Strengthening Southeast Asia

Adaptation and resilience through collaboration and innovation

seacar
ALLIANCE

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The SEACAR Alliance is a collaboration that emphasises the importance of nature-based solutions, climate analytics and AI in advancing the resilience of cities and communities.

Foreword

Southeast Asia is a region of immense potential, poised to become the world's fourth-largest economy by 2030, driven by its rapidly growing labour force and increasing intra-ASEAN trade, projected to expand by USD1.2 trillion over the next decade. The region is also home to four of the world's 25 biodiversity hotspots and three megadiverse countries, underscoring its vast natural wealth. However, climate change poses an imminent threat to this progress.

Without a comprehensive and inclusive response to climate change, the future of ASEAN's nearly 700 million strong population, to say nothing of our region's incredible socioeconomic promise, will be facing uncertainty if not completely lost. A regional, rather than purely national response is needed given how interconnected our countries are and due to the simple fact that climate change is no great respecter of borders.

While global discussions often focus on mitigation, which reduces greenhouse emissions, the equally urgent need to advance adaptation efforts must not be overlooked. Adaptation is about enhancing climate resilience, ensuring that communities, ecosystems and businesses can withstand and recover from climate-related challenges.

It was in support of these goals that SEACAR was established in 2023 at COP28 in Dubai, UAE. A collaborative initiative by BCG, Think City, and WWF-Malaysia, the SEACAR Alliance is dedicated to advancing awareness and action on adaptation and resilience (A&R) while fostering impactful collaboration. Its three core themes focus on cities and communities, nature-based solutions (NbS), and climate analytics and AI. Additionally, SEACAR addresses six key sub-themes which are trade, water, health, infrastructure, natural ecosystems, and agriculture.

I am proud to share with you the second SEACAR report, **Strengthening Southeast Asia: Adaptation and resilience through collaboration and innovation**, which showcases ten A&R efforts across Southeast Asia that have covered the essential tools or themes of climate adaptation: nature-based solutions, as well as climate analytics and AI, underpinned by collaborative actions, to fortify the resilience of cities and communities. Their efforts have also improved the six interlocking sub-themes that are crucial for the climate resilience of communities. I hope this report inspires more organisations, whether public or private to effectively implement climate adaptation measures that leverage nature and technology.

Amid all this, the fact remains that adaptation cannot progress without fair and accessible climate finance. The current financial landscape often places a heavy burden on developing countries, where much of the climate funding is structured as loans rather than grants. ASEAN must advocate for more inclusive financing mechanisms, reduce bureaucratic barriers when receiving funds, and prioritise direct access to funds for most affected communities.

Nevertheless, it should be a point of pride that some of the projects in this report have succeeded under equitable funding, which shows the potential for climate adaptation financing to be scaled up across Southeast Asia. This entails regional planning that includes sector collaboration and community support.

The journey towards scaling up nature and technology for climate adaptation requires seamless cooperation between governments, civil society, private companies, and local communities. As Malaysia takes up the ASEAN Chairmanship in 2025, let us leverage regional strengths, and knowledge exchange, foster international partnership and ensure that adaptation is one of the key priorities in the regional agenda. I am confident that Southeast Asia can lead the way in building a resilient future even under climate change.

I congratulate SEACAR on its efforts, which are in line with the Malaysian Government's own work in championing sustainability as part of the Malaysia Madani framework. I likewise wish the Alliance all the best in its future endeavours and strongly urge everyone to read the contents of this interesting report.

NIK NAZMI NIK AHMAD
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EXECUTIVE SUMMARY

About SEACAR Alliance

In 2023, the Southeast Asia Climate Adaptation and Resilience (SEACAR) Alliance was established to recognise the need for adaptation and resilience (A&R) efforts as Southeast Asia's economic and natural assets have been increasingly at risk due to climate-related challenges such as extreme weather patterns and rising sea levels, to name a few. Through collaborative efforts, SEACAR aims to scale up A&R initiatives across the region, with a particular focus on urban areas to strengthen local adaptation plans that safeguard people, the economy and nature. The alliance's approach is centered around six key themes: natural ecosystems, infrastructure, trade, water, agriculture and health. The selected themes are sectors most impacted by climate hazards in the region.

Vision

Centered on collaborative action, the Alliance aims to emphasise the importance of nature-based solutions, climate analytics and technology in advancing the resilience of cities and communities across six key themes.

Pillars

SEACAR differentiates itself from other initiatives by highlighting the combined potential of nature and technology in addressing climate risks at a city scale. We

believe that Southeast Asia is in a prime position to harness the power of nature, climate analytics and AI to accelerate this endeavour. The actions we take in cities and communities will shape Southeast Asia's resilience in the upcoming decades.

Themes

- **Infrastructure** encompasses housing, educational and healthcare facilities, transportation and more. Climate-related events such as floods and heatwaves can damage this infrastructure, impeding economic progress and leading to community displacements.
- **Trade** in Southeast Asia, a key artery of global supply and manufacturing, is increasingly exposed to climate risks that threaten major trade routes and value chains.
- **Water**, vital for human survival, also serves as an economic resource in agriculture, manufacturing, and energy. Its quality and availability can be compromised by unpredictable rainfall, flooding, and other events.
- **Agriculture** is pivotal for food security and is a major GDP and livelihood source; climate hazards can result in diminished crop and livestock productivity.
- **Health** bears the brunt of climate adversities. This includes physical health concerns such as heat-related ailments and vector-borne diseases, mental health issues arising from displacements, and strains on health infrastructure.
- **Natural ecosystems** offer crucial services, including climate regulation, water regulation, soil stabilisation, temperature control and carbon sequestration. However, climate hazards can impair these ecosystems, limiting their capability to deliver these services.

Overview of the Chapters

This year's second SEACAR report features 10 initiatives, projects and research efforts that provide examples of how Nature-based Solutions (NbS) and technology are being used and applied across the six SEACAR key themes to enhance the climate resilience of cities and communities. Of these, two chapters cover the entire Southeast Asia region, while the remaining eight focus on efforts spanning five SEA countries: Indonesia, Malaysia, Myanmar, Singapore and Vietnam. These chapters feature a diverse range of institutions, including intergovernmental organisations (i.e., United Nations, World Trade Organisation), nongovernmental and civil society organisations (i.e., Friends of Bukit Kiara), humanitarian aid organisations (i.e., Indonesian Red Cross), governmental departments (i.e., landscape and forestry departments), higher educational institutions (i.e., National University of Singapore, Monash University Indonesia, Thai Nguyen University of Agriculture and Forestry, University Kebangsaan Malaysia) and private companies (i.e., PT Astra International Tbk).

Focus: Regional Perspectives

Chapter 1 Sustainable and Resilient Cities

Highlights the vital role of international trade in helping cities adapt to climate change by improving access to resilient technologies, diversifying resource and enabling global partnerships.

Chapter 2 CORDEX-Southeast Asia

Introduces CORDEX-Southeast Asia, a climate modelling initiative that downscales global projections to regional and city levels—crucial for generating locally relevant climate data to support urban adaptation planning in Southeast Asia.

Focus: Local Actions

Chapter 3 Indonesia's Communities Ready to Act Project

Delineated the growth of a community-based project that restored and rehabilitated riverine and mangrove ecosystems to enhance communities' livelihood and resilience against floods.

Chapter 4 Indonesia's Astra Climate Village

Represents a national program that enables rural villages to increase their climate adaptation capacity through climate awareness programs, nature-based water resource management, upcycling and waste management.

Chapter 5 Myanmar Climate Change Alliance Phase 2

Exemplifies the combination of climate change vulnerability assessment, local climate action planning and ecosystem-based adaptation (EbA) across geo-climatic areas to enhance water security, gender equality and hygiene. It has also scaled up and revitalised local climate actions.

Chapter 6 Vietnam Food Forests

Showcased the significance of indigenous knowledge concerning nature-based solutions that diversify their livelihood and improve their agricultural output, ultimately enhancing the quality of life of impoverished communities.

Chapter 7 Malaysia's Bukit Kiara Federal Park

Highlighted the role of multi-sectoral and community engagement in long-term efforts to conserve Bukit Kiara—a vital green lung that provides ecosystem services, buffers extreme weather impacts and enhances urban water security and heat regulation. The community played a key role in stakeholder consultations, species and spatial mapping, and in shaping zoning strategies.

Focus: Knowledge for Actions

Chapter 8 GIS Tools for Green Infrastructure Planning in Malaysia

Outlined three GIS-based approaches that can optimise the integration of NbS into urban planning and highlight the role of social values for ecosystem services in the equitable planning of urban green spaces.

Chapter 9 Connecting Urban Habitat in Indonesia

Emphasises different aspects of urban ecological connectivity that provide essential ecosystem services for climate adaptation, such as challenges faced by habitat corridors, drawbacks of existing efforts and the role of GIS in integrating connectivity into urban planning.

Chapter 10 Project Heatsafe in Singapore

Investigated the impacts of heat stress on workers' productivity, physical and mental well-being, as well as fertility outcomes and the economy, complemented by intervention measures.

The Common Success Factors for Climate Adaptation and Resilience

Across various climate A&R projects, three key success factors consistently emerge: multi-sectoral involvement, data-sharing platforms and good governance. Regardless of scale, effective climate A&R initiatives rely on community engagement and a bottom-up approach that includes diverse stakeholders such as local communities, governments, civil society organisations, private sectors, academia and intergovernmental organisations. Every chapter in this report underscores the necessity of this approach in implementing nature-based solutions (NbS) and raising awareness of climate adaptation and artificial intelligence (AI) in A&R.

In addition to multi-sectoral engagement, establishing data-sharing or best practices platforms can significantly enhance cross-sector communication. For instance, simulation data from **CORDEX** (Chapter 2), a regional climate data downscaling project, has been utilised in the IPCC AR6 Working Group 1 Report and national climate communications in the Philippines, Vietnam, Indonesia and Thailand. Similarly, the **Indonesian Red Cross'** effort to enhance the local communities' capacity to restore riverbanks via nature-based approach (Chapter 3) has established the Manggarai Mangrove Centre (MMC) as an educational and climate adaptation hub, benefiting local communities and other stakeholders. Trade and Environmental Sustainability Structured Discussions (TESSD) under **World Trade Organisation** (Chapter 1) further illustrate how international collaboration can facilitate knowledge-sharing, allowing member states to compile best practices and explore voluntary partnerships for improved access to environmental goods and services. UN-Habitat Myanmar (Chapter 5) also developed a digital knowledge hub to disseminate ecosystem data, best practices and lessons learned from programmes, reinforcing the role of knowledge exchange in strengthening climate resilience.

Good governance is another critical factor in ensuring the success of community-led and regional A&R initiatives. It generally entails participatory planning, transparent decision-making processes, or evidence-based decision-making and policy formulation. This will fortify local communities' climate adaptation capacity and resilience. The **food forest project in Vietnam** (Chapter 6) highlighted the importance of appreciating and scaling up local nature-based knowledge. The project demonstrated quantitative and qualitative benefits of agricultural NbS, including increased crop yield and livelihood diversification, to improve community wellbeing and strengthen climate adaptation. Likewise, the **Astra Climate Village Programme** (Chapter 4) exemplifies strong collaborative efforts between the private and government sectors, supporting over 100 villages in developing infrastructure, adopting low-carbon lifestyles, enhancing their resilience against contagious diseases, climate hazards, and agricultural degradation.

Furthermore, community-driven initiatives like the **FoBK** project (Chapter 7) underscored the importance of engaging civil society organisations (CSOs), non-governmental organisation (NGOs) and local governments in identifying climate adaptation strategies. Measures like the establishment of buffer zones protect ecosystem services, which in turn help communities adapt to challenges such as flooding and the urban heat island (UHI) effect. These examples collectively demonstrate how multi-sectoral collaboration, robust data-sharing mechanisms and strong governance frameworks are essential to build climate resilience at both local and regional levels.

Moving Forward

This report has showcased a good sample of A&R projects in Southeast Asia. We hope to unlock more similar projects via the Call for Solutions initiative. We've highlighted a selection of A&R projects shaping climate resilience across Southeast Asia. Through our Call for Solutions, we're inviting more ground-breaking ideas that harness technology and nature—and are ready for pilot rollout—to drive tangible adaptation outcomes. Stay tuned for our showcase at COP30!

INTRODUCTION

Social, Economic and Natural Resources in Southeast Asia

Southeast Asia teems with economic potential and ecosystem services. By 2030, Southeast Asia (SEA) as a whole is projected to become the world's fourth-largest economy, supported by the third-largest labour force globally. Moreover, trade among the Association of Southeast Asian Nations (ASEAN) is forecast to grow by USD 1.2 trillion over the next decade (Gilbert et al., 2024). By 2031, ASEAN exports are expected to surge by nearly 90%, compared to overall global trade growth of less than 30% (Lim et al., 2024; Aggarwal & Bharadwaj, 2024).

With 67% of its populace within the working age bracket, the region is expected to emerge as the second-most rapidly expanding labour market globally in the lead-up to 2030 (Oxford Economics, 2023; International Labour Organisation, 2023). The number of individuals eligible to work will continue to rise, spearheaded by nations such as Indonesia and the Philippines. This surge corresponds to an escalating demand for employment, subsequently moderating labour costs. According to a Japan External Trade Organisation (JETRO) survey, wage levels in most Southeast Asian nations are lower than in other Asian counterparts, including South Korea, Taiwan, and China, thus boosting competitiveness.

In terms of biodiversity, Southeast Asia includes four of the 25 global biodiversity hotspots (Indo-Burma, Sundaland, Wallacea and the Philippines) and three of the 17 global megadiverse countries (Indonesia, Malaysia and the Philippines). The Coral Triangle is one of the world's richest areas for marine life. Despite covering only 1.6% of the planet's oceans, it is home to 76% of all known coral species worldwide and 37% of the global total reef (von Rintelen et al., 2017; Dirhamsyah et al., 2014).

The ecosystem services provided by Southeast Asian ecosystems hold immense value. Across the Asia-Pacific region, the value of services provided by terrestrial ecosystems is estimated at USD 14 trillion, with USD 1.7 trillion in Indonesia alone and around USD 0.6 trillion across Cambodia, Viet Nam, Lao PDR and Thailand (Kubiszewski et al., 2016). In Myanmar, the value provided by forests is estimated at around USD 7 billion (Xu et al., 2019; Emerton & Aung, 2013). In Malaysia, Endau Rompin National Park alone accounts for a total economic value of USD 222 million (Nitanan et al., 2020).

Climate and Financial Risks in Southeast Asia

The World Risk Index 2024 identifies the Philippines, Indonesia, and Myanmar as three of the ten countries with the highest disaster risks globally, with the Philippines and Indonesia occupying the top ranks (Bündnis Entwicklung Hilft, 2024). Furthermore, the Asian Development Bank (ADB) highlights that developing Asia is the most climate-vulnerable region worldwide.

Under a high-emission scenario (RCP 8.5), Southeast Asia could lose around 30% of its annual GDP by 2100 (Asian Development Bank, 2023).

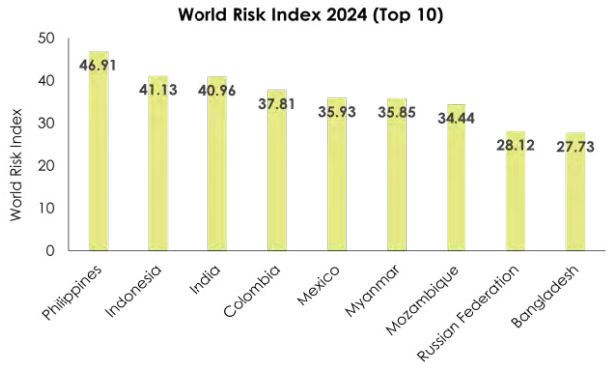


Figure 1. *Top 10 countries with the highest disaster risk (Bündnis Entwicklung Hilft, 2024)*

The Economic Case of Nature stated that the decline in ecosystem services could lead to a global GDP loss of USD 90 billion to USD 225 billion by 2030. East Asia and the Pacific, including Southeast Asia, are identified as the third most affected region (Johnson et al., 2021). Under the partial ecosystem collapse scenario, as projected by the Global Trade Analysis Project–Agro-Ecological Zone (GTAP-AEZ) database, Southeast Asian countries are expected to experience the greatest percentage decline across East Asia and the Pacific region in terms of GDP compared to a no–tipping point scenario (Baldos & Corong 2020). Among these countries, Indonesia, Vietnam, the Philippines, and Malaysia are expected to experience the most severe economic contractions in percentage terms (Johnson et al., 2021).

Moreover, the stability of sovereign credit is heavily influenced by biodiversity loss, environmental degradation, and climate-related disasters (e.g., floods, fires, and droughts), all of which undermine the resilience of the financial sector (Agarwala et al., 2024). Severe weather events such as flash floods and prolonged heatwaves, water shortages, and rising sea levels pose acute and long-term threats that damage assets, lower production output, and elevate the risk of sovereign debt (Beirne et al., 2021). Nations including Malaysia, Indonesia, and the Philippines are prone to heightened sovereign risks because of their susceptibility to ecosystem disruptions and climate-related shocks (Agarwala et al., 2024).

Climate-related risks such as rising temperatures, floods, and droughts are having a growing impact across key sectors. For agriculture, the region currently produces 26% of global rice and accounts for 40% of global rice exports, valued at USD 13.56 billion out of USD 33.9 billion (Li et al., 2017; Shaw et al., 2022; World Integrated Trade Solution, 2023). However, rice yields are expected to decline by 3–10% by 2050 due to rising temperatures, increased flooding, and more frequent droughts, with Cambodia, Myanmar, and Vietnam projected to experience the greatest losses (Li et al., 2017). Additionally, heat and humidity stress may reduce agricultural labour capacity by 30–50% in the region with a 3°C temperature increase, potentially threatening agricultural employment and overall production (Lima et al., 2021).

Furthermore, in the past two years, access to safely managed drinking water was still below 30% in Lao PDR, Cambodia, and Indonesia. While coverage is generally lowest in rural areas, low-income households in expanding urban informal

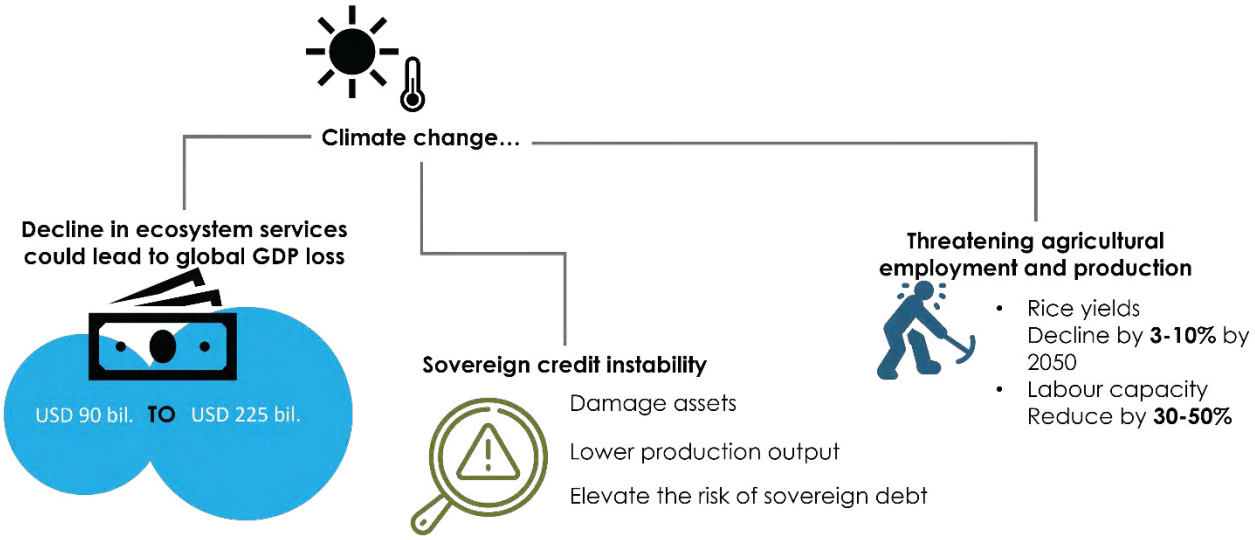
Furthermore, in the past two years, access to safely managed drinking water was still below 30% in Lao PDR, Cambodia, and Indonesia. While coverage is generally lowest in rural areas, low-income households in expanding urban informal settlements face increasing health risks due to flooding, inadequate drainage, and poor Water, Sanitation, and Hygiene (WASH) conditions (Norris et al., 2024). In Yangon's informal settlements, over 90% of water samples tested at the point of consumption in 2018 were contaminated with E. coli (FAO, UNICEF, WFP, WHO, 2023). This contamination contributes to a range of waterborne diseases commonly associated with flooding, including cholera, hepatitis A and E, typhoid, polio, and E. coli infections.

Furthermore, Southeast Asia's transport and communications systems are vulnerable to climate extremes, particularly floods. Annual damages from existing natural hazards to regional road and rail networks are estimated at USD 2.2 billion, mainly from floods and typhoons, and could be expected to increase significantly as hazards intensify.

The aforementioned risks underscore the significance of effectively building climate resilience in Southeast Asian cities. The SEACAR Alliance believe there is enormous potential to leverage the world's oldest and newest solutions: NbS and technology in the form of AI to help conduct advanced analytics to improve SEA communities' climate adaptation capacity and resilience.

The Role of Nature-based Solutions and Artificial Intelligence in Climate Adaptation and Resilience

The region, with its ecological richness, is in a prime position to leverage NbS for A&R. Solutions such as urban forests, mangrove restoration, and submerged aquatic vegetation, contribute to A&R by increasing protection against coastal erosion, storm surges, and flooding, amongst others. NbS are also unique in that they provide additional co-benefits such as, but not limited to, natural carbon sequestration, biodiversity conservation, and local job creation. Furthermore, integrating NbS with traditional built infrastructure is emerging as an effective method to build climate resilience. An example is building a combination of mangrove forests and seawalls to decrease wave energy, thereby protecting against coastal flooding and erosion.



