since the forests as natural habitat need to be protected, logging and cutting of trees is forbidden completely.
(D) Hunting, fishing, trapping and gathering grounds	Hunting, fishing, trapping and gathering grounds are known in the local language as *Kawasan Rayau*. These practices are limited to non-commercial areas where hunting, fishing and gathering are only for self-sustaining purposes and are not carried out on a large scale.
(E) Significant plants and trees	Areas labelled for significant plants and trees are ones where medicinal plants, plants and trees specific to cultural activities (i.e. handicraft making, blow pipes for hunting, etc.) and plants used for food and construction are concentrated. There should be no overharvesting of plants and trees in this area and harvesting must be done with care, so that cutting of any whole tree or plant is not permitted.
(F) Culturally important landmarks	Culturally important landmarks are the cultural heritage of Indigenous peoples and need to be preserved. Components in this category are items that are viewed by the societies as sacred and as a representation of identity. The category includes old sculptures, old nomadic camps, ancestral burial grounds and other elements culturally significant to the communities.

Source: Author, 2020

Additionally, any programme, project, or policy related to climate change (e.g. REDD+) implemented on any Indigenous lands should be conducted only when free, prior and informed consent (Tauli-Corpuz et al., 2009) has been obtained from the

Indigenous people. In sum, this work will hopefully provide fresh perspective for the Sarawak government and we urge the government to consider and protect Indigenous rights. Such consideration is critical to avoid climate change maladaptation that threatens to burden the most vulnerable (Barnett & O'Neill, 2010).

(b) Safeguarding the TEK

TEK plays a key role in the range of actions needed to mitigate climate change and helps local communities adjust to climate change impact. It is at the root of Indigenous identity, culture, languages, traditions and livelihoods, so its transmission must be secured, preserved and promoted from one generation to the next. Traditionally, it is passed to subsequent generations through folktales, festivals, songs, paintings, performance and related activities. However, these aspects continue to be undermined and undervalued within global histories of colonialism, exploitation and dispossession. Therefore, this study recommends the use of tourism planning to prevent future TEK losses and ensure the continuity of its transmission.

Tourism is recognised for its capacity to promote the protection of tangible and intangible components of Indigenous cultural heritage (Figure 34). Tourism undeniably makes up a significant sector of the world economy and cultural heritage tourism is growing in popularity. As a consequence, within the context of sustainability, some countries have developed tourism policies supporting the preservation of cultural heritage and communities. Moreover, intangible cultural heritage is now recognised by UNESCO as equal in significance to buildings. The demand for cultural and heritage tourism experiences and traditional ventures can contribute to maintaining these skills and traditions. Tourism can act to preserve cultural heritage and all efforts aimed at developing this sector with heritage in mind can provide a positive impact in local communities, especially in safeguarding their TEK.

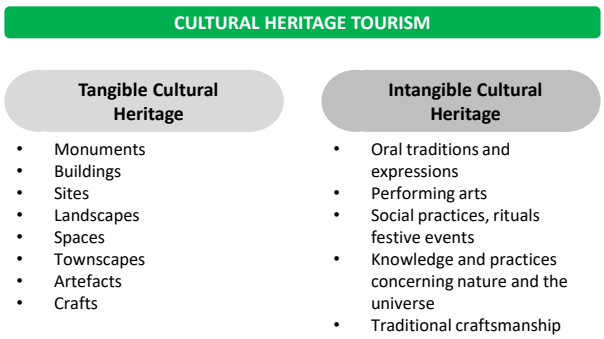


Figure 34: Elements of Cultural Heritage Tourism
Source: UNESCO, 2003

8.3 Research Limitations

There are two forms of limitations to this. The first relates to the limitations of the TEK itself and the second to the framework and results of the study.

1. Limitations of TEK

    a. Natural signals less reliable

    The magnitude of climate change has significantly affected the relevance of TEK. Natural signals used in the past to predict weather and seasons are now less reliable. For example, rainy seasons come sooner or later than normal, so that people become disoriented in their everyday lives. Lunar signals that they have depended on for scheduling crop planting activities may no longer coincide with the appropriate timing of such activities and may mislead communities in making decisions.

    b. Loss of TEK

    TEK is currently threatened by both modernity and globalisation. According to previous studies (e.g. Federici, 2004; Toledo, 2012), TEK has decreased in many parts of the world, due to diverse and multifaceted causes. This research found that TEK is under pressure due to urban-from-rural migration, with many young people migrating to urban areas to study, work and reside. Therefore, the opportunity for young people to learn TEK from older people is declining, which may contribute to TEK disappearing in the future. Because TEK develops from long-term observation of local ecological dynamics and depends on learning from crises and mistakes, once the body of TEK is lost, its regeneration may be irreversible over the short and medium terms, generating a loss of options in responding to disturbance and global change.