NbS has been growing in popularity among the public and private sectors, but there exists a significant gap in adoption. In 2020, NbS received only 0.3% of overall spending on urban infrastructure, and investments are unequally distributed across and within cities (Birch *et al*, 2023). Several challenges exist hindering NbS scalability to achieve our climate goals. These challenges include difficulty in measuring impact, vulnerability to changing climate dynamics and complexity in reaching consensus among a wider range of stakeholders. Nevertheless, given its potential, NbS suitability and application should be thoroughly assessed and applied as part of broader A&R strategies. NbS can contribute to potential cost savings of USD 393 billion by 2050 in developing countries (WWF-IFRC, 2022). This provides promising options for the region. As with all A&R measures, NbS should be thoroughly assessed in each context to guard against maladaptation.

Technology in the form of AI and advanced analytics, when applied to climate data, provides transformative insights into the realm of climate action for adaptation. These technologies offer enormous benefits in decision-making support. For example, simulating varying climate scenarios and quantifying the cost of inaction to people, the economy, and nature enables better prioritisation and optimal resource allocation towards A&R projects and programmes. In the remainder of this publication, we will refer to this as Climate AI.

In a case study from the Philippines, for example, Climate AI was instrumental in quantifying the social, economic and natural impact of sea level rise in a local municipality. Findings include the number of people at risk, cost of inaction in GDP terms, critical infrastructure (e.g., hospitals and schools) and natural assets (e.g., wetland areas) exposed. These insights help the prioritisation of specific vulnerable communities and economic sectors, identifying opportunities for private-public partnerships and potential sources of funding for A&R. Beyond higher resolution risk assessments, Climate AI can also be used to build early warning systems, strengthen infrastructure, predict large-scale migrations and preserve biodiversity, amongst others.

Despite its substantial potential, Climate AI still faces some notable limitations. These include challenges in data availability and uncertainty, limited data accessibility due to technological infrastructure constraints and the technical capacity needed to apply AI for climate A&R where it is most needed. Notwithstanding these challenges, rapid progress is being made to ensure the responsible and effective integration of AI into climate A&R efforts.

One fundamental aspect to consider in deploying these adaptation and climate-related solutions is the interrelation of various risk factors. Recognising these interactions and relations is essential for decision-makers. It is critical to understand both opportunities and challenges for solutions with multifaceted impact across multiple risks. Understanding how risks intersect and affect each other can lead to more comprehensive and effective strategies for climate adaptation.

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SECTION 1

REGIONAL PERSPECTIVES

Chapter 1:

Sustainable and Resilient cities: How Does International Trade Support Climate Adaptation?

Aik Hoe Lim

CHAPTER HIGHLIGHTS

The effect of climate change on trade

Climate change disrupts production processes and supply chains, while further damaging infrastructure, with this being more dire in developing nations.

Trade as a climate adaptation strategy

Trade diversifies sources of essential goods and services, while encouraging foreign investment and collaboration.

Potential of Artificial Intelligence (AI)

AI can be combined with environmental goods and services or international trade to offer advanced analytics and improve urban climate resilience.

Summary

- **Main Content:** The complex relationship between international trade, technology and urban climate adaptation strategies
- **Key Takeaways:**
  - o There is a **disparity between the adaptation capacity of transport infrastructure** in developed and developing nations after climate disruption.
  - o Trade is **instrumental in disaster prevention, recovery and rehabilitation** via diversifying sources of goods and services and encouraging foreign investment and collaboration.
  - o Trade can help **enhance the potential of technological tools in climate adaptation efforts** by reducing their cost and creating economies of scale.

Relevance of this chapter to SEACAR's themes

Summary

This paper explores the critical role of international trade in supporting cities to adapt to climate change. With urban areas increasingly exposed to climate-induced disruptions, such as extreme weather events and rising sea levels, the paper highlights how trade can enhance urban or national resilience by diversifying resource origins and improving access to climate-resilient technologies. The paper examines how trade policies facilitate access to essential environmental goods and services, including renewable energy technologies, smart city systems and advanced technology-driven climate tools that support infrastructure resilience. Additionally, international trade encourages foreign investment in infrastructure and enables cities to source food and essential goods from regions less affected by climate events, enhancing urban stability and economic security. The paper emphasises Southeast Asia's vulnerability and underscores that developing cities can bolster climate resilience through global partnerships and by integrating trade considerations and policies into adaptation strategies. Overall, trade emerges as a key driver of sustainable urban growth in a climate-adaptive future.

1.1 Introduction: The Growing Importance of Cities in International Trade

Nearly half of the global population, about 4.4 billion people, live in cities, which is expected to double by 2050 (UNDP, 2024). Moreover, more than half of Southeast Asia's population currently resides in cities, and by 2050, urban areas are projected to house 68% of the region's population. Cities are crucial to Southeast Asia's economy, contributing 80% of its GDP and driving 40% of future economic growth (BCG, Think City & WWF, 2023). In today's interconnected global economy, climate disruptions in one region can affect others. For instance, in 2021, a drought in Chinese Taipei à Taipei caused by shifting typhoon patterns nearly crippled the global semiconductor supply chain (Taiwan Supply Chain Case Study 2023, 2023). With urban populations growing rapidly, these cities face increasing risks from supply chain disruptions caused by climate change and extreme weather events. This paper examines the critical role of cities in international trade and their vulnerability to climate change. It also highlights the significance of environmental goods, services and advanced technologies, particularly AI, in mitigating climate risks and promoting sustainable urban development.

1.2 Climate Change and Its Effects on Trade

Climate change significantly increases the costs of international trade by disrupting production processes and supply chains (WTO, 2022). Extreme weather events pose severe risks to transport infrastructure (Brenton & Chemutai, 2021). A one-degree Celsius rise in temperature has been shown to reduce the annual export growth of developing countries by 2 to 5.7 percentage points (WTO, 2024).

In Southeast Asia, four countries, the Philippines, Indonesia, Myanmar and Vietnam, are among the fifteen most vulnerable to climate change (OECD, 2024). Cities in this region face major challenges from unpredictable weather patterns. For example, erratic rainfall causes rising sea levels and flooding, which can damage critical trade routes such as roads, bridges, ports, railways and airports, disrupting navigation. Inland waterways may also become unusable due to extreme weather events and rising sea levels in coastal cities (WTO, 2022). To illustrate this point, in 2024, Typhoon Yagi devastated northern Vietnam, particularly impacting coastal cities like Hai Phong and Ha Long City. With winds reaching 149 km/h, the storm caused extensive structural damage, uprooted tens of thousands of trees, and led to significant flooding along the Red River in Hanoi. Vulnerable communities outside Hanoi's flood protection dyke suffered heavily, with many losing homes and belongings. The typhoon's unusual strength underscored the effects of climate change, as experts attribute its intensity to shifting weather patterns, including La Niña (Tatarski, 2024).

Temperature increases further damage to infrastructure, degrading bridges, roads, runways and railways. Maritime transport accounts for at least 80% of the volume of world trade. This mode of transport is particularly vulnerable to climate change and extreme weather events. Consequently, climate change leads to delays in exports and imports, adding costs for freight insurance. In the worst-case scenario, where global temperatures rise by 4 degrees Celsius by 2100, the number of ports at risk globally could double from 385 out of 2,013 to 691 out of 2,013 globally (WTO, 2022). This creates uncertainties about the reliability of maritime transportation systems and raises operational risks. Given the complexity of global value chains, such disruptions can ripple across the world, affecting

economies globally (BCG, Think City & WWF, 2023).

There is a disparity between the transport infrastructure of developed and developing economies. Developed nations have greater financial resources, technological capabilities, and diversified transport networks, allowing them to invest in resilient infrastructure, advanced climate forecasting and adaptive technologies. These countries can quickly repair or upgrade roads, ports and railways to withstand climate-related disruptions. In contrast, developing nations often face underfunded, outdated, or geographically vulnerable infrastructure, rely on a single mode of transport, and lack access to advanced technology and financing for climate-resilient upgrades. As a result, they are more susceptible to trade disruptions caused by climate events and have limited capacity to adapt effectively. These factors increase vulnerability to climate-related challenges. For example, the Paraná River, which transports 90% of Paraguay's agricultural trade and significant portions of Argentina's and Bolivia's exports, has experienced exceptionally low water levels due to severe and recurrent droughts (WTO, 2022). In countries like Vietnam or the Philippines, sea-level rise threatens key ports, increasing their vulnerability to climate change-related disruptions, affecting both domestic and international trade.

1.3 Trade as a Climate Adaptation Strategy

Trade and trade policies can alleviate some of the impacts of climate change, particularly for cities. By diversifying sources of essential goods and services, international trade enhances a country or region's resilience to environmental shocks and improves food security, strengthening economic stability (WTO, 2022). Trade plays a crucial role in climate adaptation strategies by allowing cities to import essential goods from regions less affected by climate disruptions (WTO, 2022). When local agriculture suffers from climate-related events like droughts or floods, international trade ensures that cities can maintain food supplies by sourcing from more climatically conducive regions (WTO, 2022). Singapore, for instance, is a small city-state with limited resources. Only 1% of its land is available for food production. Over 90% of its food is imported. Moreover, it has diversified import sources to minimise the impact of supply disruptions. In 2004, it sourced its food from 140 countries and

regions. It has increased its sources of food to 170 countries and regions.

International trade encourages foreign investment and collaboration, which can help cities strengthen their infrastructure. Investments in resilient transport systems, renewable energy, and smart city technologies provide the necessary tools for cities to adapt to climate risks. For instance, trade partnerships can introduce innovative construction techniques or climate-resilient materials, which improve infrastructure sustainability in the face of extreme weather. For example, partnerships can facilitate the adoption of self-healing concrete or living shoreline techniques, combining these with locally adapted solutions to enhance infrastructure resilience (OECD, 2024).

Trade is also instrumental in disaster prevention, recovery, and rehabilitation. It allows access to goods, services, and technologies essential for adapting to climate risks and supports global cooperation in managing climate impacts (WTO, 2022). Through global markets, cities can import essential goods such as construction materials, food and medical supplies to aid in rehabilitation efforts. Trade also provides access to financial resources and expertise, helping cities rebuild faster and more sustainably after major climate events.

As climate change increases the frequency and intensity of disruptions, trade plays a key role in maintaining economic stability. By exporting products and services to regions with different climate risks, cities can continue generating income even when local industries are affected by climate-induced events. This diversification of economic activities helps buffer cities against localised climate shocks.

One way for developing countries to pursue climate change adaptation for their cities is to engage in fora for international cooperation, where policy experiences and expertise are being shared. This could include participation in the WTO's Committee on Trade and Environment and initiatives such as the Trade and Environmental Sustainability Structured Discussions (TESSD). TESSD is a forum at the WTO which provides a platform for members to share experiences, good practices and possible trade-related solutions to environmental challenges. Its membership is open to all WTO Members and includes developed and developing countries (WTO, 2024). At TESSD, Members identify and compile best practices, as well as explore opportunities for voluntary actions and partnerships to ensure that trade and trade policies contribute to promoting and facilitating access to environmental goods and services. The TESSD Working Group on Environmental Goods and Services explored climate change mitigation and adaptation in the renewable energy sector in 2023 (WTO, 2024). They highlighted goods that are instrumental in climate change mitigation and adaptation including solar photovoltaic cells, wind turbines and hydro generators. Addressing challenges faced by developing LDC Members, including through technical assistance and capacity building, is one of the focus areas of work in the TESSD (WTO, 2024).

1.4 Environmental Goods and Services

Access to environmental goods and services is essential for building climate-resilient cities (Brenton & Chemutai, 2021). The transition to a low-carbon economy hinges on the widespread adoption of these goods and services (WTO, 2022). By utilising climate-resilient technologies, sustainable energy and other critical resources, cities can reduce their vulnerability to climate disruptions. Environmental goods can be broadly categorised into pollution management technologies, cleaner technologies, and resource management products (WTO, 2022).

A collaborative approach is essential for maximising the benefits of environmental goods and services. By opening markets to foreign investments, cities can attract expertise in critical sectors that bolster their resilience to climate shocks. International trade also facilitates the sharing of best practices and innovations related to climate adaptation. Cities engaged in global markets can adopt successful strategies, such as green building technologies and advanced water management systems, which improve local resilience while stimulating economic growth (BCG, Think City & WWF, 2023). Cities could also combine environmental goods and services deployment with advanced technologies. For example, smart grids powered by AI can dynamically manage energy supply and demand in cities, improving energy efficiency and reducing carbon footprints.

Advanced technologies combined with environmental goods and services hold great potential for climate adaptation by offering advanced analytics in weather forecasting and disaster preparedness. In the Philippines, for example, Climate AI was used to assess the socioeconomic and environmental impacts of sea level rise on a municipality. This analysis provided critical information, including the number of people at risk, the cost of inaction in terms of GDP, and the exposure of vital infrastructure, such as hospitals and schools. Such data is essential for prioritising vulnerable communities and economic sectors and identifying opportunities for public-private partnerships and funding for adaptation initiatives (BCG, Think City & WWF, 2023).

Advanced technology, combined with international trade, can support the building of sustainable and resilient cities. Through trade, cities can access advanced technologies, while advanced technologies help in designing resilient urban environments, ensuring that new infrastructure is better prepared for future climate impacts. Together, trade and advanced technology provide cities with critical tools for adapting to climate change. Trade enables access to essential technologies, environmental goods and services, resources, and innovations that improve climate resilience, while advanced technology enhances urban planning, infrastructure management, and climate risk assessment. By leveraging both, cities

can better manage the effects of climate change, ensuring a more sustainable and resilient urban future.

While advanced technology offers considerable promise, challenges remain. These include limited data availability, technological infrastructure constraints and a lack of technical capacity to implement advanced technology effectively in climate adaptation efforts. Trade can significantly alleviate these challenges. For instance, trade can reduce the cost of AI tools and services by creating economies of scale. As demand for climate adaptation technologies grows globally, the production and distribution of these tools become more affordable. This allows cities, particularly in developing countries, to access advanced AI systems at lower costs, overcoming financial barriers related to technology adoption. The exchange of data and information could also be enabled by cross-border collaboration. For example, by establishing partnerships between countries and cities, trade agreements can include provisions that encourage the sharing of climate data, satellite imagery and meteorological information. This helps cities in developing regions access critical data that is often scarce locally.

1.5. Conclusion

This paper underscores the growing importance of cities in international trade and their vulnerability to climate change. Climate-induced disruptions, including extreme weather events, rising sea levels, and higher temperatures, threaten critical trade routes and infrastructure, leading to higher operational risks and economic instability. Southeast Asia is particularly vulnerable, with many countries facing significant challenges from these climate impacts.

The paper also highlights how trade policies can be leveraged as a climate adaptation strategy. Diversifying trade relationships and accessing essential goods and services from regions less affected by climate change can enhance urban resilience. International trade facilitates the exchange of environmental goods and services that are crucial for a low-carbon economy, including climate-resilient technologies and AI-powered weather forecasting tools.

In summary, international trade is vital in strengthening urban resilience by providing access to diverse resources, technologies, and knowledge. This enables cities to adapt to climate risks, maintain food security and reduce dependence on vulnerable trade partners. Through global collaboration and innovative climate strategies, cities can bolster their infrastructure and economies, paving the way for a more sustainable and resilient urban future.

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Chapter 2:

Bridging Global Climate Projections to Local Actions: An Introduction to CORDEX-Southeast Asia

Ju Neng Liew

CHAPTER HIGHLIGHTS

What is CORDEX?

It is an initiative that aims to improve regional climate modelling and downscaling to provide actionable climate data at local and regional scale.

CORDEX - Southeast Asia Downscaling Experiment

Implemented in three different phases, CORDEX-Southeast Asia provides downscaled climate projections at 25km x 25km and 5km x 5km resolution.

Regional Contribution of CORDEX

Its simulation outputs are crucial for the 6th IPCC Assessment Report and several official national assessments.

Summary

- **Affiliation:** Universiti Kebangsaan Malaysia and Manila Observatory, Philippines
- **Beneficiaries:** 600 – 700 million people
- **Project Type:** High resolution future climate projections (up to 5 km x 5 km)
- **Time Scale:** 2013 - present
- **Stakeholders involved:** IPCC Assessment Reports, UNFCCC's national Communications
- **Funding:** NA
- **Sponsor:** Asia Pacific Network for Global Change Research (APN)
- **Impacts:** Understanding how climate change may impact various local socioeconomic systems in the Southeast Asia region up to the year 2100.

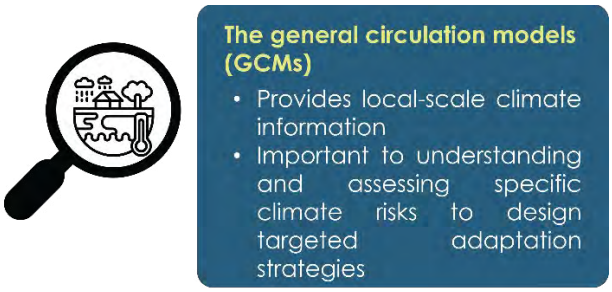
Relevance of this chapter to SEACAR's themes

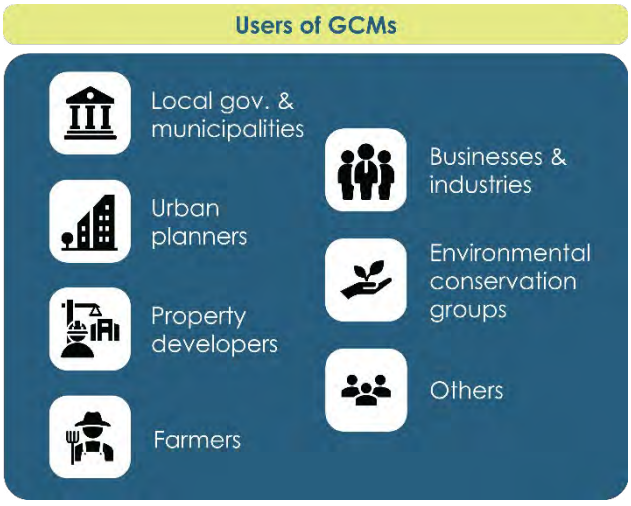
Summary

Information on future climate conditions at specific locations is vital for the planning and implementation of localised adaptation strategies, which may not always align with national or regional projections. However, the availability and accessibility of such information are often constrained by the computational resources required to generate high-resolution climate data. Additionally, when data are available, users are frequently overwhelmed by the enormous volume of datasets required to generate meaningful and interpretable information. CORDEX-Southeast Asia, a regional component of the Coordinated Regional Climate Downscaling Experiment (CORDEX) coordinated by the World Climate Research Programme (WCRP) under the World Meteorological Organisation (WMO), aims to address these challenges. The current chapter introduces CORDEX-Southeast and outlines its contributions to bridging the gaps between global, regional and local climate projections to enhance the accessibility and relevance of climate data for decision-making.

2.1. Introduction

Local-scale climate information is vital to understand and access specific climate risks to design targeted adaptation strategies. Local government and municipalities, urban planners, property developers, farmers, businesses and industries, environmental conservation groups and others can benefit from a comprehensive understanding of a specific locality's historical and potential future climate. Globally, this information is provided by the simulations of global climate models (also called the general circulation models, GCMs). GCMs provide projections of how Earth's climate may respond to different greenhouse gas (GHG) emissions in the future and form an important scientific basis for decisions on climate change mitigation and adaptation worldwide. Strategies in response to a changing Earth's climate are of national and local government concern. Therefore, the simulation output from the GCMs needs to be downscaled to a much higher resolution to fit the local scale assessment need. This is particularly true in areas with various topographies like Southeast Asia where coarse resolutions of GCMs fail to capture the complexity of regional and local climate systems.

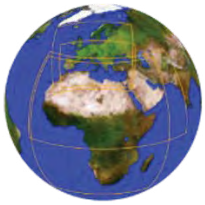




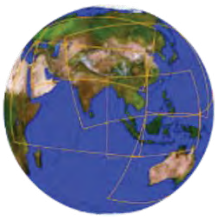
2.2 The Coordinated Regional Climate Downscaling Experiment (CORDEX)

The Coordinated Regional Climate Downscaling Experiment (CORDEX) represents a crucial global initiative to improve regional climate modelling and downscaling to provide actionable climate data at the regional and local scales. It is coordinated by the World Climate Research Programme (WCRP) under the World Meteorological Organisation (WMO) and is instrumental in addressing the urgent need for high-resolution climate data to support Vulnerability, Impact, and Adaptation (VIA) assessments. These assessments are critical for understanding how different regions might be affected by climate change and for developing effective regional adaptation strategies. CORDEX provides an essential framework, bridging the gaps between the global climate models (GCMs) and the localised climate change impacts assessment requirement.

- **Arctic CORDEX**
- **North America CORDEX**
- **Central America CORDEX**



- **EURO-CORDEX**
- **MED_CORDEX**
- **CORDEX Africa**
- **MENA-CORDEX**



- **Central Asia CORDEX**
- **South Asia CORDEX**
- **East Asia CORDEX**
- **South East Asia CORDEX**
- **Australasia CORDEX**

- **South America CORDEX**
- **CORDEX Antarctica**

Figure 1. *The 14 CORDEX domains on earth where the downscaling experiments are performed.*

2.2.1 Southeast Asia Domain

CORDEX-Southeast Asia is a part of this global CORDEX (https://cordex.org/) effort to advance and coordinate the science and application of regional climate downscaling through global partnership. Currently, there are a total of 14 CORDEX domains (**Figure 1**) covering almost every part of the land mass on Earth. CORDEX-Southeast Asia specifically focused on Southeast Asia, a region with a total population of close to 670 million people. Southeast Asia is rich in biodiversity but prone to climatic hazards. Rising temperatures, changing rainfall patterns and more frequent extreme weather events can affect the region significantly. Given its strong geography and sophisticated configuration of land-sea boundaries, the climate change signals over this region can vary significantly from place to place. Therefore, various adaptation strategies are required. Thus, the CORDEX-Southeast Asia project with its high-resolution future climate projections over Southeast Asia up to the year 2100, plays a critical role in understanding how climate change may impact various local socioeconomic systems in the Southeast Asia region, to inform decision-making and adaptation planning.

Since its inception in 2013, CORDEX-Southeast Asia has been financially supported by the Asia-Pacific Network for Global Change Research (APN) for experiments coordination meetings. The computing time and resources were voluntarily sponsored by respective modelling centres that participated in the project. CORDEX-Southeast was coordinated by Universiti Kebangsaan Malaysia from 2013-2023 and is currently coordinated by Manila Observatory, Philippines. More than 20 different centres are involved in the numerical experiments and conducting simulations to produce high-resolution future climate projections for the Southeast Asia region. These centres are located both within and outside the Southeast Asia region. Collaboratively, these centres carried out the regional climate downscaling experiments following a standardised protocol designed and agreed upon by all the members within the CORDEX-Southeast Asia community and providing future climate information for regional, national and city-scale applications. For further information on CORDEX-Southeast Asia, readers are referred to https://www.ukm.edu.my/seaclidcordex/ and https://rucore.ru.ac.th/seaclidcordexphase2.

2.2.2 CORDEX-Southeast Asia Downscaling Experiments

Overall, the downscaling experiments are carried out in three different phases. Phase 1 experiments were accomplished in 2018, and all the downscaling simulations were driven by the 5th Phase Couple Model Inter-comparison Project (CMIP5) GCMs and were conducted on 25km x 25km grid resolution. The scenario sets used are the Representative Concentration Pathways (RCPs) and include the RCP2.6, RCP4.5 and RCP8.5. Several GCMs and regional climate models (RCMs) participated in the experiments. The large sets of GCM-RCM couplets as well as the multiple scenarios used allowed a better sampling of projection uncertainties associated with model sensitivity and future socioeconomic development. The simulation output and datasets were made available on the Earth System Grid Federation (ESGF) database for public consumption, which is a global network of data centres that provide access to climate and earth system data. It enables climate scientists and also other research communities to access, share, and analyse large-scale climate datasets such as those produced from the CMIP and CORDEX experiments. It plays a crucial role in IPCC reporting and informing policy decisions for climate change adaptation and mitigation.

CORDEX-Southeast Asia Phase 2 experiments started in 2017 and focused only on selected sub-domains within the CORDEX-Southeast domains. This includes Peninsular Malaysia, Mindanao Island, the lower Mekong River basin, and Java Island (**Figure 2**). The Phase 1 projections at 25km x 25km grid resolution were further downscaled using RegCM4 to 5km x 5km grid resolution. The higher resolution simulations better resolved the local processes with much smaller biases compared to the 25km simulations and therefore are more suitable for local

adaptation planning purposes. However, due to limited computing resources, the simulations were only able to cover the four selected subdomains.

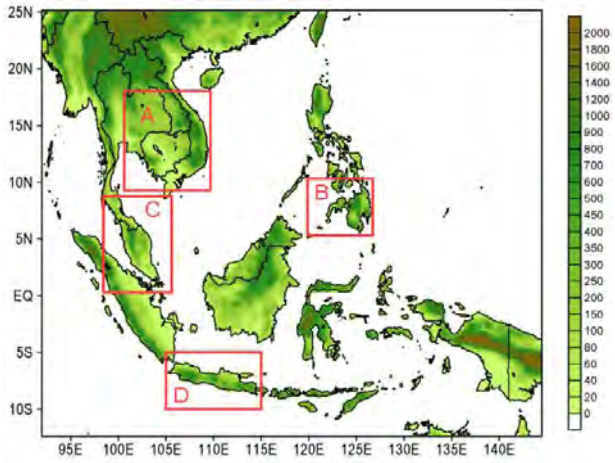
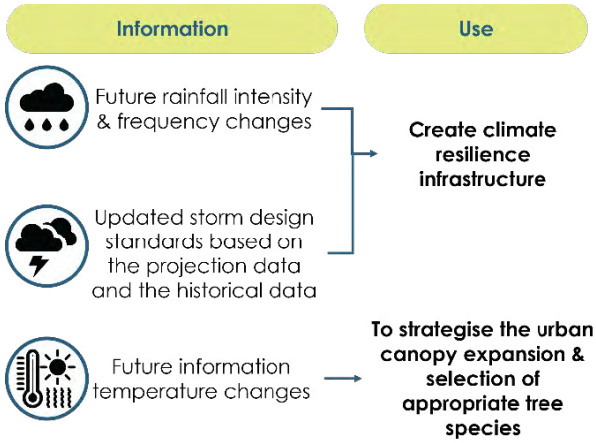


Figure 2. *The subdomains where CORDEX-Southeast Asia Phase 2 experiments were conducted. (Source: Chung et al. 2023).*

The Phase 3 CORDEX-Southeast Asia experiments were conceptualised and finalised in 2022. The simulations were completed in late 2024 and the team is currently analysing the simulation's output. While the exact date for the public release of the data on the Earth System Grid Federation (ESGF) remains uncertain, personal arrangements can be made to access and work with the data in the meantime. The experiments were designed in line with the commencement of the IPCC 6th Assessment Report (AR6) era following the publishing of IPCC AR6 in 2021. AR6 uses a new set of scenarios, known as the Shared Socioeconomic Pathways (SSPs), which offer a narrative to the broad range of possible future developments compared to previous reports. Alongside these scenarios, AR6 is also based on the much-improved GCMs (from 6th Coupled Model Inter-comparison Projects, CMIP6) that provide more robust future climate projections. These new models incorporate better data and climate process representation and provide clearer insights into how different socioeconomic developments may affect the future of Earth's climate. Phase 3 CORDEX-Southeast Asia experiments downscaled these latest AR6 GCMs projections to 25km x 25km grid resolutions and covered the entire Southeast Asia domain similar to that used in Phase 1. Aside from the new sets of scenarios and new sets of driving GCMs used in Phase 3 CORDEX-Southeast Asia experiments, another crucial addition is the consideration of city or urban scale information in the overall simulation framework. The focus on urban scale projection is in line with the upcoming planned IPCC AR7 with an additional focus on reducing climate risk and emissions over the urban areas. Therefore, in addition to the 25km x 25km downscaling covering the entire Southeast Asia, alternative modelling and downscaling techniques were developed to further downscale the projections to 2km x 2km resolution to support the city-scale applications. This is carried out under the APN-funded project "Climatic Hazard Assessment to Enhance Resilience against Climate Extremes for Southeast Asian Mega-cities (CARE for SEA mega-cities)".

CARE for SEA mega-cities aims to generate city-scale climate hazard information for SEA mega-cities (Bangkok, Hanoi, Jakarta, Kuala Lumpur and Manila) under multiple SSP scenarios that will be relevant and

useful for policy making to enhance urban resilience in a globally warmer future. The focused hazards are extreme heat and rainfall. Due to the complexity of the surface morphology in an urban area, future changes in extreme rainfall are expected to exhibit remarkable spatial variabilities within mega-cities. Urban planners can use this high-resolution climate projection to evaluate and test different urban design and mitigation strategies, to enhance the climate resilience of cities. For instance, to create climate resilience infrastructure, future rainfall intensity and frequency changes need to be considered and the storm design standards need to be updated based on the projection data and the historical data. Also, future information on temperature changes is crucial to strategies for the urban canopy expansion and selection of appropriate tree species. Integrating climate data with urban planning allows the development of targeted interventions to address localised vulnerabilities and optimise adaptation measures. The project is expected to be accomplished by the end of 2025 and is coordinated by CORDEX-Southeast Asia.

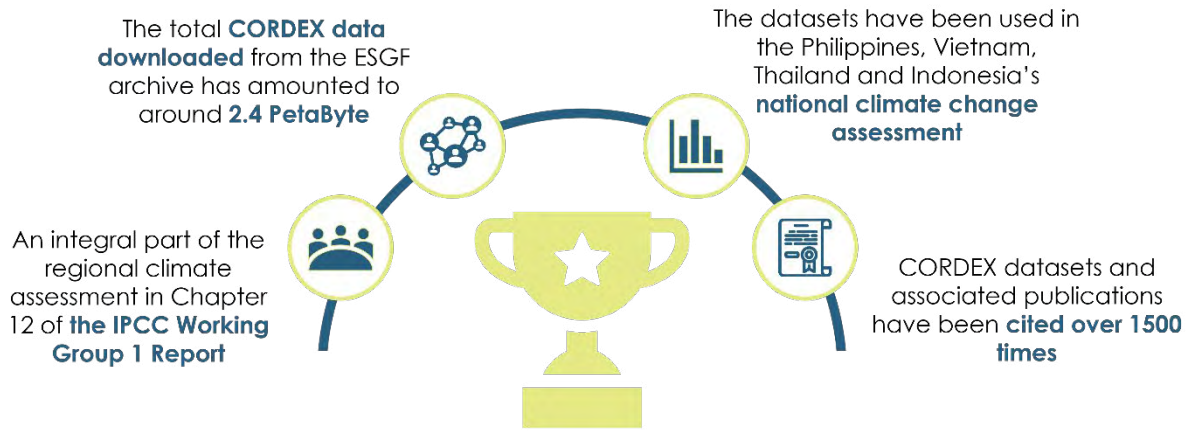


The use of high-resolution climate projection by urban planners.

2.3 Contribution to Regional Assessments

Around 10 years of scientific effort by CORDEX-Southeast Asia has contributed remarkably to the understanding of regional climate over Southeast Asia. Together with other CORDEX domain outputs, its simulations output and associated publications are vital to the regional climate change assessment reported in Chapter 12 of the IPCC AR6 Working Group 1 (WG1) report. The total CORDEX data downloaded from the ESGF archive has amounted to ~2.4 PetaByte. The datasets produced are also used extensively in the IPCC WG1 interactive atlas available online at https://interactive-atlas.ipcc.ch/. The atlas enhances accessibility and understanding of climate data presented in the AR6 by allowing users to explore regional climate information through an interactive platform, offering detailed projections and observed climate trends for various regions and variables. It supports informed decision-making in climate adaptation and mitigation efforts globally.

In addition to contributing to IPCC AR6, CORDEX-Southeast Asia simulation output has also been used by various countries within ASEAN for climate change assessment. In particular, the datasets have been used for official national assessment in the Philippines, Vietnam, Indonesia and Thailand. The outcome of these assessments is featured in their national communications and climate adaptation reports to assist in shaping national policies. For instance, CORDEX-Southeast Asia datasets were used for risk



Regional Contributions of CORDEX

and vulnerability assessments in Thailand's Fourth National Communication as well as the National Communication for Indonesia. The same datasets were used for the COP26 assessment report for Climate Change in Vietnam Impact and Adaptation. In addition to these official national reports, the CORDEX-Southeast Asia datasets are also used by numerous researchers around the world to understand Southeast Asia's climate. Readers are referred to Tangang et al. (2020) and their citations for further information on future climate changes in Southeast Asia. The CORDEX-Southeast Asia datasets and associated publications have been cited thousands of times since its inception in 2013.

2.4 Conclusion

Adaptation plans and strategies to improve climate resilience must be evidence-based to avoid unintended consequences or maladaptation. The high-resolution future climate projections produced through CORDEX-Southeast Asia's multinational collaborative effort are crucial to determining future hazards.

The information concerning the levels of exposure and vulnerability of specific sectors, communities or areas provides an in-depth understanding of climate change risk underpinning specific sectors, communities or areas. Climate change will undoubtedly impact multiple critical sectors in Southeast Asia in the coming decades, though the nature and extent of these impacts remain uncertain. Further in-depth research by the VIA community to better assess the associated climate risks is vital. In the past, the lack of access to high-resolution climate projection data posed significant challenges to such efforts. CORDEX-Southeast Asia offers essential resources that should accelerate and enhance the quality of climate risk assessment and climate adaptation in the region (Tangang & Chung, 2022).

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SECTION 2

LOCAL ACTIONS

Chapter 3:

Nature-based Approach through Communities Ready to Act (CoRTA) Project – Phase 3, Manggarai, Indonesia

Aristia Fathah

CHAPTER HIGHLIGHTS

Increasing environmental risks

Manggarai District is prone to river and sea flooding, which have been exacerbated by climate change and local unsustainable agricultural practices.

Involvement of local communities

This project enhances the local communities' capacity to restore riverbanks via bioengineering, cultivating native vegetation and diversifying agricultural practices.

Best practices of ecosystem rehabilitation

This project has established nursery houses for flood-preventing and flood-mitigating plants in five villages/sub-districts as well as the Manggarai Mangrove Centre.

Summary

- **Affiliation:** The Indonesian Red Cross
- **Beneficiaries:** 324,501 people
- **Project Type:** Regional ecosystem-based adaptation
- **Time Scale:** 2017 - present
- **Stakeholders involved:** Disaster Management Agency, Public Works Department, Forestry Department, Agriculture Department, Social Department, villagers and Sub-district government
- **Funding:** USD 1.54 million
- **Sponsor:** The Indonesian Red Cross and the American Red Cross
- **Impacts:** Diversifying livelihoods, enhancing local capacity for community-based nature-based solutions and village regulations for pro-environmental behavioural changes

Relevance of this chapter to SEACAR's themes

Summary

The Indonesian Red Cross (PMI), supported by the American Red Cross, implements Nature-based Solutions (NbS) through the Communities Ready to Act (CoRTA) Phase 3 project in Manggarai, Indonesia. Key activities include flood mitigation, watershed and coastal ecosystem restoration, and capacity building. The project promotes sustainable practices, establishes nursery houses (watershed and coastal's stabilising vegetation), alternative livelihood and advocates local policies. Mangrove restoration and bioengineering techniques stabilise riverbanks and enhance climate resilience. Despite facing various challenges, progress has been made in ecosystem rehabilitation, livelihoods and policy advocacy. Long-term collaboration and upscaling efforts are vital for enhancing the climate resilience of ecosystems and local communities.

3.1 Introduction and Context Setting

Since 2017, the Indonesian Red Cross (PMI, Palang Merah Indonesia), with support from the American Red Cross (Amcross), has been working to strengthen disaster preparedness in four Indonesian provinces through the Communities Ready to Act (CoRTA) project. The CoRTA project, Phase 3, was implemented in seven villages in Tanggamus district, Lampung province, and five villages in Manggarai district, East Nusa Tenggara province, Flores Island. It aimed to build community resilience using nature-based solutions (NbS) and integrated risk management (IRM).

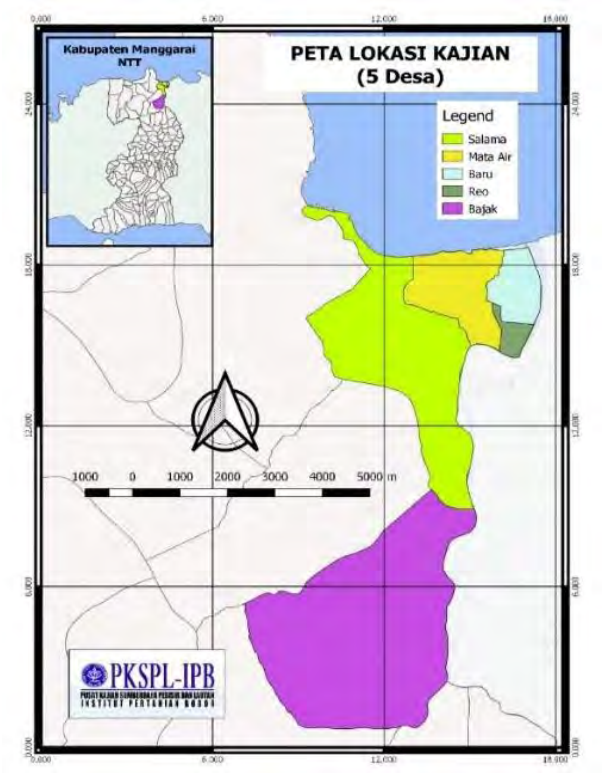

Figure 1. *Map of study locations (5 villages).*

The initiative focuses on flood risk reduction and ecosystem conservation in coastal and watershed areas. The total project budget was USD 1,541,978. This case study focuses on the implementation in Manggarai District where PMI and Amcross worked on the following activities:

- NbS feasibility study (including carbon/ blue carbon) and action plan.
- Community-based NbS implementation: restoration of catchment areas, watershed and coastal vegetation (seedling nurseries, planting and replanting).
- Natural retaining wall and bioengineering for flood mitigation restoration.
- Development of community environmental regulation and

protection policies for catchment, watershed and coastal areas.

- Training community groups to expand their livelihood assets or alternative livelihood options related to catchment, watershed and coastal ecosystems.
- Advocacy to the local government to adopt the Integrated Watershed/ Coastal Management Plan in the District Development Plan.

Wae Pesi River crosses Bajak Village.

River gabions destroyed by flood in Bajak Village.

3.2 Identification of Key Issues

Manggarai District, with a population of 324,501, is vulnerable to natural hazards such as river and sea flooding, mainly due to its geography and the flow of major rivers such as Wae Pesi, Wae Ncuring and Wae Renca. Flooding affects villages and sub-districts in five intervention areas and is exacerbated by environmental degradation and unsustainable agricultural practices. Vulnerability and Capacity Assessments (VCA) show the need for comprehensive watershed and coastal management:

Bajak village situated in a bowl-shaped basin surrounded by hills, regularly experiences flash floods. These floods are caused by surface runoff that accumulates in the river even without local rainfall. In addition, damage to the river gabion walls has been observed, due to poor design and construction that does not meet technical standards, reducing their durability.

The river's gabion was destroyed due to a strong water current in Salama Village.

The Early Warning System (EWS) *siren installed on the side of the Wae Pesi.*

Condition of the existing coast of Salama Village.

Wae Pesi River that crosses the Mata Air Sub-district.

Salama Village faces critical issues beyond flash floods, particularly coastal abrasion due to the loss of key coastal vegetation, such as Casuarina Equisetifolia. The absence of this vegetation leaves the coast vulnerable to strong winds and sea salt corrosion, exacerbating land degradation along the coastline.

Mata Air Sub-district, like Bajak and Salama, suffers from flash floods and weakened gabion walls along the river. In addition, the historically significant karst hill in the area gradually loses vegetation due to increasing settlement density, reducing the hill's ability to store water and posing further environmental risks such as soil erosion.

Mangrove tourism in Baru Sub-district.

Wae Pesi River that crosses the Reo Sub-district.

The river abrasion at Baru Sub-district.

Settlement on the riverbank of the Reo Sub-district.

Baru Sub-district mangrove beach area has untapped potential for ecotourism. However, the development of this area requires proper spatial planning, facilities management and rehabilitation of the mangroves which are essential for environmental health and tourist attraction.

Reo Sub-district, located in the downstream watershed, faces regular flash floods and pollution events. The river is polluted with E. coli bacteria above acceptable levels primarily due to waste disposal in the upstream and middle catchment areas which accumulates in the downstream section of Reo, causing public health concerns.

3.3 Working with Nature to Protect People in Manggarai District

In 2022, PMI and Amcross conducted assessments and identified roadmaps for integrated watershed and coastal management. Based on these assessments and a VCA, they formulated and implemented several key adaptation efforts to help communities protect and sustain their environment.

One of the main actions was strengthening riverbanks through bioengineering. For example, gabions and rock-filled structures that are reinforced with plants can form natural barriers against erosion. This approach helped stabilise the soil, reduce the risk of floods, and support the health of the surrounding ecosystem.

To support ecosystem rehabilitation, this project supports the establishment of nursery houses in five villages/Sub-districts involved in the programme. These nursery houses are responsible for providing various types of local or naturalised vegetation, including vetiver (locally known as *akar wangi*), spruce and bamboo. The plants produced from these nurseries will then be planted on gabion structures and in flood-prone areas. Growing these plants locally allowed communities to manage and restore their land sustainably.

PMI also promoted sustainable agricultural practices suited to the region. This included cashew-based food processing, silvo-fishery/silvo-aquaculture (an approach that combines mangrove rehabilitation with fish farming) and mangrove cultivation. These methods helped support local economies while fostering environmental stewardship.

Another critical part of the project was capacity building for local communities. Communities received training in NbS, river basin management, and ecosystem rehabilitation, along with the promotion of alternative livelihoods like superior rice varieties and aquaculture. Capacity building also includes carbon stock sequestration observations and calculations for the Community-based Action Team (CBAT) which plays a crucial role in managing nurseries, planting vegetation, and collaborating with government agencies such as the Department of Environment. Capacity building was conducted over two days in Baru and Reo villages to assess the amount of carbon in the environment, with sample collection at eight different points. The results of observation showed that most of the plants that did not grow or die were due to livestock damage, not because of errors in cultivation or care. The worst area was in Bajak Village, where vetiver replanting has been carried out four times. Reo Village had good plant conditions, with 80% of the plants surviving, though many vetiver plants need to be replanted using better methods.

Policy support and village regulations were also essential to ensure the long-term success of these efforts. PMI and Amcross helped strengthen local policies and encouraged collaboration with regional river basin forums (*Forum Daerah Aliran Sungai*) and disaster risk reduction forums (*Forum Pengurangan Risiko Bencana*), creating a foundation for better management and protection of local riverine and coastal resources.

PMI and Amcross also proposed the establishment of the Manggarai Mangrove Centre (MMC) as an educational and climate adaptation hub. In partnership with the Centre for Coastal and Marine Resource Studies (PKSPL) at Bogor Agricultural University, the MMC is designed to help communities learn about mangrove conservation and build resilience to climate change. In this area, nine species are listed on the IUCN Red List (version 2022-2); among them, one species is classified as Near Threatened, which is *Ceriops decandra*. The MMC initiative emphasises the importance of protecting these species and provides a practical platform for local communities to engage in climate adaptation practices.

3.4 Barriers and Challenges

One of the major challenges is the time required to see visible results. NbS needs a long-term commitment to show substantial benefits. While planted vegetation in Manggarai has reduced floods, economic and environmental benefits are still in the early stages.

Encouraging positive changes in community behaviour is another hurdle. Some individuals dispose of garbage in the river, believing PMI will clean it up. There needs to be more awareness about the negative effects of allowing livestock to roam freely, which damages vegetation along riverbanks and coastlines. This highlights the need for better community education on waste management and protecting natural habitats.