2. Limitations of the study

    a. Research participants

    This study focuses only on a few ethnic groups in Sarawak and there are several more tribes in the interior of Sarawak. Although it is important to also examine these communities in terms of climate change effects and local response, this study focuses on only three communities, namely, Lun Bawang, Sa'ban and Penan, due to time and resource constraints.

b. Scope of research

This research focuses only on the social and environmental implications of climate change. The economic aspect is not considered in this study.

c. Methodology

This study used a fully qualitative approach, as it was intended to provide a deep understanding of the role of TEK among Indigenous peoples as they adapt to climate change. Therefore, the responses were not quantified.

8.4 Future Research

Based on the limitations just described, this research provides a basis for some suggested future research.

1. Further topic to be addressed

Further research should be conducted to develop insights on how to ensure the potential success of TEK use, based on the TEK limitations found in this study. In particular, we propose (a) the study of TEK and science integration that ensures optimum adaptation to climate change. The climate crisis threatens traditional lifestyles; thus, partnerships between Indigenous communities and scientists can orient toward helping communities make use of climate data and modern technology that enables their communities and landscapes to become more climate resilient. Also suggested is (b) collaboration in climate change adaptation planning with government and other stakeholders. Such research can improve our understanding of how government and other external assistance enable Indigenous communities to better cope with the effects of climate change.

2. Research participants

Our findings underscore the need for ongoing work on the role of TEK in adaptation across a variety of cultural and geographical settings that are, in various ways, influenced by environmental and climate change. How do communities across the country adapt to climate change when using TEK to promote community resilience, particularly in view of future predictions of climate change? To address this question, longitudinal, in-depth, comparative studies are needed with community-based approaches that respond to community priorities.

3. Scope of research

It is of interest to extend the scope of future study to economic aspects, as climate change also affects the local economy. When this aspect is added to the study, TEK's function in the broader sense should become clearer.

4. Methodology

The research methodology should include a mixed methods approach for future analysis of TEK. Combining quantitative and qualitative methods offers a better basis for interpretation of research issues than either approach alone. Future research should therefore involve the collection, analysis and mixing of both quantitative and qualitative data.

8.5 Conclusion

Overall, this study has met the objectives set at the beginning of the study. TEK is the basis for foundational systems on which Indigenous peoples rely for their livelihoods. It emerges from centuries of experience; for a given ecosystem, it provides an incomparable foundation for holistic perspectives. TEK observations, sustainability practices and active participation in resource management are based in hundreds of years of knowledge and practice. These long-held foundations have often been exclusionary and in Western scientific contexts, TEK still remains an 'underdog'. Increased TEK documentation can contribute information on the effects of anthropogenic climate change and other human–environmental impacts.

Applications of TEK have been able to explain details that could further clarify and interpret climate change research, incorporating basic knowledge of cycles and predicted effects and describing those impacts with additional depth and breadth that were missing from Western scientific methods. In the face of climate change uncertainty, TEK can be applied to generate insightful results, bridging an interdisciplinary gap that exists within the current rigour of modern scientific research. Basic human–environmental relationships form the core of environmental adjustment and adaptation. With this recognition, TEK moves to the forefront in framing climate change research that provides in-depth understanding in a rapidly changing world.

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LIST OF PUBLICATIONS

A. INTERNATIONAL JOURNAL (PEER REVIEWED)

1. Hosen, N., Nakamura, H. & Hamzah, A (2019), Traditional ecological knowledge and climate change adaptation: The Sa'ban experience. *Journal of ASIAN Behaviour Study*, 4(14), 63-77.
2. Hosen, N., Nakamura, H., & Hamzah, A. (2020). Adaptation to Climate Change : Does Traditional Ecological Knowledge Hold the Key? *Sustainability*, 12, 676.