Kelurahan Baru, *Manggarai Mangrove Center*

Skedul Penanaman *Planting Schedule*

No.	Latin Name Nama Latin	Local Name Nama Lokal	Plant Distance Jarak Tanam (m)	Total Jumlah (Btg)	Rice gap-filling Penyulaman (Btg)	Total
1	*Ceriops decandra*	Tengar	1x1	15680	1568	17248
2	*Excoecaria agallocha*	Buta-buta	1x1	2030	203	2233
3	*Lumnitzera racemosa*	Teruntum	1x1	3700	370	4070
4	*Rhizopora mucronata*	Bakau Merah	1x1	10960	1096	12056

Ceriops decandra
(Tengar)

Excoecaria agallocha
(Buta-buta)

Lumnitzera racemosa
(Teruntum)

Rhizopora mucronata
(Bakau Merah)

Figure 2. *Type of Mangrove*.

Figure 3. *Site Plan of Manggarai Mangrove Centre.*

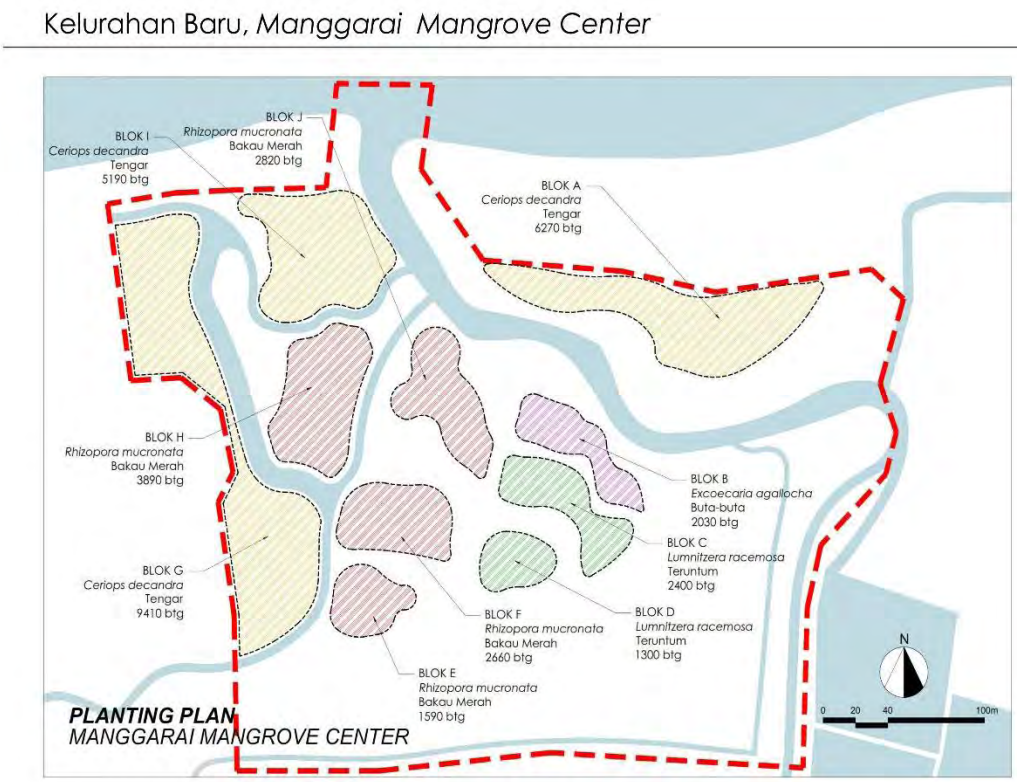

Figure 4. *Planting Plan of Manggarai Mangrove Centre.*

Maintaining economic sustainability is also challenging. New income opportunities, like cashew processing and fish farming, remain small-scale. While some community members see financial benefits, the scale needs expansion to bring broader impacts to the local economy and provide stable livelihoods.

Promoting good governance and gaining policy backing for long-term NbS initiatives is difficult, especially at district and provincial levels, where policies are more complex and require longer intervention periods.

Finally, the lack of financial capacity often restricts local community investments in resilience building. The community and stakeholders' contributions in Manggarai have never been measured financially.

These challenges underscore the need for continuous community engagement, educational efforts and policy advocacy to ensure the project reaches its full potential and brings long-lasting benefits to Manggarai.

3.5 Opportunities for Improvement

The following opportunities exist to address these challenges:

(e.g., strengthening monitoring measures, enforcing regulations and imposing strict penalties on violators)

3.6 Case Studies and Best Practices

The project can act as a case study for other regions with similar sociocultural and ecological conditions to follow the best practices that have been implemented. Local communities and CBATs have innovated in ecosystem restoration and building climate resilience. A key effort is establishing nursery houses in each village or Sub-district, managed by CBATs. These teams plant flood-preventing vegetation like vetiver, spruce, and bamboo in flood-prone areas, including coastal zones and watersheds. They also cultivate productive crops for alternative livelihoods. CBATs are crucial in nurseries, ecosystem management, carbon sequestration studies, and collaborating with government agencies. Their recognition as focal points for environmental management has opened opportunities in tourism management and other income-generating activities. Each nursery has made different progress in seedling production and ecosystem management:

Bajak Village:

The nursery successfully exceeded its target, with the number of bamboo seedlings produced exceeding expectations. Due to the unavailability of vetiver seedlings, these were replaced with wild cane and local grasses. Despite this, the total number of seedlings produced was still on target. In addition, the production of Aren (sugar palm) seedlings also exceeded the initial target. For riverbank planting, *angsana* tree seedlings met the target, but there was a significant shortfall in vetiver seedlings. This gap was partially filled with wild cane, senga, and hibiscus, but there remains a shortfall of 1,758 vetiver seedlings.

Salama Village:

The production of bamboo seedlings met the target. Vetiver seedlings were replaced with wild cane and local grasses due to availability issues. The casuarina seedling has not met the target, the gap was filled by Cattapa. The casuarina seedlings have been successfully planted to support coastal restoration.

Mata Air Sub-district:

Seedling shortages were resolved with wild cane and local grasses as substitutes. Leichhardt and cashew seedlings have been successfully planted, helping the rehabilitation of watersheds in the region.

Baru Sub-district:

The nursery faced a shortfall of 1,893 seedlings. Vetiver seedling shortages were addressed with wild cane and local grasses, while Bruguiera was substituted with Hibiscus, Mucronata, and *Ceriops decandra* due to seasonal limitations. The hibiscus seedlings are planted in the Baru sub-district, while the mangrove have

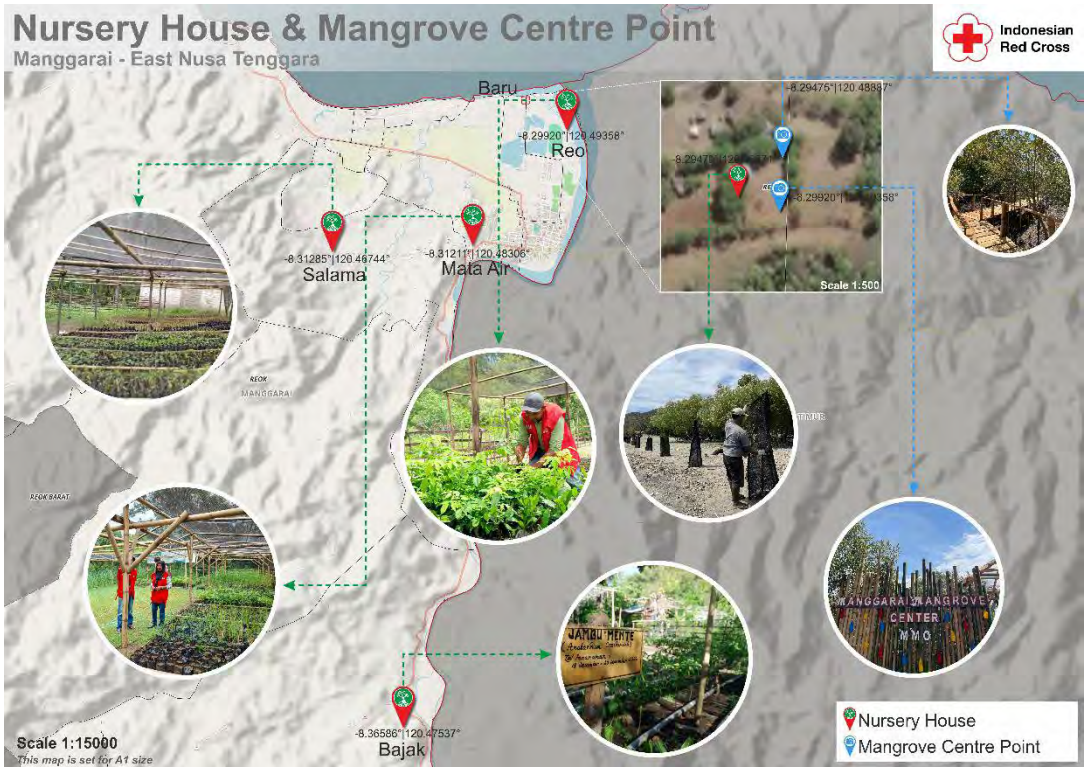

Figure 5. *Nursery Houses & Manggarai Mangrove Centre.*

been successfully planted in the Reo mangrove forest, contributing to its restoration.

Reo Sub-district:

Demonstrated excellent performance in developing nurseries (water catchments), with the total number of seedlings produced exceeding the targets set. Vetiver shortages were addressed with wild cane and local grasses. Leichhardt, ficus, and cashew seedlings have been successfully planted, contributing to riverbank and coastal rehabilitation efforts.

Despite facing various challenges, each village has shown progress and effective adjustments in seedling development (water catchments). Adjustments such as the substitution of seedlings and the addition of alternative species have been implemented to meet the goals of ecosystem rehabilitation and restoration in all regions.

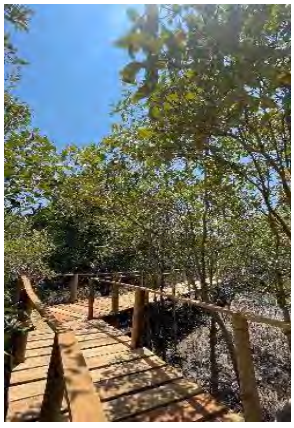

Figure 6. *Manggarai Mangrove Centre (MMC).*

Another success is establishing the Manggarai Mangrove Centre (MMC) at Nanga Banda Beach in Reok District to promote climate adaptation practices and knowledge as well as tourism for mangrove conservation, together with partners and local communities. In this area, we found the Near Threatened species, *Ceriops decandra*. This MMC is part of ecotourism development, ecosystem conservation, and supports creating new livelihood opportunities for local communities. The initiative is led by PMI's Community Based Disaster Preparedness (SIBAT) team in the Baru and Reo sub-districts.

Figure 7. *Manggarai Mangrove Centre.*

The mangrove ecosystems in Reo and Baru Villages, Manggarai Regency, East Nusa Tenggara (NTT), are dominated by *Sonneratia alba* species. However, the tree density is sparse, indicating a need for rehabilitation. The species diversity and richness at the site are low, though species evenness is moderate to high. The site stores 354.03 tons/ha of carbon, within the average range of carbon storage in Indonesia but below the global average, due to low organic carbon content and tidal fluctuations. In addition, this project has also supported the development of local regulations and policies such as Village Regulations (*Perdes*) and Joint Policies on the Protection of River Basin Areas (*DAS*) and Disaster Risk Reduction. It supports the establishment of Disaster-resilient Villages/ Sub-districts in five programme areas: Bajak Village, Salama Village, Baru Sub-district, Reo Sub-district and Mata Air Sub-district in Reok, Manggarai.

Figure 8. *Carbon Stock Measurement.*

3.7 Importance of Stakeholder Engagement

Stakeholder engagement is crucial to the success of the CoRTA project. Multi-sectoral collaboration has been established, involving government departments such as the Disaster Management Agency, Forestry, Agriculture, Public Works, local NGOs, and local villages. These partnerships have facilitated the integration of NbS into local policies, to enhance the community's climate resilience in flood-prone areas.

3.8 Call to Action

The success of NbS in Manggarai depends on sustained commitment from all stakeholders. PMI, Amcross and their partners must continue to:

- Advocate for policy changes that support NbS.
- Scale up NbS interventions to achieve lasting impacts.
- Foster greater community engagement and participation in resilience-building activities.
- Promote awareness campaigns on the importance of ecosystems in disaster risk reduction.
- Continuously invest in NbS and collaborate with different stakeholders to create resilient communities against climate change.

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Chapter 4:

Astra Climate Village Programme: Fostering Climate Action Through Community Development

Triyanto, Yulika, Irwan and Wulan Reyhana

CHAPTER HIGHLIGHTS

The objectives of Astra Climate Village (ACV) Programme

ACV's objectives include enhancing community resilience, reducing GHG emissions, and promoting low-carbon awareness and sustainable lifestyles.

Integrating climate adaptation into daily life

One case study is the enhancement of water security via the implementation of biopore and rainwater harvesting systems to reuse water for gardening and hydroponics.

Local communities taking the lead in sustaining the project

Local communities, aware of climate change's impacts, lead and sustain these climate initiatives that provide tangible benefits to their livelihoods

Summary

- **Affiliation:** PT Astra International Tbk
- **Beneficiaries:** 118 climate villages
- **Project Type:** Local development
- **Time Scale:** 2013 - present
- **Stakeholders involved:** Indonesian Ministry of Environment and Forestry, Local communities, NGOs and Environment and Forestry Services in Cities and Province Level
- **Funding:** N/A
- **Sponsor:** PT Astra International Tbk
- **Impacts:** Enhancing local climate resilience via, but not limited to, improving local waste management, scaling up energy and water conservation, increasing villagers' awareness of climate change

Relevance of this chapter to SEACAR's themes

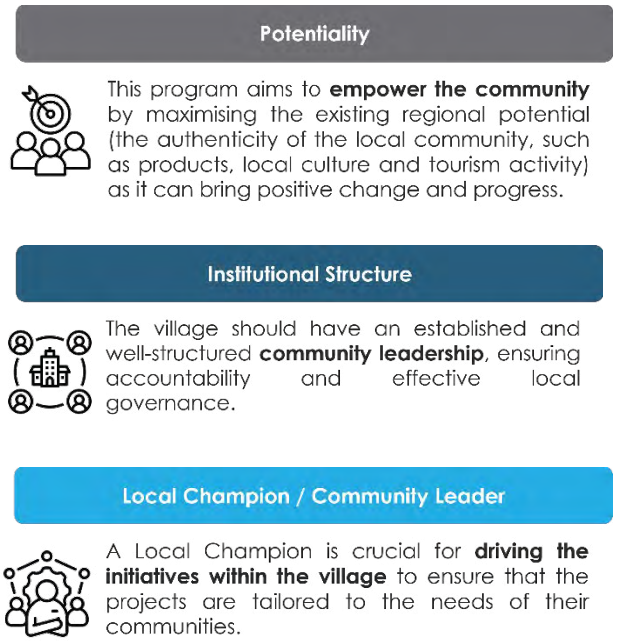
Summary

Astra, a leading Indonesian conglomerate, fosters community development through its flagship Kampung Berseri Astra (KBA) Programme, or Astra Berseri Village, launched in 2013, empowering communities to build healthier, more sustainable living environments. In several KBA locations, Astra has further strengthened community-based climate action through the Astra Climate Village (ACV) initiative, supporting mitigation and adaptation via capacity building, infrastructure development and PROKLIM registration. As of 2023, the program has supported 118 ACVs across 34 provinces in Indonesia. The program is delivered in collaboration with the Ministry of Environment and Forestry or *Kementerian Lingkungan Hidup dan Kehutanan* (KLHK) in Indonesian, Subject Matter Experts (SMEs), and state governments, achieving integrated environmental, sociocultural and ecological outcomes.

4.1 The Kampung Berseri Astra (KBA) and Astra Climate Village (ACV) Programme Concept

The development of Astra Berseri Villages (KBA) builds on the unique potential and strengths of each participating community. In some cases, this work progresses into a more advanced phase that focuses on climate change mitigation and adaptation. This phase is known as Astra Climate Village (ACV), a thematic extension of the KBA program.

Three main criteria drive the village selection process:



For example, in 2023, three criteria were used to select one of the KBA villages in Bodeyan, Sukoharjo Regency, to become an ACV.

ACV of Bodeyan, Sukoharjo Regency, Central Java

Potentiality	Implementing urban farming could lead to environmental programs that address climate change adaptation and mitigation challenges.
Institutional Structure	Has a comprehensive local structure and works closely with local stakeholders to ensure effective implementation.
Local Champion / Community Leader	Mrs Warsini was identified as the leader based on her projects focusing on preserving the village's natural resources via urban farming, waste banks, and environmental awareness campaigns. She empowers residents via local environment community gathering and action.

ACV that performs well will be recognised by the *Program Kampung Iklim* or Climate Village Programme (PROKLIM), a national certification given by the Indonesian Ministry of Environment and Forestry (KLHK) aimed at increasing the resilience and ability of villages to adapt and mitigate the impact of climate change (Ministry of Environment and Forestry of the Republic of Indonesia, 2016). The benefits of being registered under PROKLIM include having their adaptation and mitigation efforts recognised by KLHK, supporting Indonesia's Nationally Determined Contributions (NDCs), and enhancing the economic growth of the villages, indirectly amplifying their reputation. As a result, other villages and/or communities will look to PROKLIM villages as a model, integrating their environmentally friendly lifestyle that incorporates nature-based solutions (NbS) through agricultural, water, waste management and climate-friendly initiatives as part of their livelihood.

Astra supports the government's programme by developing the ACV programme, which has a strength in environmental conservation.

The objectives of ACV are:

(1) Increasing community resilience in facing climate hazards and the impact of climate change.

(2) Measuring the potential of reducing GHG emissions

(3) Promoting low carbon awareness and lifestyle in the community.

4.2 Astra Climate Villages (ACV) Programme Development

The development of the KBA was undertaken through a structured series of stages, each serving as a platform to foster community growth and resilience. These stages comprised the following initiatives:

4.2.1 Kampung Berseri Astra (KBA) Climate Awareness Movement (GENERASI KBA):

This programme aims to identify community characteristics and behaviours. At this stage, Astra collaborates with the KLHK and state-level government. The potential partner villages are trained in climate resilience, problem and potential mapping, as well as programme planning. Problem mapping involves identifying the challenges and vulnerabilities the community faces, while potential mapping focuses on recognising available local resources and solutions to their challenges.

4.2.2 Kampung Berseri Astra (KBA) TUNAS:

This programme aims to prepare potential partner villages to enter the Astra ecosystem through activities such as developing local champions, introducing ACV schemes and procedures, mapping potential programme development, and providing guidance in programme planning. This stage is led by Internal Astra Teams and Subject Matter Experts (SMEs).

4.2.3 Kampung Berseri Astra (KBA) ACCELERATION:

Several KBA villages have been further developed at this acceleration stage to

focus on climate change mitigation and adaptation. This targeted effort aims to prepare selected KBAs to transition into ACV, equipped with stronger capacities and measurable contributions to climate action.

This programme aims to develop and strengthen ACV through intensive mentoring within a series of activities such as strategies, mentoring programme implementation, and assisting in registration with the National Registry System (SRN) of the KLHK. This programme is specifically for KBA which does not have a climate programme and/or wants to improve its PROKLIM status, starting from *Pratama, Madya, Utama, to Lestari* status. Astra officers will work closely with village representatives to ensure local nature-based knowledge is integrated into the development of environmental and sustainable practices, helping communities improve their status within the PROKLIM certification.

4.2.4 Kampung Berseri Astra (KBA) INNOVATION:

This programme recognises and appreciates villages that have successfully implemented innovative initiatives that cover health, education, environmental and entrepreneurial aspects. Internal Astra Team ensures that these innovations are scalable and replicable across other villages, amplifying the initiative's positive effects.

4.2.5 Management Systems and Monitoring

The KBA programme is planned to run for 5 years for each village. Within this timeframe, Astra implements several approaches to ensure the sustainability and success of the programme, including continuous mentoring and supervision, training, institutional strengthening and support of the maintenance of facilities and infrastructure (**Figure 1**).

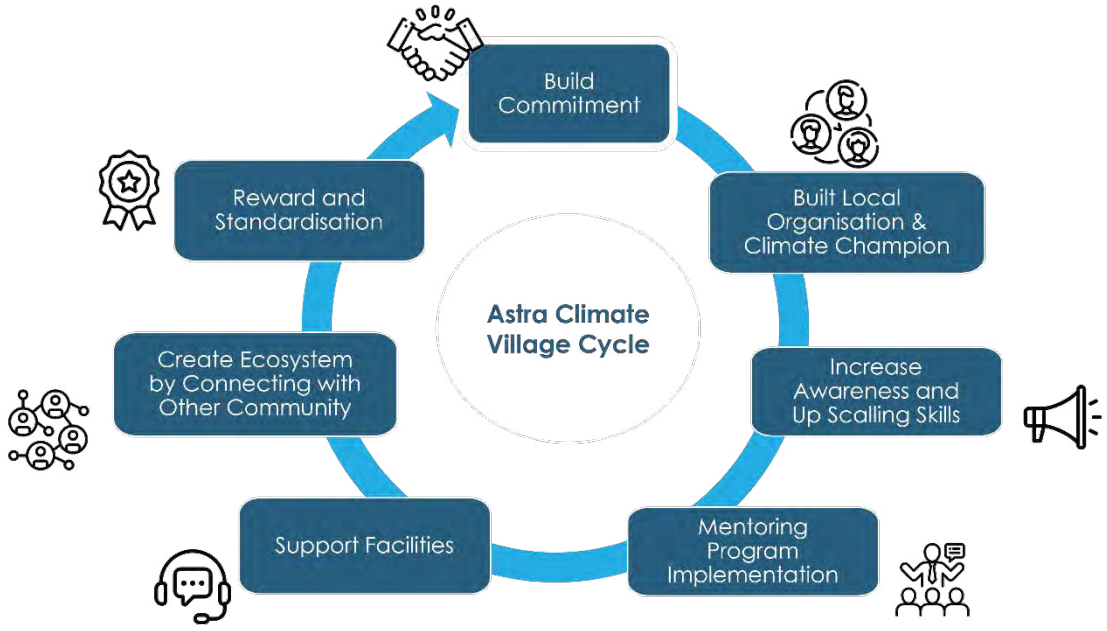


Figure 1. *Kampung Berseri* Astra Cycle.

To ensure the sustainability of this programme, Astra implements a quality management system and monitoring through several key activities such as:

Progress Reports:

Each KBA is required to submit an annual progress report to monitor the implementation of activities, and challenges faced while evaluating the positive outcomes experienced by community members. This requirement applies during the first five years of the programme. After the initial five years, villages are only required to submit a simplified progress document annually.

Assessment:

Assessment is conducted in two stages: self-assessment and cross-assessment by KBA mentors using an assessment tool designed by Astra to measure the potential of each village. This process involves a rating system of 1 to 5 stars, providing a clear evaluation of progress and areas for improvement.

KBA Mentors:

This is a platform for experienced KBAs to facilitate communication with local champions in each KBA, ensuring regular and effective monitoring, as well as assisting in the development of strategies and consultations related to issues in the KBA.

In addition, this programme encourages KBA to go independent, especially after 5 years of mentoring. Independent KBAs are encouraged to become mentors for other KBAs in their region, helping to develop the next generation of KBAs.

4.3 Engaging the Community Members: The Onboarding Process

The Onboarding Process of the ACV Programme unfolds through several stages, as follows:

4.3.1 Potential Mapping:

Identifying the KBA characteristic to improve its resiliency against climate change through ACV. In this process, the local community would be consulted with Astra while a needs assessment is conducted.

4.3.2 Community Education and Training:

The community members participate in workshops and training sessions tailored to their local potential. These activities focus on raising awareness about PROKLIM and how their village can actively contribute to climate adaptation and mitigation.

4.3.3 Engaging State-level Government:

Introducing the ACV programme and collaboration support that aligns with the PROKLIM initiative and local priorities.

4.3.4 Facilitating Certification:

The community members are encouraged to pursue PROKLIM certification from the KLHK. The ACV Programme guides this process, assisting in meeting certification requirements and preparing the village for assessment.

4.3.5 Field Verification:

The field assessment of the target village will be held by the KLHK to confirm its compliance with PROKLIM criteria.

4.3.6 PROKLIM Certification:

The village that fully meets the PROKLIM

Figure 2. *Distribution of sustainable social contribution flagship programme.*

criteria would be officially recognised as a Climate Village, integrating it into the National Registry System (SRN).

The process ensures that communities are not passive recipients of aid but are fully empowered to drive their progress towards sustainability. The focus is not merely on compliance but on fostering a deeper sense of ownership, enabling the community members to enhance their climate resilience independently.

4.4 Data of Astra Berseri Village (KBA)

By the end of 2023, 200 KBAs had been developed across 34 provinces in Indonesia, of which 118 were ACV. Each KBA comprises 2050 households with an estimated 60-150 individuals (**Figure 2**).

4.5 Stakeholder Involvement

Astra has established strong partnerships with several stakeholders to ensure the sustainability of the ACV programme, which are:

Environmental foundations and Subject Matter Experts (SME):

These partners provide essential technical support for climate adaptation and mitigation, enabling communities to adopt sustainable practices and enhance resilience.

Local Champion/Community Leader:

They promote community engagement and oversee project implementation.

Household (Community Member):

The community actively implements climate solutions and innovations to ensure long-term sustainability.

The collaboration progresses through the following processes:

Programme Launch and Coordination:

The ACV programme was launched by engaging with local communities and state-level governments, ensuring alignment with the programme's commitment to sustainability.

Capacity Building:

By collaborating with internal and external

stakeholders, ACV aimed to enhance community understanding of climate change issues and promote climatefriendly behaviours.

Government Collaboration:

Astra works closely with local and national government bodies to ensure its sustainability initiatives align with government policies and regulations.

This multi-stakeholder approach creates a solid foundation for achieving the goals of the Astra Climate Village. With each group playing a well-defined role, the collaboration drives both environmental improvement and community wellbeing.

4.6 Challenges of Astra Climate Villages (ACV)

Implementation of ACV faced the following challenges:

- Sustaining community commitment proved challenging, particularly during the later stages of climate adaptation program implementation.
- Leadership continuity within the community was inconsistent, mainly due to frequent changes in the Local Champion (ACV leader) role.
- The ACV program's broad geographic coverage posed challenges for maintaining effective monitoring and ensuring consistent reporting quality during the empowerment process.

4.7 Astra Climate Village (ACV) Model – Benefits and Challenges

By the end of 2023, several achievements from the ACV programme have enhanced local climate adaptation, mitigation capacity, and resilience. First, in terms of waste management, ACV has been able to process more than 247.8 tons of plastic waste annually through several integrated waste banks. In addition, there is organic waste management where 533.1 tons of compost are produced annually to support reforestation initiatives. Moreover, 414,000 trees have been planted in 210 hectares of green areas in ACV areas from 2016 to 2023. Additionally, Astra has collaborated with various partners to install 83 solar panels for renewable energy projects and has successfully encouraged the community to use rainwater harvesting up to 150.2m^3 per year as an alternative water source. Thus, the ACV programme has potentially reduced emissions by up to 2,786 tonnes of CO_2 annually.

Beyond reducing greenhouse gas emissions, the ACV programme has had broader ecological and socio-cultural impacts. Ecologically, the programme helps maintain hydrological functions in ACV areas and contributes to ecosystem preservation through waste management and reforestation efforts. Socio-culturally, the programme has increased public awareness about environmental conservation, leading to behaviour changes in the community. Communities now better understand the impact of climate change on their livelihood and it encourages them to develop behavioural change that revolves around climate

mitigation and adaptation initiatives to enhance their climate resilience.

Changing longstanding behaviours towards more sustainable practices has been a challenge. However, with consistent and collaborative efforts, the communities have been empowered to adopt sustainable practices into their daily lives. For instance, in the Astra Berseri Village of Pulau Pramuka, Kepulauan Seribu, a serious waste problem was addressed through home waste sorting, the development of waste banks and the processing of waste into alternative fuels through pyrolysis, which increased their climate resilience and circularity from the plastic waste. Additionally, community members have transformed waste into marketable products, such as eco-friendly handicrafts, which support ecotourism while improving local economies without sacrificing environmental sustainability.

Another example is the Astra Berseri Village of Pekayon, Bekasi, where the community initially faced challenges conserving clean water. The community responded by implementing biopores and rainwater harvesting systems, allowing them to conserve and reuse water for gardening, hydroponics, and other purposes. This proactive approach has not only met their immediate needs but also helped the community develop climate resilience.

4.8 How do communities sustain the project?

From the beginning, the ACV programme aims to help the communities gain self-sufficiency and be resilient against climate change. Hence, the community members have been actively briefed about the benefits of nature-based climate action, as they lacked knowledge about it.

The community then tried to identify the impacts of climate change on their village, such as contagious diseases (dengue fever, diarrhoea), climate hazards (flood, drought, landslide), and agricultural disruptions (soil degradation, reduced crop yield), which resulted in the risks and opportunities mapping. This output led to the formulation and conceptualisation of PROKLIM that could address the problems in the community.

Several climate initiatives have been implemented, including water conservation, waste management, electricity efficiency and tree-planting programmes. These initiatives have changed community behaviour and mindset, as they have benefited from reduced risks and increased community resilience, leading to a higher level of community resilience to climate change. As a result, many community members are now actively and voluntarily continuing these climate initiatives because they recognise the tangible positive impacts on their livelihoods. The community also develops income-generating activities such as eco- or edu-tourism and urban farming. These projects not only boost the local economy but also support the continuation of environmental initiatives.

4.9 Conclusion

ACV Programme creates a model of clean, healthy, creative, and intelligent

villages but also empowers communities to become agents of change in adapting to and mitigating climate change. The successes achieved thus far prove the effectiveness of this approach and demonstrate great potential for future local sustainable development. Moving forward, strengthening collaboration between communities, local governments, and partner organisations will be key to ensuring the sustainability and scalability of the program's impact.

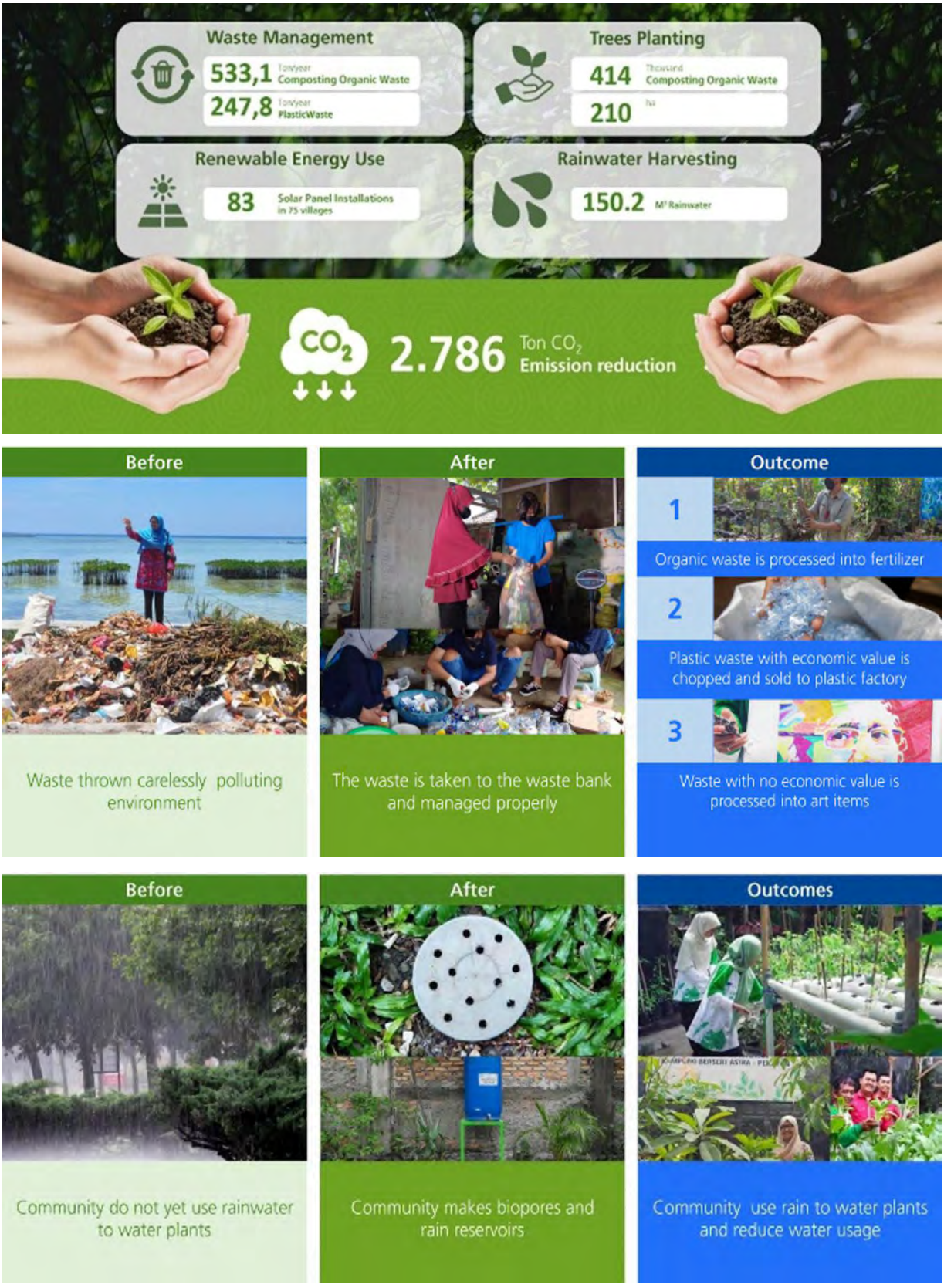


Figure 3. *Impacts of ACV programme.*

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Chapter 5:

Myanmar Climate Change Alliance Phase 2

Shashank Mishra and Kyu Thin Cho

CHAPTER HIGHLIGHTS

Disaster risk of Myanmar

The World Risk Index 2024 has listed Myanmar as the sixth most vulnerable nation towards climate and humanitarian crises.

The role of Myanmar Climate Change Alliance (MCCA)

MCCA has scaled up community-led climate actions in eight townships, spanning across four geoclimatic zones.

The impact of Myanmar Climate Change Alliance

MCCA supported Myanmar government in developing the Myanmar Climate Change Policy, Strategy and Master Plan, as well as drafting the Intended Nationally Determined Contributions.

Summary

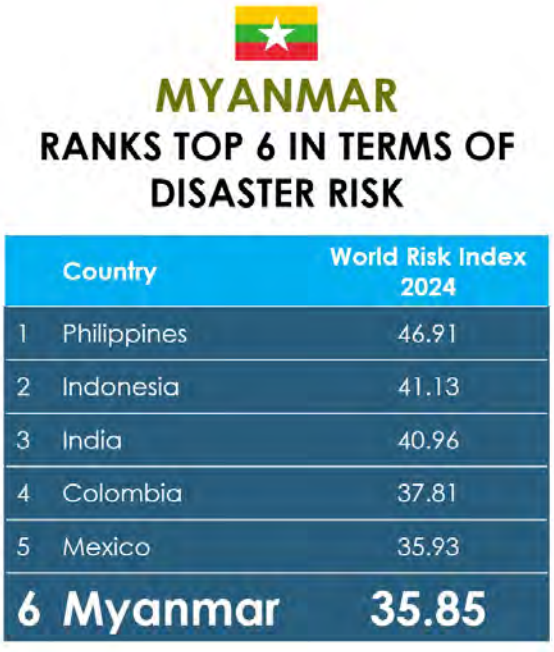
- **Affiliation:** Global Climate Change Alliance (GCCA+) initiative of the European Union
- **Beneficiaries:** 2.5 million
- **Project Type:** Regional development
- **Time Scale:** 2020 - 2025
- **Stakeholders involved:** UN-Habitat, European Union, public and private sectors, local communities
- **Funding:** USD 6.8 million (EUR 6.1 million)
- **Sponsor:** The European Union
- **Impacts:** Scaled up locally led climate action in Myanmar and revitalised the climate dialogue in the country;

Relevance of this chapter to SEACAR's themes

Summary

Myanmar, despite being one of the world's lowest GHG emitters (0.61 tons CO2e/ person), consistently ranks among the top three nations most affected by climate extremes. Rising temperatures, shifting rainfall, and sea-level rise are causing droughts, cyclones, floods, and threats to food, energy security, and forests, compounding the struggles of conflict-affected communities. Through the EU-funded Myanmar Climate Change Alliance Phase 2 (MCCA2) programme, UN-Habitat scales up community-led climate actions, emphasising youth and women's inclusion and fostering national climate dialogue. Key initiatives include establishing the Myanmar Climate Action Network (M-CAN) to drive grassroots climate actions and enhance cross-sectoral collaboration to address pressing climate challenges.

5.1 Background and Objectives



The World Risk Index 2024, which evaluates the disaster risk of 193 countries, places Myanmar in the top 6 positions on the list, underscoring Myanmar's vulnerability and lack of readiness for impact of climate change. (World Risk Report, 2024). Climate projections in Myanmar indicate more challenges to come. Temperatures are expected to rise by 2050 by 1.3°C – 2.7°C on average (and up to 3°C in the eastern and northern hilly regions), and the number of hot days (>38°C) can go from 1 day per month to at least 4 and up to 17 days per month (Horton *et al*, 2017). Also, the duration of the monsoon, responsible for 75-90% of the rainfall, has shortened due to both late onset and early withdrawal (Lwin, 2022). Sea level rise in Myanmar is projected to reach 20–41 cm by mid-century. Frequent climate-related disasters and ongoing ethnic conflicts have hindered sustainable development, caused significant economic losses and delayed climate action.

Under the EU's Global Climate Change Alliance (GCCA+), the first phase of the Myanmar Climate Change Alliance (MCCA) (2013–2018), implemented by UN-Habitat and UNEP, helped develop Myanmar's Climate Change Policy, Strategy, and Master Plan (2018–2030), launched in 2019. It also piloted local adaptation in Labutta, Pakokku, and Hakka, and supported Myanmar's first Intended Nationally Determined Contribution (INDC) under the Paris Agreement. The ongoing second phase (MCCA2, 2020–2025) focuses on implementing the policy, scaling up locally led actions, and fostering cross-sectoral climate dialogues to address challenges in Myanmar's current political context.

The key objective of MCCCA2 is to support Myanmar in becoming a climate-resilient, low-carbon society that is sustainable, prosperous, and inclusive. The MCCA2 programme emphasises the following two components of intervention:

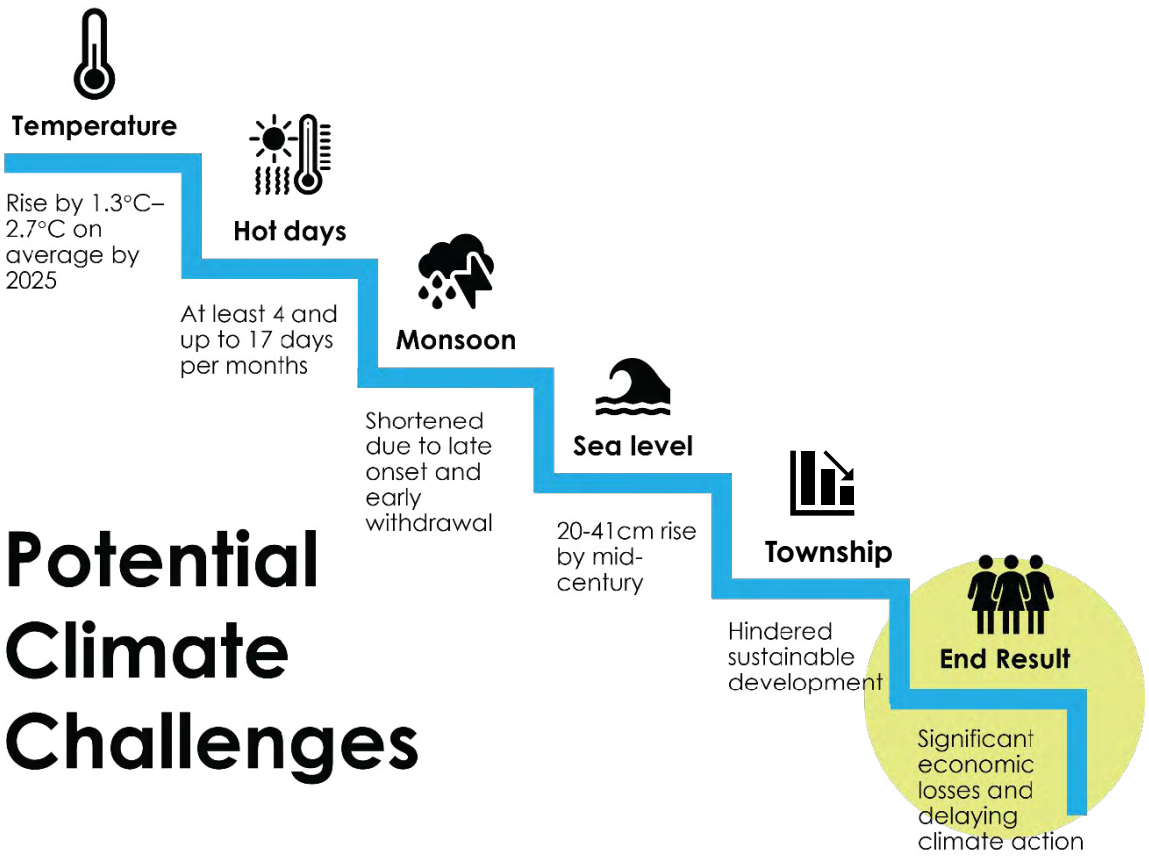
1) Support, at the local level, of resilience-building, considering the specific needs and demands of women and youth; and

2) Improved climate sector dialogue through knowledge generation, awareness raising and communication.

Through climate actions across various sectors, MCCA2 aims to support Myanmar in meeting the targets of Sustainable Development Goal 13 (SDG13) and also contribute to achieving the targets of other SDGs such as SDG 2 (food security), SDG 3 (health), SDG 5 (gender equality), SDG6 (clean water and sanitation), SDG7 (affordable and clean energy) and SDG 11 (sustainable cities and communities).

5.2 Targeted Project Areas and Beneficiaries

MCCA2 aims to scale up community-led climate action in different geoclimatic areas across Myanmar (delta, dry zone, hilly region and urban areas) in a conflict-sensitive environment and strengthen the climate resilience and climate sector dialogue by engaging with different non-state stakeholders. MCCA2 is being implemented in eight townships of the



aforementioned climatic zones. A multidimensional analysis was conducted to select the location of the MCCA2 programme. Climatic and geographic profile, demographic profile, presence of development partners/ongoing programme and security and accessibility were the main criteria considered while selecting the eight townships. The target areas and population are listed in **Table 1** (Humdata.org, 2022).

5.3 Approach and Programme Description

The MCCA2 programme takes a holistic, community-driven approach to building climate resilience, emphasising interdisciplinary collaboration and integrated responses to climate change vulnerabilities. It empowers local communities through active participation in climate action planning and decision-making. Capacity-building efforts included regular climate change awareness sessions and training on Ecosystem-Based Adaptation (EBA) in targeted townships. Tools like Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) captured community perspectives on climate hazards and impacts. Simplified Climate Change Vulnerability Assessment (CCVA) and Local Climate Action Planning (LCAP) tools prioritised local knowledge, ensuring communities were engaged from the beginning as active contributors rather than mere beneficiaries in planning workshops.