B. CONFERENCE PROCEEDINGS (PEER REVIEWED)

1. Hosen, N. and Nakamura H. (2018), Traditional Ecological Knowledge and Climate Change: An Introduction, *Proceedings of the 12th South East Asian Technical University Consortium* (SEATUC 2018), 1-6
2. Hosen, N. and Nakamura, H. (2019), Conceptualising the Role of Traditional Ecological Knowledge (TEK) in Climate Change Adaptation, *The 3rd International Conference on Climate Change 2019* (ICCC 2019), 1-9.
3. Hosen, N., Nakamura, H., & Hamzah, A. (2019), The Role of Traditional Ecological Knowledge in Building Adaptive Capacity for Climate Change: Case of the Lun Bawang Tribe, *The First International Graduate Conference of Built Environment & Surveying: Towards Continuity and Livability Revolution (GBES 2019),* 242–255, Johor Bahru: Universiti Teknologi Malaysia.
4. Hosen, N., Nakamura, H. & Hamzah, A. (2019), Using Traditional Ecological Knowledge to Adapt to Climate Change in Interior Sarawak, *Environment-Behaviour Proceedings Journal*, 4(11), 185-191.
5. Hosen, N. & Nakamura, H. (2020). Local Knowledge for Global Actions: The role of traditional ecological knowledge in climate change adaptation, *Environment-Behaviour Proceedings Journal*, 5(13), 37-43.

APPENDIX A

EXAMPLE SURVEY QUESTIONNAIRE

Name:
Sex:
Age:
Occupation:
Ethnic:

A. CLIMATE RISKS, THREATS, ENVIRONMENTAL CHANGES, WEATHER FORECASTING AND BIOCLIMATIC INDICATORS

Climate risks and threats affecting the livelihoods within the area

1. What are the major weather/climate issues facing local residents? (Examples: earthquakes, hurricanes, heavy rain, hot weather etc...)
2. What are the effects of this issue? (Examples: flood, landslide, drought etc...)
3. Did it ever happen before? (When?)
4. History of local disasters
5. How did the community deal with such risks in the past?

Environmental changes

1. Is there a difference in daytime and night time temperature than before? (Hotter, colder) Since when has that (years) changed?
2. What do you think causes this change?
3. What impact does this shift have on the community and their environment?
4. What do you and the villagers do when faced with such conditions?
5. Does the rainfall change? Especially in terms of rainfall frequency, length and others
6. If so, what effect does it have on the community?
7. What has the community done to cope with those effects?
8. Is there a difference in the season in terms of length in particular? (Example: this is a longer summer than before)?
9. If changes occur, how does this change impact the community?
10. What has the community done to cope with those effects?
11. What other changes do the community notice?

Weather forecasting and bioclimatic indicators

1. Do people forecast weather/disaster?

2. If so, what is the basis for that forecast? (e.g bioclimatic indicators)
3. Does that still apply today? Why?

B. TRADITIONAL STRATEGIES ON LAND AND RESOURCE MANAGEMENT WHEN FACING DISTURBANCES
    a. How people find food and other resources? (e.g hunting, planting, fishing etc.)
    b. What kinds of plants are grown in the home / garden / farm area?
    c. Why did you choose this type of plant?
    d. Can you explain the planting/harvesting technique?
    e. In the event of disaster, what will your people do to ensure food and resources are secure?
    f. How do you handle livestock or meat that you get from hunting/fishing?
    g. If there is a surplus, what do you do?
    h. How do you and your community manage the water supply so that water supply is always available throughout the year?
    i. How do you and your community manage land resources to keep the soil fertile?
    j. How do you and your community manage forest resources so that forest products are always available?
    k. Are there any areas that need to be protected? Why is it protected? Who's in charge? How it's protected

C. ROLE OF SOCIAL NETWORKS AND INSTITUTIONS WHEN A CALAMITY STRIKES
    a. If you or your community member are affected in the event of disaster, who will help?
    b. What kind of help/assistance that the people affected will get?
    c. What are the traditions/customs/activities/associations in the village that strengthen the relationship between the villagers?

D. WORLDVIEWS AND BELIEF SYSTEMS RELATED TO THEIR PRACTICES
    a. What are your reasons for upholding such practices/culture?
    b. Are there any rituals before, during and after the farming/hunting/harvesting of forest products and others?
    c. Are there any restrictions before, during and after the farming/hunting/harvesting of forest products and others?
    d. What kind of festival did your community celebrate? Why are you celebrating this festival?
    e. How can you make sure that the younger generation doesn't forget these old traditions and knowledge?