States and Regions	Geo Climatic Areas	Townships	Population
Yangon Region	Tropical Urban area	Dagon Seikkan	200,709
		Thanlyin	322,739
		South Dagon	445,991
Ayeyarwaddy Region	Delta Area	Pyapon	314,387
		Bogale	323,684
Mandalay Region	Dry zone area	Nyaung-U	262,457
Shan State	Hilly region area	Taung Gyi	503,620
		Kalaw	212,956

Table 1. *Target project areas of MCCA2,*

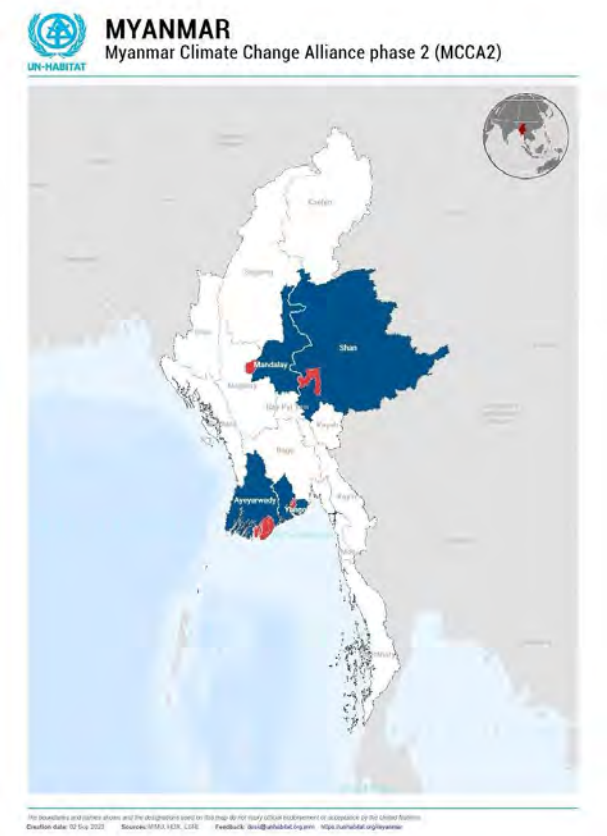


Figure 1. *Target project areas under MCCA2.*

Figure 2(a). *Community participation at township level CCVA and LCAP workshops.*

Figure 3(a). *Enhanced women participation throughout CCVA and LCAP workshops.*

Figure 2(b). *Community participation at township level CCVA and LCAP workshops.*

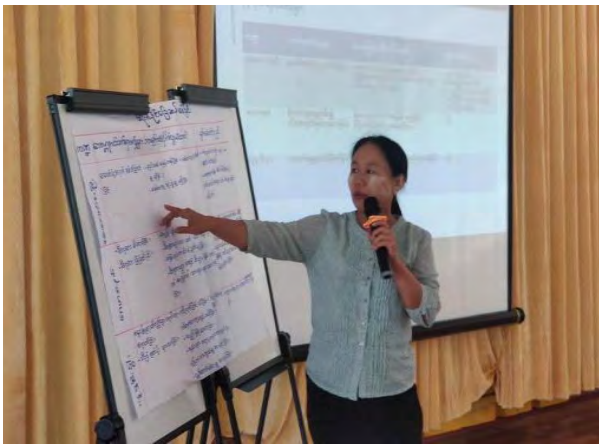


Figure 3(b). *Enhanced women participation throughout CCVA and LCAP workshops.*

CCVA includes participatory hazard mapping and vulnerability analysis under three categories (Infrastructure, socioeconomic and ecosystem) and creating impact chain analysis to understand direct and indirect consequences resulting from climate change projects. This participatory process enabled the identification of context-specific vulnerabilities and the development of tailored local-level climate action plans that address the unique needs of each community. Inclusion (gender and youth) and conflict sensitivity are at the core of the climate resilience framework developed by the MCCA2 programme.

Central to the programme's approach is developing and implementing the Local Climate Resilience Model (see **Figure 4**), which prioritises interventions across critical sectors. LCAP focuses on analysing the three scenarios i.e., **1)** Business as usual, **2)** Adaptation to maintain current standards and **3)** Resilience to provide sustainable development. The MCCA2 local climate resilience model emphasises the Water-Energy-Food nexus, recognising the interdependence of these sectors in ensuring community resilience. By focusing on resilient shelter, water safety and security, energy security and food security, the programme aims to mitigate

the risks associated with climate change and enhance the adaptive capacity of the most vulnerable populations. Furthermore, the model integrates public health and disaster risk reduction (DRR), education, science and technology, and cross-sectoral interventions such as Nature-based Solutions (NbS), inclusive and gender-responsive climate action, and support for green and blue growth opportunities.

This comprehensive approach ensures that resilience-building efforts are both sustainable and equitable, leaving no one behind. MCCA2 programme has supported climate change vulnerability assessment and locally led climate action planning in eight townships of Myanmar where climate change is impacting differently targeted groups such as informal settlers/slum dwellers, farmers, women, youth etc.

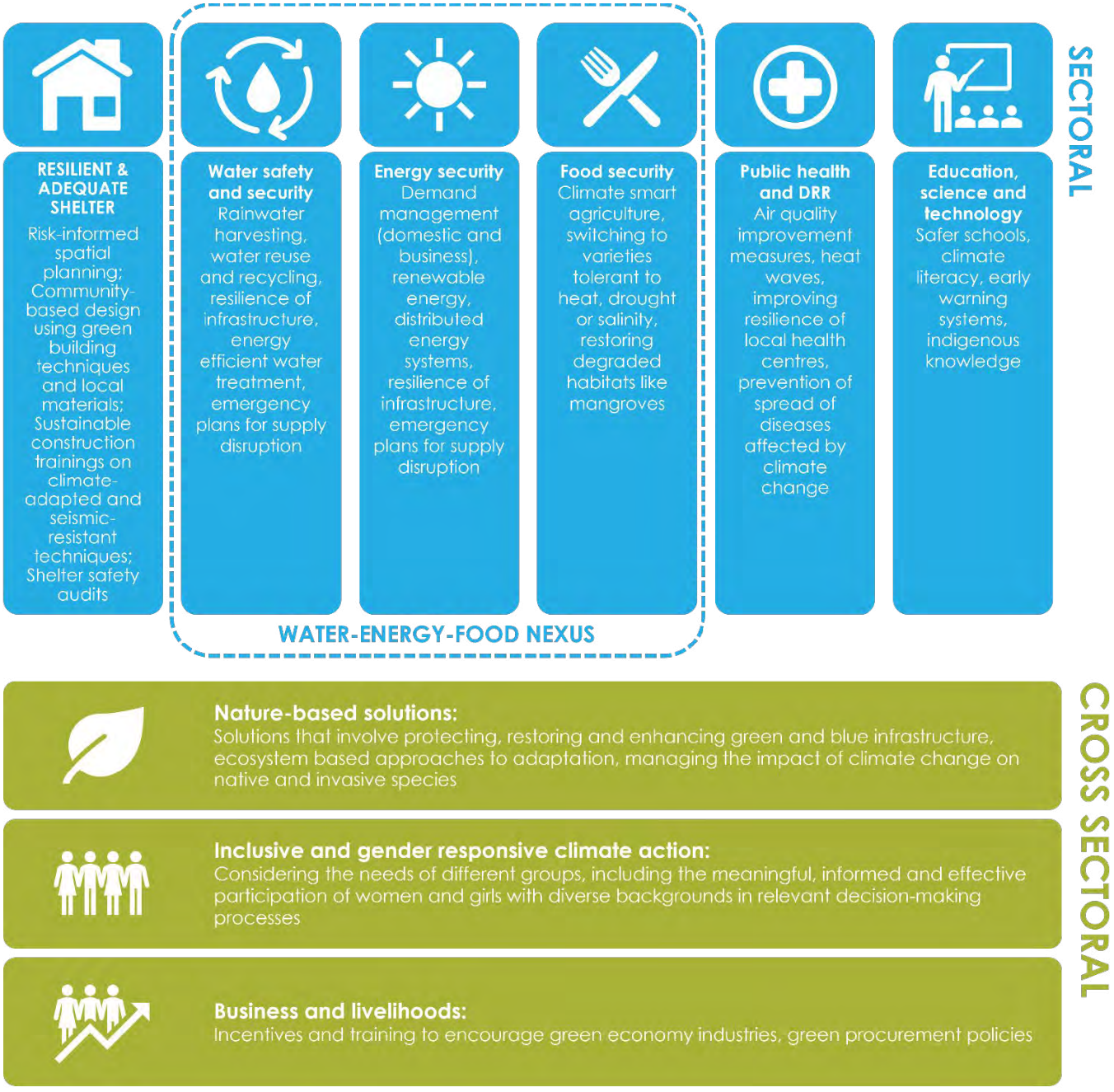


Figure 4. *MCCA2 Local Climate Resilience Model.*

Identified climate adaptation actions (including actions causing co-benefits of both adaptation and mitigation) are prioritised based on criteria such as feasibility, cost, effectiveness, community acceptability, co-benefits and timeline for implementation. MCCA2 is implementing climate actions such as providing water security through standalone water systems for slum dwellers, capacity building on climate-smart agriculture to farmers, climate risk-sensitive livelihood opportunities for women and youth, mangrove restoration, solid waste management and drainage improvement as flood risk management etc.

In September 2024, Typhoon Yagi struck Southeast Asia, affecting many countries including Myanmar. The deadly storm triggered widespread flooding and landslides, affecting people across 70 townships in nine states and regions of Myanmar, including Bago, Kayah, Kayin, Eastern and Southern Shan, Mandalay, Magway, Mon and Naypyidaw. In response to this crisis, MCCA2, in collaboration with local stakeholders, has implemented flood recovery and response initiatives in Taunggyi and Kalaw townships. These efforts focus on conducting comprehensive post-disaster assessments to evaluate the extent of damage and identify the needs of affected communities. Moreover, MCCA2 has constructed disaster-resilient shelters in Taunggyi and Kalaw in Shan State. These shelters aim to provide safe, sustainable and climate-adaptive housing solutions for vulnerable communities impacted by the flood. The initiative emphasises the use of locally available materials and sustainable designs, ensuring affordability and replicability while promoting resilience against future climate shocks.

To ensure drinking water supply for informal settlers in peri-urban Yangon, MCCA2 is constructing standalone water systems along with the provision of groundwater recharge and solar energy. The standalone drinking water supply systems are being operated by off-grid solar systems which are installed on the roof of the water supply system. This provision will avoid unsustainable consumption of resources and reduce energy dependency on fossil fuels.

The MCCA2 initiative is also enhancing energy security in Myanmar by deploying household solar lights, off-grid solar photovoltaic (PV) systems and solar pumping systems in electricity-deprived communities. By providing reliable and clean energy, MCCA2 ensures sustainable power access for households and schools where government electricity supply is limited. The initiative strengthens climate resilience, supports education through uninterrupted power for schools and improves livelihoods by contributing to energy independence and long-term sustainability in vulnerable regions.

Mangrove restoration as a part of nature-based solutions is implemented in coastal townships to provide multiple benefits such as enhanced resilience against cyclone and coastal erosion, and food security through aquaculture and reforestation. Local community forestry groups have been involved since the beginning to take the leadership and manage community forests. Shifting patterns of rainfall and temperature and sea-level rises are pushing farmers to adopt new agriculture practices to ensure food security. MCCA2 also provides training on climate-smart agriculture in dry zones and hilly areas.

Under MCCA2, eight monastic schools (one in each township) are targeted to develop and implement school-led climate actions such as solar energy, rainwater harvesting, waste management etc., and creating eco-clubs to create a culture of climate resilience and ensure sustainability of climate actions. Monastic schools are selected for the project as they are filling the education gap in the hard-to-reach areas and in the vulnerable areas of Myanmar.

Figure 5(a). *Targeted villages in Bogale township for mangrove plantation*

Figure 5(b). *Targeted villages in Pyapon township for mangrove plantation.*

In rural, conflict-prone, and underserved regions, monastic schools are sometimes the only functioning educational institutions. They help ensure that basic education continues where state services are weak or disrupted. Monastic schools in Myanmar have often served as emergency shelters and community hubs during natural disasters or humanitarian crises. Therefore, MCCA2 programme has targeted them as ideal platforms for delivering climate change education, Nature-based Solutions and disaster risk reduction activities. The targeted schools act as a key place to engage students, parents and local communities in demonstration of innovative climate change adaptation actions which can be further replicated beyond schools in the communities.

Figure 5(c). *Meeting with communities and local experts for mangrove plantation planning (in Pyapon township and Bogale township).*

Figure 5(d). *Preparation of mangrove plantation site by engaging local communities (in Pyapon township and Bogale township).*

Figure 5(e). *Solar powered Standalone water treatment station.*

Figure 5(f). *Shelter construction in Taung Gyi township.*

Figure 5(g). *Household rainwater collection system.*

Figure 5(h). *Climate Change awareness-raising activities at the targeted monastic schools.*

Figure 5(i). *Climate Change awareness-raising activities at the targeted monastic schools*

Figure 5(j). *School Led Climate Action Planning Activities at the targeted monastic schools.*

Figure 5(k). *School Led Climate Action Planning Activities at the targeted monastic schools.*

Strengthening the capacity of local partners is the most crucial step to scale up locally led climate actions and to ensure the sustainability of these actions. MCCA2 has initiated capacity building of local CSOs on developing climate change proposals and project management skills to access available climate financing in the country.

In addition to implementing targeted interventions, the programme places a strong emphasis on knowledge creation and dissemination to enhance awareness of climate change issues amidst urgent humanitarian needs in the country. By

establishing a digital knowledge hub, the MCCA2 programme facilitates the sharing of lessons learned, best practices, and local ecosystem information, contributing to a broader understanding of climate impacts. All climate actors are invited to use the portal for knowledge management and dissemination. Digital portal is also being used to organise various workshops and the annual event "Myanmar Climate Action Week (MCAW)". MCAW is organised both at the national and local level in various townships to involve local communities and CSOs.

Figure 6(a). Opening Session of MCAW 2023.

Figure 6(b). Opening Session of MCAW 2023.

Figure 6(c). *Opening of MCAW 2024.*

Figure 6(d). *Keynote presentation at MCAW 2024 by Catarina Teles Ferreira Camarinhas, Country Programme Manager (ad interim), UN-Habitat Myanmar.*

The programme also supports the development of key analytical tools, including climate gender analysis, and climate change communication strategies, which are essential for informed decision-making. MCCA2 programme is also developing a private sector engagement strategy on climate change and supporting the private sector to access their climate risk to promote a climate resilient and responsible business approach to contribute back to the communities in Myanmar. Through these efforts, the programme not only addresses immediate climate risks but also builds a foundation for long-term resilience and sustainable development in line with SDG 13 and the 2030 Agenda for Sustainable Development.

5.5 Stakeholder Engagement

MCCA2 addresses Myanmar's political sensitivity and the complex operational environment by enhancing local climate resilience through collaboration with non-state stakeholders, including UN agencies, INGOs, LNGOs, CSOs, the private sector, youth groups, academia, media, and community organisations. Key activities include fostering multi-sector climate dialogue via knowledge sharing, awareness campaigns, and implementing community-level adaptation and mitigation actions. UN-Habitat established the Myanmar Climate Action Network (M-CAN) to revitalise climate discussions across sectors. M-CAN's strategic framework prioritises 1.) Knowledge Management 2.) Capacity Building 3.) Partnerships and Collaboration and 4.) Advocacy for resource mobilisation. With 70+ member organisations, M-CAN engages with national and international networks to share information, coordinate efforts and build synergies.

5.6 Impact of the Programme

The Myanmar Climate Change Alliance (MCCA) programme has been instrumental in advancing the climate change agenda across sectors in Myanmar. It supported the government in developing the Myanmar Climate Change Policy (adopted in 2019), Strategy, and Master Plan, prioritising six key sectors. MCCA has also produced sector-specific policy briefs, tools, and guidelines on climate-resilient architecture, risk-informed urban planning, adaptation training, communication strategies, and gender climate analysis to facilitate policy implementation. As the key implementing agency of MCCA2, UN-Habitat has mainstreamed climate change into urban development, disaster risk management, and education policies. Additionally, MCCA2 assisted Myanmar in drafting its INDC under the Paris Agreement and amplifying its voice in regional and global climate forums.

The second phase of MCCA (MCCA2) has scaled up locally-led climate action in Myanmar and revitalised the climate dialogue in the country when COVID19 and the ongoing political and humanitarian crisis have slowed down progress on climate change. The formation of M-CAN has played a key role in scaling up climate actions through partnerships and collaboration with other climate actors. MCCA2 is engaging with CSOs and other national/international partners to disseminate the results of CCVA and LCAP and to get their support to continue implementing climate actions beyond the project timeline. After climate change awareness and training on Ecosystem-based Adaptation, communities are better equipped with the knowledge to support community-led climate actions being implemented under the MCCA2 programme.

M-CAN, a rapidly growing network in Myanmar, has garnered strong interest from development partners and donors on climate change. Through MCCA2, UN-Habitat and M-CAN partners organised the annual "Myanmar Climate Action Week"

in 2023 and 2024, fostering innovative discussions on climate solutions in a complex political context. The event provided a unique platform for climate actors and donors to advocate for action. As M-CAN's chair, UN-Habitat has successfully pushed for the prioritisation of climate change in the UN Transitional Cooperation Framework and other strategic plans, gaining increased donor attention.

M-CAN has organised various climate change events both at the national (World Environment Day, World Cities Day, World Cleanup Day, International Youth Day, COP28 debriefing etc.) and international level (Asia Pacific Climate Week, World Urban Forum etc.) to raise awareness on climate change and draw attention of donor communities for more support in Myanmar. In the absence of formal representation of Myanmar in regional and global climate forums, MCCA2 is supporting climate actors through M-CAN to ensure that voices from Myanmar are not forgotten in these important forums.

Figure 7(a). *Community Climate Change Awareness Raising Activities at the targeted townships.*

Figure 7(b). *Community Climate Change Awareness Raising Activities at the targeted townships.*

Figure 7(c). *Keynote presentation at MCAW 2024.*

Figure 7(d). *Community mangrove plantation activities during MCAW 2024 at Pyapon township and Bogale township.*

Figure 7(e). *Community plantation activities during MCAW 2024 at Taung Gyi township and Kalaw township.*

Figure 7(f). *Youth-led session at MCAW 2023.*

Figures 7(g). *2024 World Cleanup Day Campaigns in collaboration with the schools, Let's Do It Myanmar and M-CAN members.*

Figures 7(h). *2024 World Cleanup Day Campaigns in collaboration with the schools, Let's Do It Myanmar and M-CAN members.*

Figures 7(i). *2024 World Cleanup Day Campaigns in collaboration with the schools, Let's Do It Myanmar and M-CAN members.*

Figure 7(j). *Green skill training for youths conducted in collaboration with M-CAN members.*

Figure 7(k). *Green skill training for youths conducted in collaboration with M-CAN members.*

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Chapter 6:

Nature-based Solutions for Food Security and Community Resilience to Climate Change Impacts: A Case Study of Food Forest in Vietnam

Ho Ngoc Son and Bui Tuan Tuan

CHAPTER HIGHLIGHTS

Vulnerability of ethnic minorities in Vietnam to Climate Change

This section shows ethnic minorities in Vietnam have been experiencing slower income growth.

Food forests for climate adaptation

This section shows food forest development has reduced flood damage, increased crop yield and locals' income.

Challenges of implementing food forests

This section shows limited awareness as well as understanding of nature-based solutions as the main obstacle.

Summary

- **Affiliation:** Thai Nguyen University of Agriculture and Forestry
- **Beneficiaries:** 1.3 million
- **Project Type:** Nature-based solution to climate change
- **Time Scale:** 2022 - 2024
- **Stakeholders involved:** villagers, government officials and local commune leaders
- **Funding:** USD 83000
- **Sponsor:** Asia Pacific Network for Global Change Research
- **Impacts:** Improved food security and climate change adaption among local communities. Scaled up of nature-based solutions/food forest for food security and climate change resilience

Relevance of this chapter to SEACAR's themes

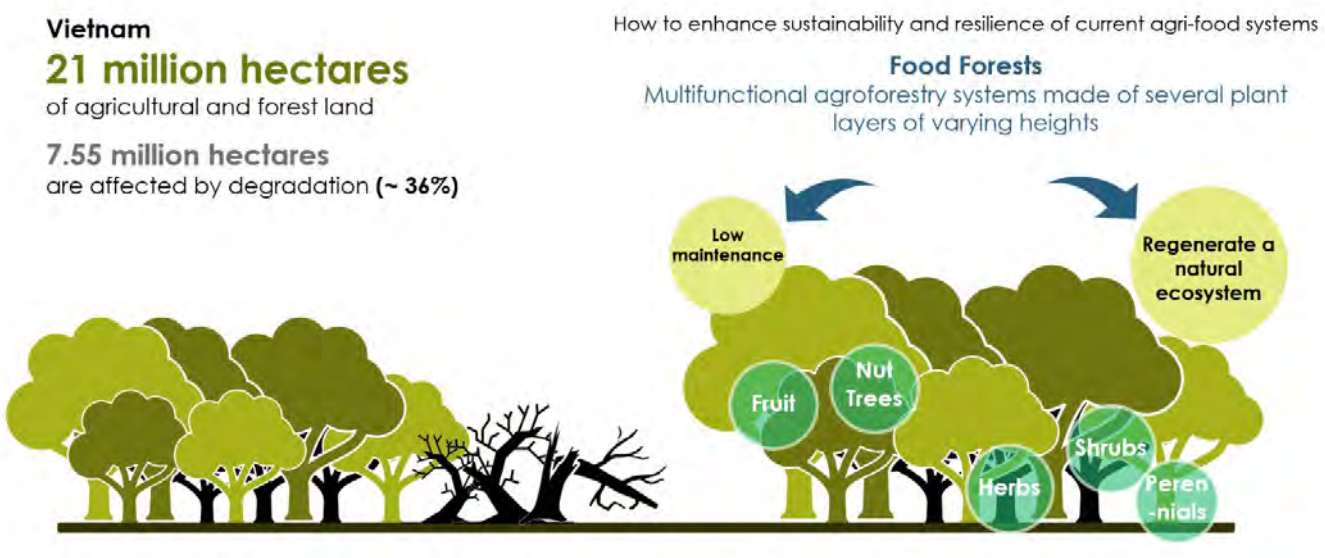
Summary

Climate change and food insecurity are major societal challenges faced by humanity. Food security depends on the sustainable management of healthy ecosystems. The syntropic food forest is a nature-based solution which is low-maintenance. It helps to regenerate a natural ecosystem by combining forest trees with fruit, nut trees, shrubs, herbs and perennials in different layers.

Food forests perform well with suitable or appropriate social-cultural and environmental conditions by building capacity, providing quality food, enhancing biodiversity, and regenerating soil fertility. The development of food forests as nature-based solutions in the project area has contributed to the reduction in crop loss from drought in 2023 between 20-35%, reduced flood damage as a result of tree growing along stream banks, increased crop yield about 25%, and improved income and livelihoods for local villagers from selling food forest products. In addition, the project has raised awareness about climate change impacts and food forests as nature-based solutions for more than 2000 people in the locality.

6.1 Introduction

Food security depends on the sustainable management of healthy ecosystems. However, 50% of the world's agricultural land and marine ecosystems have been degraded (Iseman & Miralles, 2021). For example, Vietnam has approximately 21 million hectares of agricultural and forest land, of which 7.55 million hectares are affected by degradation (Gobin et al., 2020). Current agri-food systems need to become more sustainable and resilient. Nature-based solutions (NbS) offer the potential to achieve this. NbS were endorsed in the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Global Assessment, the Climate Change and Land Report of the Intergovernmental Panel on Climate Change, and the Global



Adaptation Commission Report, and were highlighted as one of nine key action tracks at the 2019 UN Climate Action Summit (Seddon et al., 2020).

Food forests as nature-based solutions, are multifunctional agro-forestry systems made of several plant layers of varying heights, including trees, shrubs, and ground-cover plants (Albrecht & Wiek, 2021). In the late 20th century, alternative agriculture known as syntropic agriculture or food forest which mimics nature in food production was developed by Ernst Götsch. Unlike most modern agricultural systems that rely heavily on fossil fuels, herbicides, pesticides and fertilisers, which are frequently linked to issues such as pesticide accumulation, degradation of soil structure, nitrate leaching and groundwater pollution, the syntropic forest is a NbS which is low-maintenance and helps to regenerate a natural ecosystem by combining forest trees with fruit, nut trees, shrubs, herbs and perennials in different layers. This combination creates a closed circulatory system, which does not require the addition of external fertilisers. The majority of food forests perform well on social-cultural and environmental criteria by building capacity, providing quality food, enhancing biodiversity and regenerating soil fertility. However, the practice and application of food forests are still very limited. Therefore, it is essential to implement measures to promote the development of syntropic food forests, especially in the Mountainous Region of Vietnam where the majority of the population are ethnic minority people.

6.2 Ethnic minority, climate change vulnerability and adaptation

6.2.1 Poverty, food security and vulnerability among ethnic minority people in Vietnam

Viet Nam has achieved a historically rapid reduction of extreme poverty over the past three decades. However, conditions for some groups have lagged. Some remote and mountainous areas, where agricultural productivity has grown more slowly and fewer jobs are available outside of agriculture, have experienced slower income growth than most. Ethnic minorities make up 15% of the total population but accounted for 79% of the poor in 2020. Ethnic minority households living in mountainous and remote areas, especially in the northern mountainous provinces, the Central Highlands and the Northwest mountainous region were more likely to be among the chronically poor (World Bank, 2022).

Vietnam is one of the world's most vulnerable countries to climate change (World Bank, 2021). Climatic stresses most impact vulnerable communities, such as those in the upland areas of the Northern Mountainous Region (NMR) (Son et al., 2019). It is also within NMR where many of the ethnic minorities of the country reside. Since they often live in the more remote areas, their limited access to markets and services adds to their vulnerability.

Key concerns associated with climate change in the NMR of Vietnam are drought in the dry season; soil erosion, landslides, and flooding in the rainy season (summer); and changing temperature regimes such as additional cold spells (Son & Kingsbury, 2020).

Son La is a mountainous province in the Central Northwest of Vietnam. In the past years, Son La has been regularly affected by floods, flash floods, landslides and drought (DONRE, 2019). In addition to climate stresses, the vulnerability of local communities is also determined by other social processes such as poverty, inequality, unsustainable use of natural resources and poor infrastructure.

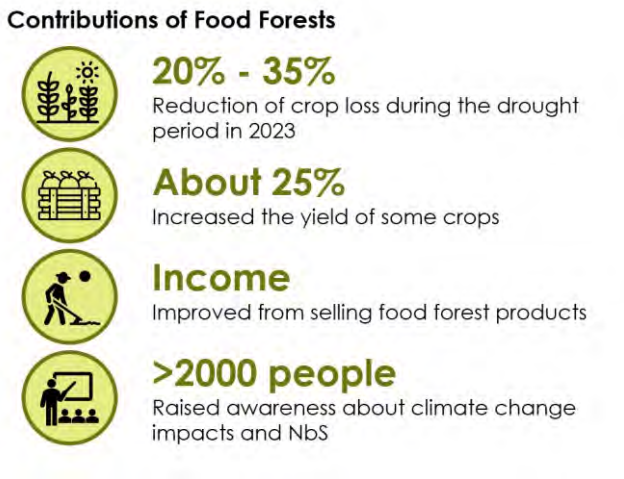
6.2.2 Adaptation to climate change impacts

Livelihood diversification has been the main strategy adopted for living with climate variability and other stressors in the project area. The diversity of the economic portfolio gives greater flexibility to households for adjusting to change. The biophysical factors of the mountainous environment have encouraged the local people to adopt multiple livelihood strategies and a variety of different agricultural production methods to support their subsistence.

Traditional and local knowledge are essential principles for communities to cope with climate variability and change in the project area. For example, local communities were found to use small reservoirs and ponds and created dams to hold water on smaller streams. Villagers used combinations of these measures, often simultaneously. In the case of land management, strategies include manuring, mulching, ploughing in crop residues and fallowing. In crop management, strategies included planting native varieties, timing of planting, crop diversification and crop rotation. In agricultural production, local knowledge-based responses include using local drought-resistant crops and switching from rice to other cash crops. Numerous native crops and animals are cultivated in the home gardens or farms. Native plants and animals support maintaining the natural ecosystem and increasing the resilience to climate change. These examples illustrate the importance of local knowledge and experience for communities in coping with and adapting to climate change impacts.

6.3 Food Forest as a nature-based solution to food security and climate change resilience

In the project area, food forest models have been developed as nature-based solutions (NbS) to food security and climate change resilience. The development of food forests as NbS contributed to the reduction of crop loss by 20 to 35% during the drought period in 2023, reduced flood damage as a result of trees growing on slopes or stream banks, increased the yield of some crops by about 25%, and improved income for local villagers from selling food forest products. In addition, the project has raised awareness about climate change impacts and NbS for more than 2000 people.



The pilot of a food forest that follows the International Union for Conservation of Nature (IUCN) Global Standard for NbS supports both the public and private sectors to reliably scale up NbS to accelerate its transition to a low-carbon future and to assist in the design, implementation, and verification of NbS actions (IUCN, 2020). Some food forests are established to regreen the bare hills while some have been developed to diversify the existing home garden or agro-forestry systems practised by local people.

Common farming systems in the project areas are garden-pond-barn or *Vườn – Ao – Chuồng* (VAC) in Vietnamese, and forest-garden-pond-barn or *Rừng – Vườn – Ao – Chuồng* (RVAC) in Vietnamese (**Figure 1**). The VAC system is a traditional and integrated farming system widely practiced in Vietnam. It combines crop cultivation, aquaculture, and livestock raising within a single household or farming area. This circular approach enables farmers to recycle organic waste, reduce input costs, and diversify their food and income sources. By utilising manure from livestock as fertilizer for crops and using agricultural byproducts to feed fish or animals, the VAC enhances resource efficiency, environmental sustainability, and resilience against climate and market fluctuations. While the RVAC is an expanded version of VAC that integrates forest or agro-forestry components, it is especially relevant in mountainous and upland regions of Vietnam, where forest ecosystems are part of rural livelihoods. In RVAC systems, farmers manage both productive and protective forests alongside agricultural and aquaculture activities, which helps conserve biodiversity, prevent soil erosion, and store carbon. This model strengthens climate adaptation and mitigation while offering diversified income streams from timber, non-timber forest products, and agro-forestry crops.

These existing farming systems are innovative but could be further improved to be more resilient in the context of climate change. Food forests developed in the project area are designed to be multifunctional biodiverse agro-forestry systems consisting of varying plant layers, including trees, shrubs and ground cover.

Figure 1. *Garden-pond-barn practice in Son La province.*

Training on NbS principles and food forest design and implementation has been provided to villagers, government officials and local commune leaders (**Figure 2**). Technical support from the Thai Nguyen University of Agriculture and Forestry has been provided to households who pilot the demonstrations. Today, 59 households in the same village applied NbS principles and practices at their farms in different forms such as mixed farming, vermi-composting or ecological gardens. For example, farmers reported that by applying a circular agriculture model with vermicomposting, animal raising and growing crops, the cost of animal raising was reduced by at least 35% and the revenue from selling agricultural products was increased by 15%. This is due to crops with higher quality produced through this method. The application of these NbS has promoted the development of organic agriculture in the area which facilitates the agri-tourism business and improves livelihoods for local villagers.

Figure 2. *Training on designing and piloting nature-based solutions for local farmers.*

NbS practices and food forests are closely connected with the concept of mixed farming. In the project area, households are supported to adopt mixed farming practices under food forest and agro-forestry models. Particularly, farmers have been taught to intercrop maize and bean, growing red peanuts in the one-crop rice land to adapt to drought and lack of water in the dry season. They also practise rice and duck farming systems. Experts from the Thai Nguyen University of Agriculture and Forestry guided farmers to mix different crops such as shade-tolerant plants growing in the home gardens (**Figure 3**). Mixed farming implies a switch away from mono-crop agriculture to growing a set of interdependent crops where the cultivation of one creates favourable conditions for others. Crop diversity is seen as an effective strategy to improve soil fertility, and enhance the resilience of the production systems. The use of local feed and manure instead of imports and chemical fertilisers can also contribute to the reduction of CO_2 emissions in agriculture. The minimum size for a food forest is 0.5ha in an ecologically rich environment. For a severely impoverished environment, a larger area is recommended.

Figure 3. *Mixed farming practice in Son La province.*

Food forests adopt basic principles of agro-forestry (Albrecht & Wiek, 2021). Agro-forestry, which is tree planting in combination with crops or pastures, is an integral part of the NbS approach. It is well known that tree planting can help restore biodiversity in agricultural landscapes while increasing soil fertility by enhancing the accumulation of organic matter from decaying materials. All households in the project area are practising agro-forestry in different forms and prioritising local varieties and animal breeds for market preferences and biodiversity conservation purposes. The project only provides training for local people to make use of local resources and improve resource use. For example, farmers are trained to intercrop the right species (tolerant crops, nitrogen-fixing crops, medicinal plants) in the home gardens. For forest tree planting, this project supports farmers to grow local species to stabilise stream banks (**Figure 4**) and multipurpose trees such as *Canarium* and *Cinamomum* to maximise the benefits of the agro-forestry systems. These trees provide economic products such as edible fruits (*Canarium*), resins used in medicine or varnish (*Canarium*), and bark or leaves used as spices and essential oils (*Cinnamomum*). Additionally, their timber is valued for furniture or construction. Beyond economic benefits, they offer ecological services, acting as windbreaks, shade trees, and contributing to soil conservation and biodiversity. Their integration into farming systems helps maximise land productivity while supporting both livelihoods and environmental resilience.

Figure 4. *Growing Melia trees to stabilise stream banks.*

6.4. Challenges and opportunities for improvement

6.4.1 Challenges

Limited awareness and understanding of NbS and food forests is the main challenge of this project as they are new concepts for most stakeholders. Limited awareness, understanding and agreement around NbS are barriers to scaling up their use. As argued by Nelson et al. (2020), NbS confront diverse challenges including a lack of awareness; knowledge gaps surrounding applications and effectiveness; insufficient understanding of costs and benefits; diverse stakeholder values and perspectives; and limited policy and economic instruments. Building a common understanding of the nature and value of NbS will be important for scaling up. Other challenges include limited research on NbS effectiveness, scalability, and long-term impacts on ecosystem services and community welfare. Understanding socioeconomic benefits and trade-offs is also crucial for informed decision-making.

6.4.2 Stakeholder engagement and opportunities for improvement

This project empowers farmers, officials and policymakers through capacity building and upscaling of the practices in other villages. The promotion and upscaling of NbS practices are often hindered by the lack of both technical knowledge and market access for produce. Therefore, capacity building for relevant stakeholders, especially local communities is essential. Farmers need to be allowed to experiment with the new practices with technical support. Model farmers have played an important role in encouraging and convincing their fellow farmers to apply and scale up.

The Markets Systems Development approach has been applied in this project. It is crucial for scaling up sustainability and NbS practices. Cooperating with businesses to develop markets for nature-based products to sustain the NbS agricultural production is essential for scaling up the NbS proposed in this project. The project has collaborated with social enterprises working in the area to pilot the selling of given products and services to sustain the nature-based solutions proposed in this project. In this context, 'products' refer to tangible goods such as organic agricultural produce, medicinal herbs, honey, bamboo crafts, or forest-based items that are cultivated or harvested through nature-based practices. 'Services' include ecosystem and cultural services that promote biodiversity conservation and climate adaptation, such as ecotourism experiences, guided forest walks, or traditional farming demonstrations. For example, a local social enterprise like The Northwest Development Cooperation Center (TABA) can generate income by offering biodiversity-based services selling the village's natural beauty, cultural landscapes, and ecological knowledge as experiences to tourists. Visitors may pay for eco-tours, fish stream watching, herbal garden visits, or to learn about sustainable land use practices, thus helping sustain both community livelihoods and the nature-based solutions promoted by the project.

Private sector participation incentivises farmers and local authorities to pilot and upscale NbS practices for sale at higher prices. This is to ensure the sustainability of nature-based production with the participation of the private sector. The project works with authorities and farmers to promote NbS, products and other ecosystem services.

6.5 Conclusions

The project results showed that food forests as a NbS has improved food security and climate change adaptation among local communities. There is a positive acceptance among local people, especially young people to pilot food forest practices. Local people see the benefits of developing food forests when it attracts more tourists to visit their village and experience the beauty of nature. NbS practices such as food forest, organic agriculture, circular agriculture such as vermi-composting, agro-forestry and mixed farming have been applied in the project area to rebuild soil organic

matter, improve soil fertility and increase soil organism biodiversity, creating many environmental and economic benefits to farmers. The promotion of NbS principles and practices could transform agricultural production in the way that can unlock local indigenous resources to develop a local economy where the people can earn livelihoods from their land sustainably.

6.6 Recommendations

The success of promoting NbS in general and food forests, particularly in Son La, for food security and climate change resilience comes from many reasons. The main reason is the application of the market system development approach where climatefriendly enterprises are involved in planning agriculture production and co-investing in production and consumption.

The scale-up of NbS practices benefits from the appreciation of local and indigenous knowledge. NbS practices promoted in this project are not new to local communities. Local communities in the mountainous region of Vietnam in general have adopted many NbS practices to adapt to the changing environment. In this project, we value the local knowledge through their voices and ideas and this gains acceptance from the communities.

In addition, improving the adoption of NbS requires learning from previous experience. Knowledge derived from previous cases would support the identification of the drivers and barriers of NbS implementation in other areas, generate lessons learned, and support upscaling in different regions or areas.

Acknowledgement

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Chapter 7:

Bukit Kiara Federal Park: A Community-Led Green Lung for Critical Ecosystem Services

Kribanandan Gurusamy Naidu

CHAPTER HIGHLIGHTS

Bukit Kiara's River Ecosystem Services

Bukit Kiara plays a vital role in the health of surrounding rivers, providing clean water sources and acting as a natural flood barrier. Its contribution to flood mitigation was evident during the 2021 floods.

Bukit Kiara and Heat Island Effect

The park significantly reduces surrounding temperatures through processes like evapotranspiration and shade provision. This cooling effect improves air quality and encourages outdoor activities, enhancing the overall liveability of the city.

Building a Sustainable Legacy

Protecting Bukit Kiara is crucial for a sustainable future. Community-led action, collaboration between civil society, the private sector and government, is essential to safeguard these vital urban ecosystems.

Summary

- **Affiliation:** Friends of Bukit Kiara
- **Beneficiaries:** Approx 5,000 to 7,000 visitors during a typical weekend and 1,500 to 2,500 persons during the week to Bukit Kiara
- **Project Type:** Urban ecosystem management
- **Time Scale:** 2014 - present
- **Stakeholders involved:** UNDP, local government departments such as The National Landscape Department, NGOs, local communities
- **Funding:** Approx MYR 765,000 (2020-2024)
- **Sponsor:** UNDPSGPGEF, member of parliament for Segambut, corporate and individual donors
- **Impacts:** Scaling up community-based ecosystem service management for climate mitigation, adaptation and resilience in Klang Valley while promoting green lung interconnectivity

Relevance of this chapter to SEACAR's themes

Summary

Bukit Kiara is a federal park partially gazetted in July 2020 with a rich history that was once a commercial plantation. The park which was formally acquired by government for public purpose in the mid-70s was forced to give way to development needs and reduced to only 162 hectares. It was this loss of public land that sowed the seeds of activism within the local community; a movement which was initially led by the Taman Tun Dr Ismail Residents' Association. The Friends of Bukit Kiara (FoBK) which was registered as a society in 2014, has been at the forefront of the Save Bukit Kiara movement since 2001 when it began as a coalition of various community-based and civil society organisations from across the KLPJ conurbation. Some of the work that FoBK has done to protect the Bukit Kiara Federal Park includes policy advocacy, conservation, development of Citizen Science Platforms, and undertaking research studies leading to publications. A community-led green lung initiative was developed to drive nature-based solutions for the Bukit Kiara Federal Park providing multiple ecosystem services that benefit the surrounding communities, such as flood mitigation, water security, biodiversity, and cooling effects.

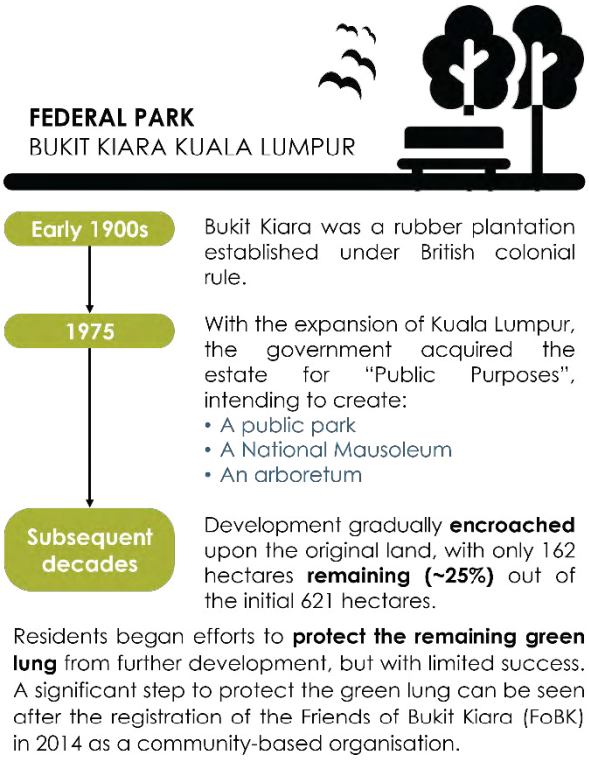
7.1 Introduction and Context Setting

Malaysia, encompassing only a fraction of the world's land mass, is home to some of the oldest and most biologically diverse tropical rainforests. Its varied terrain—from dipterocarp forests and peat swamps to mangroves and limestone ridges—showcases a rich tapestry of tropical biodiversity. Within the greater Kuala Lumpur area, a mix of primary, secondary, and urban forests serve as an ecological crosssection of Malaysia's green spaces. These areas support local wildlife and indigenous communities, functioning as the city's "green lungs" and providing essential environmental services such as air purification, temperature regulation, water catchment, and flood mitigation.

Rapid development in the 1990s transformed Kuala Lumpur, with highways and skyscrapers dramatically altering the skyline overnight. As the urban footprint expanded, Greater Kuala Lumpur emerged as a socioeconomic hub, attracting a steady influx of immigrants from neighbouring states and abroad. This growth, coupled with natural population increase, is projected to elevate the population from an estimated 8.8 million in 2024 to 10 million by 2032, with over 2 million in the federal territory of Kuala Lumpur itself (World Population Review, 2024).

The surrounding communities and natural environments are increasingly vulnerable to the adverse effects of development, such as rising temperatures, droughts, landslides and floods, which are expected to intensify with climate change. The growing population and relentless urban sprawl highlight the urgent need for efficient and scalable urban planning that balances immediate progress with long-term sustainability.

7.2 The Bukit Kiara Federal Park



The Bukit Kiara Federal Park (BK) within the city was originally part of a commercial plantation alienated to British colonial planters at the turn of the last century to cultivate rubber. As part of the expansion of the newly established federal territory of Kuala Lumpur in the early 70s, the government acquired this estate in 1975 'for Public Purposes'. The original stated intention was to establish a public park, a National Mausoleum and an arboretum, but unfortunately, over the years, this original intention gave way to other developments, and what remains today is only 162 Hectares (~ 25%) of the original 621 hectares, with the bulk of the development departing from the public use intent. The area has spawned 25 years of community activism with valiant efforts to stave off unbridled development but with limited progress towards achieving Gazettement for all the efforts. This changed with The Friends of Bukit Kiara (FoBK) being registered as an NGO in 2014. This took a further turn in 2018 when the green lung protection agenda moved from the usual letter writing and appealing to the good consciousness of lawmakers and the local council, to a Klang Valley-wide mobilisation of activism. This included the community using Legal Instruments to stop development as per the landmark decision in the Taman Rimba Kiara legal case widely regarded as a significant victory (April 2023) for not only the community in Kuala Lumpur's Taman Tun Dr Ismail (TTDI) but the country as a whole in terms of planning law. Changes in the political structures of Malaysia following the National Elections in 2018 provided further impetus to make some lasting changes including achieving the gazettement of 2/3 of the green lung i.e., 111 hectares of the 162 hectares of the remaining green lung in 2020. A booklet on BK was also published by FoBK in 2020 and provides a comprehensive summary of the history and biodiversity of the green lung. This charts the associated activism which has led to a vibrant nongovernmental organisation spearheading the protection and engagement agenda (Ong, 2022).

7.3 A Community-led Green Lung Initiative

Increasingly community-led participation is being recognised as instrumental in driving a bottom-up approach to nature-based solutions. The longstanding campaign for protection in BK led by FoBK has mobilised not only residents living in the surrounding township of Taman Tun Dr Ismail but also a network of support from the wider Klang Valley.

Over the years several like-minded community-based organisations (CBOs) and nongovernmental organisations (NGOs) have been bought together for the greater good of BK, expanding the influence for green lung protection to a Klang Valley wide effort. The wider support network has been participating in various ways in policy advocacy, conservation, citizen science platforms, research studies and publications enriching not only the advocacy in BK but also other communities facing similar threats to green lung protection. Since the formative years of FoBK in 2014 and especially since 2018, FoBK has been collaboratively working with various government agencies, the private sector and NGOs. A list of projects funded through the UNDP-GEF Small grants programme undertaken and completed under the Auspices of FoBK between the years 2020 to 2023 and one awarded in 2024 which is ongoing is as follows.

The Magical Mysteries Project

A study of solitary fireflies in BK and the development of a Citizen Science Protocol for continuous data gathering of the health of the firefly population.

Bukit Kiara - A Sanctuary in the City

A compilation of the 35-year history of community action to protect BK and a record of the regeneration of a mono-crop plantation into a biodiverse secondary forest within 50 years of acquisition and the ceasing of all commercial plantation activity.

Scoping and mapping of Green Lungs

A study of communities involved in sustaining green spaces and the green lung protection agenda in the Klang Valley including the development of the idea of green lung connectivity, a precursor to the wider Rantaian Urban Green Spaces (RUGS) project which is currently ongoing.

Legal and Regulatory Advocacy Framework for the Establishment of Buffer Areas

The study suggests ways to enhance protection by leveraging upon existing regulations and defining the need for buffer zones to protect biodiverse green lungs to meet certain defined metrics ensuring a way of regulating urban development which can encroach into the long-term stability of ecosystems.

Bukit Kiara: Leaf a Legacy

A systematic stock-take of tree health in BK and further advancing replanting of dipterocarp & rare species in an urban regenerative forest. The project aims also to produce updated guidelines for tree management practices, establish Citizen Science Protocols for tree- planting/ monitoring efforts and field-testing eco-acoustics to monitor the effectiveness of forest replanting. The overall partners, the key persons involved, and the project outcomes are summarised in **Figure 1**.

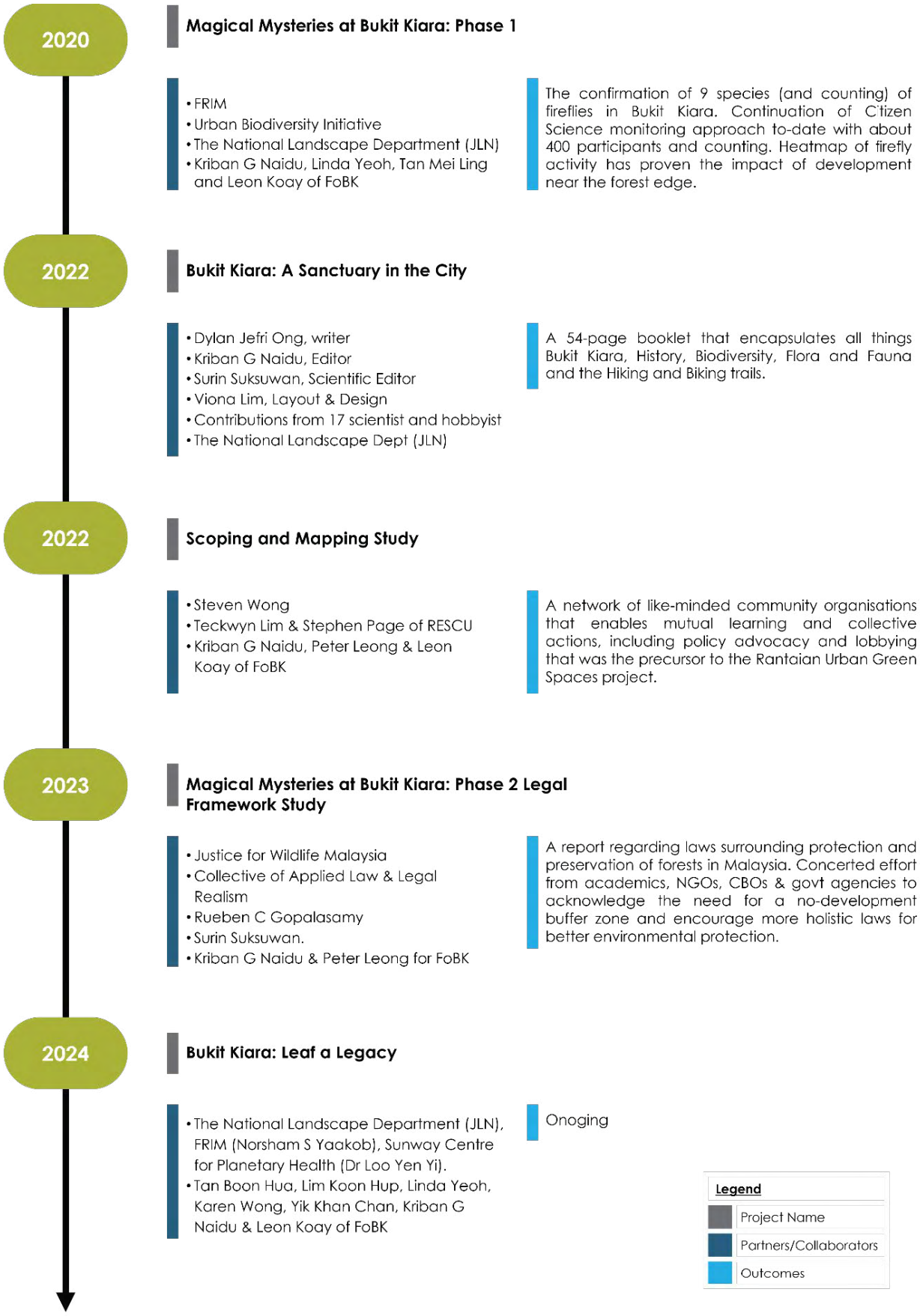


Figure 1. *Summary of FoBK's projects 2020-2025.*

7.4 The Stakeholder Roundtable Engagement

In October 2018 all the key active CBOs, NGOs totalling 22 organisations and the office of the newly elected member of parliament for Segambut were invited to attend and participate in a stakeholder roundtable discussion with two lofty aims (FoBK, 2018; You've Got a Friend in Bukit Kiara, 2022):

- *Networking, information sharing, and Brainstorming*
- *Strengthening our stand as stakeholders by uniting voices*

This meeting was held after the unprecedented changes to the makeup of Government which resulted from the 2018 National elections, whereby the opposition replaced the ruling government for the first time since independence. The preamble to the roundtable invitation stated "As you well know the neighbourhoods surrounding BK have undergone rapid development and this has been exerting pressure on the green lung. Our roundtable discussion will be an opportunity to develop a framework for presentation to government to seek partnership in conserving BK in a way that is most relevant to its stakeholder communities by aligning with the United Nations Sustainable Development Goals (SDGs)." A total of 17 out of the 22 organisations invited participated in the engagement.

The stated Roundtable Discussion Plan/ Objectives were as follows:

- Participating organisations to **share their respective work/experiences** (e.g., challenges faced, success stories/lessons learned) and **perspectives** on issues, pressures and threats impacting BK and other local green lungs in their areas of interest.
- **Brainstorm on strategies and methods** to protect and conserve BK with an inclusive consideration of all stakeholder needs.
- **Consolidate the varied messages** into a unified statement succinctly articulated in terms of the 10 Sustainable Development Goals (out of 17) where it was envisaged that FoBK and its partners can make a difference and produce tangible results to improve people's lives.

The near-term outcome from the roundtable was the creation of a strategic outline for protecting and conserving BK for submission to the newly minted Federal Territories Minister and to the KL City Hall (DBKL). This was to become FoBK's action plan.

This seminal meeting attended by 17 CBOs/ NGOs and several other stake holders including representatives of the Member of Parliament for Segambut provided the overall impetus for the transformation of the Friends of Bukit Kiara (FoBK) over the next seven years, a story still unfolding.

There was keen awareness that larger ecosystems need Increasingly to be managed properly — to avoid sedimentation, prevent flash floods and retain the quality water source for at least 3

rivers originating in the hill as an 'insurance' for the future. There was a need for data generation in relation to BK with the wider issues of biodiversity and the development of citizen science protocols to encourage scientific discourse and publications (FoBK, 2022; Badruddin & Goh, 2022; Goh & Ilyana, 2023). The importance of buffer zones in protecting green lungs was also mooted as part of a comprehensive study as to what was practically possible in the short term and ideas for longer-term considerations in relation to green lung protection for future generations.

In relation to increasing awareness and dialogue on the need for adaptation and resilience in the Southeast Asian region, the protection of BK provides an example of what is possible in two broad areas i.e., in river ecosystem services and management of heat island effects.

7.5 Bukit Kiara and the Overall River Ecosystem Services

The Penchala River is the main water source in BK (SEACAR Alliance Report, 2023). BK also forms part of the sources for Sg Toba and Sg Kayu Ara and as the map clearly illustrates the green lung is next door to the suburb of TTDI housing over 6,000 households with a settled population of over 20,000 people (**Figure 2**).

The average discharge at the source of Sungai Penchala, i.e., on the Keladi, trail the eastern branch of the river was measured as 2390 m^3 per day in year 2023 and it is estimated that up to 5x this amount will form the total discharge if the whole eastern branch is considered.

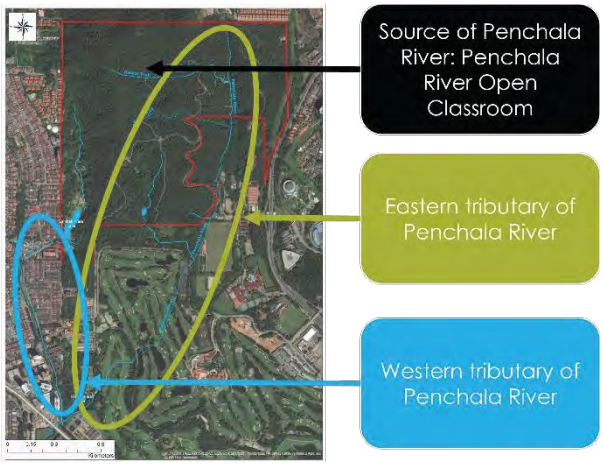


Figure 2. *The source of Penchala River (Courtesy of Global Environment Centre [GEC]).*

This contributes to continuous flow in Sg Penchala especially from the upstream catchment. BK has a protected river system which is of the highest water body class with rich freshwater aquatic life like shrimps, otters and river crabs (Sathis, 2020). These are all good biological indicators of water quality.

BK provides key ecological functions and services related to flood mitigation. During the 1 in-100-year storm in Malaysia in December 2021 leading to the worst case flooding the nation has seen, the surrounding leafy neighbourhood of TTDI adjacent to the green lung was spared any major mishap even though the storm drains which were built as part of the infrastructure of the township in the 1980s collapsed in part due to the ferocity of the water flows. There is no doubt that if not for BK providing the natural absorption capacity for the rains, the whole of the TTDI neighbourhood would have been submerged.

Concerns for flooding in the country are being continually highlighted and as recently as February 2024 significant flooding around the Segambut area north of BK was reported with huge losses and the associated government expense involved with compensation (**Figure 3**). The Deputy Prime Minister has reported that RM7.9 billion (USD 1.77 billion) was lost between 2021-2023 due to floods. In the face of increasing extreme weather incidents due to climate change, Bukit Kiara provides critical services to protect residents from severe impacts.

The watershed service value offered by BK has not been studied extensively. The limited studies conducted thus far have primarily focused on water quality monitoring and hydrology within specific stretches of BK, despite its status as a Class I river and its vital role as a natural reservoir and sponge for flood control. A detailed study is warranted, to be urgently carried out to emphasise and document the importance of BK in managing the urban water cycle. However, it is clear that as long as the green lung is in place there is a lower risk of flooding from the ecosystem services that is provided.

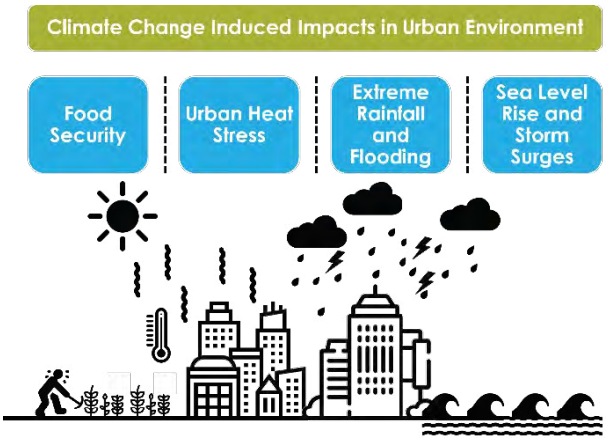
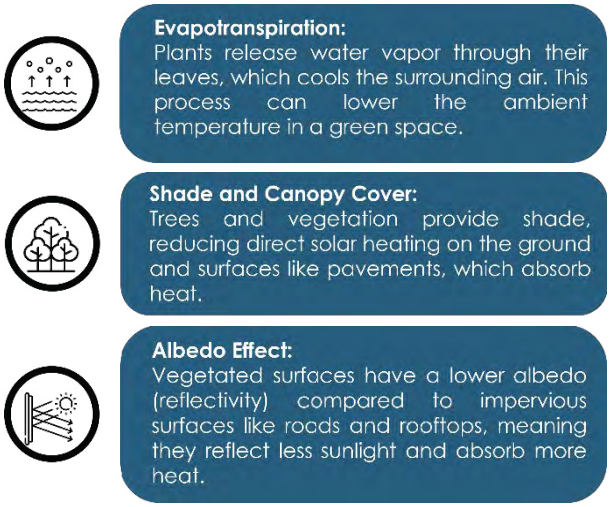


Figure 3. *A view of Jalan Segambut Dalam on Feb 24, after an hour-long downpour caused Sungai Keroh (beside the houses) to overflow.*

7.6 Bukit Kiara and the Heat Island Effect - Temperature Reduction in Green Spaces

In tropical cities like Kuala Lumpur, where temperatures often reach **30–35°C** (86–95°F) or higher during the day, green spaces can significantly mitigate heat stress. The cooling effects of green lungs can be attributed to several factors:



Research in tropical cities, including Kuala Lumpur, suggests that **urban green spaces** can lower surrounding temperatures by **2°C to 4°C (3.6°F to 7.2°F)** or more. Some studies and urban planning reports indicate higher temperature reductions in localised areas, especially where the density of vegetation is high.

Green lungs also **improve air quality**, making it easier for people to breathe and reduce the risk of heat-related respiratory issues. Access to green spaces encourages **physical activity** like walking or jogging in cooler conditions, which has positive health benefits, especially during periods of high heat.

Urban green spaces like BK provide these services and their protection is instrumental in feeding into the National Adaptation Plan (NAP) and providing resilience to communities. Protecting and enhancing these spaces are critical to achieving Malaysia's climate adaptation targets.

7.7 Conclusion: Building a Sustainable Legacy for the Future

This is a pivotal moment for the greater Klang Valley and Malaysia, as a paradigm shift to sustainable and conservation-focused development will safeguard the future of the next generation. It will also position the city to become a leading model of liveability for the region and beyond. The mobilisation of communities is the key to achieving this agenda.

As population pressures and urban expansion continue, the need for sustainable, community-led action is more urgent than ever. Protecting green lungs like BK is not just about preserving trees or landscapes; it's about safeguarding the future of our cities and planet. It's about ensuring that future generations inherit not just a functional urban environment, but also a thriving natural sanctuary, a place to reconnect with nature amidst the city's fast-moving pace.

Communities can, and must, be the stewards of their environment. The story of BK shows that even in the face of development pressures and environmental challenges, collective action can carve out spaces of hope and sustainability—turning potential loss into a legacy of green, vibrant life. A lot more needs to be done but it is heartening to note that the pathway to protection has begun at BK, and the community has made a firm stand. The way forward requires a concerted coming together of civil society, the private sector and ultimately the government to secure a future for the common good.

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SECTION 3

Knowledge for Action

Chapter 8:

GIS Tools for Supporting Spatial Planning of Urban Nature-Based Solutions

Alex M. Lechner

CHAPTER HIGHLIGHTS

Nature-based solutions in urban areas

Urban ecosystem services have deteriorated due to rapid urbanisation and nature-based solutions are emerging as one of its key solutions.

Tools for integrating urban Nature-based solutions

The tools include ecological connectivity modelling, Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) and Social Values for Ecosystem Services (SolVES).

Ways to unlock the tools' full potential

Continuous investment in data collection, advanced GIS technology and capacity-building initiatives across SEA are needed to improve the inclusiveness of urban planning.

Summary

- **Affiliation:** Monash University Indonesia and University of Nottingham Malaysia
- **Beneficiaries:** Around 8.8 million
- **Project Type:** Research
- **Time Scale:** 2020 - 2023
- **Stakeholders involved:** Malaysian academic experts (urban and ecological), local communities
- **Funding:** NA
- **Sponsor:** University of Nottingham Malaysia and Strategic Research Council (SRC) established within the Research Council of Finland (grant no. 358365, WP4 grant no. 35381)
- **Impacts:** One of the first applications of ecosystem services, PPGIS and connectivity modelling to urban environments in Malaysia and Southeast Asia. These tools represent modern, global leading practice applications.

Relevance of this chapter to SEACAR's themes

Summary

Rapid urbanisation in Southeast Asia has significantly impacted natural ecosystems, leading to habitat loss, and fragmentation, affecting blue and green spaces that provide crucial ecosystem services for climate resilience. Urban nature-based Solutions (NbS), which leverage green and blue infrastructure, offer a sustainable approach to mitigate these impacts by delivering multiple ecosystem benefits for climate change adaptation, including temperature regulation, flood mitigation, and enhanced biodiversity. This paper examines three GIS-based modelling approaches — Ecological Connectivity, Urban Ecosystem Services (UES), and Public Participatory GIS (PPGIS) — for optimising NbS deployment in urban planning. Using case studies from Greater Kuala Lumpur, the research demonstrates the potential of these models to provide spatially explicit data to urban planners, enabling targeted interventions and community-inclusive planning. The paper calls for a multidisciplinary approach to urban planning that combines GIS tools to address both ecological and social dimensions of urbanisation. Increased investment in GIS capacity-building and data integration is essential to embed these methods within Southeast Asia's urban planning frameworks, enhancing resilience against climate change and supporting sustainable development goals. Further work is needed to develop region-specific approaches that effectively model climate change impacts and adaptation measures in Southeast Asia's unique urban landscapes.

8.1 Introduction and Context Setting

Rapid urbanisation in Southeast Asia has placed immense pressure on natural ecosystems, leading to the degradation of ecosystem services (Lechner et al., 2020; Lechner et al., 2021). The region's urban landscapes are undergoing extensive land-use changes, transforming natural and semi-natural areas into built environments. This trend has led to habitat loss, fragmentation, degradation and the reduction of ecological connectivity for blue and green spaces, such as parks, urban forests and riparian corridors (i.e., vegetated areas along riverbanks), which are crucial for urban ecosystem functioning and climate resilience. These blue and green spaces also provide essential ecosystem services for people living in cities such as temperature regulation, flood mitigation and recreational opportunities and are crucial for climate change adaptation (Lechner et al., 2021). However, as urban expansion continues, these services are increasingly under threat. Many of these urban impacts are further exacerbated by climate change in particular urban heat and hydro-meteorological disasters such as flooding.

To address the impacts of urbanisation, urban Nature-based Solutions (NbS) are emerging as a key approach to restoring urban resilience through the provision of ecosystem services. While grey infrastructure solutions to many of these urban challenges such as the construction of dams to reduce flooding commonly provide a single service, green and blue infrastructure developed by NbS provide

co-benefits in terms of multiple ecosystem services and additionally support urban biodiversity. These ecosystem services support climate change adaptation by reducing urban climate risks and impacts. Increased hydro-meteorological hazards, such as flooding associated with climate change, can be managed through wetlands, green roofs, riparian buffers, and permeable surfaces. Rising urban temperatures can be mitigated by tree shading and green corridors, while carbon sequestration in vegetation contributes to climate change mitigation. Within this context, GIS-based tools, are crucial for the effective deployment of NbS, through the quantification of ecological processes and services, and potential benefits. These tools also provide spatially explicit mapping data which can be integrated readily with existing urban planning approaches.

In this chapter, we introduce three modelling approaches and tools which represent three key dimensions of urban nature and ecosystem services that underpin the application of urban NbS. The three approaches, all conducted in Greater Kuala Lumpur Malaysia, are (**Figure 1-3**):

1) Ecological Connectivity modelling using the Graphab least-cost path and graph metric analysis connectivity software (https://sourcesup.renater.fr/www/graphab/; Foltête et al. 2012) (**Figure 1**);

2) Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) for modelling a range of ecosystem services using process-based spatially explicit biophysical models (https://naturalcapitalproject.stanford.edu/software/invest; Sharp et al. 2020) (**Figure 2**);

3) Social Values for Ecosystem Services (SolVES) tool (https://solves.cr.usgs; Sherrouse et al., 2022; 2011)) in combination with Maptionnaire (https://www.maptionnaire.com/) an online Citizen Engagement platform to map the spatial distribution of social values a tool for analysing PPGIS data (**Figure 3**).

8.2 Identification of Key Issues

There are a range of ways in which the impact of rapid urbanisation and land use changes in Southeast Asia, needs to be considered when they are addressed with NbS (Lechner et al. 2020). Firstly, ecological connectivity plays a crucial role in sustaining urban biodiversity, especially in regions experiencing rapid urbanisation like Southeast Asia. Fragmentation of habitats caused by urban development restricts wildlife movement and increases the risk of local extinction. Green and blue spaces in cities are often isolated by buildings and roads, which impedes the movement of animals between patches of urban habitat, leading to population decline and eventually the loss of biodiversity. In the long term, connected habitats enable species to adapt to climate change by migrating to areas with more favourable climatic conditions.

Wildlifeconnectivitymodelling

Outputs: Maps of urban green space connectivity and their importance for biodiversity

Inputs: Land cover maps derived from remote sensing and harmonisation with other data including Open Street maps and DWI; and species movement data such as maximum dispersal distance from experts

Methods: Least-cost paths to calculate wildlife linkages between green spaces and graph metrics to identify the importance of patches and links for connecting the whole landscape

Software: Graphab

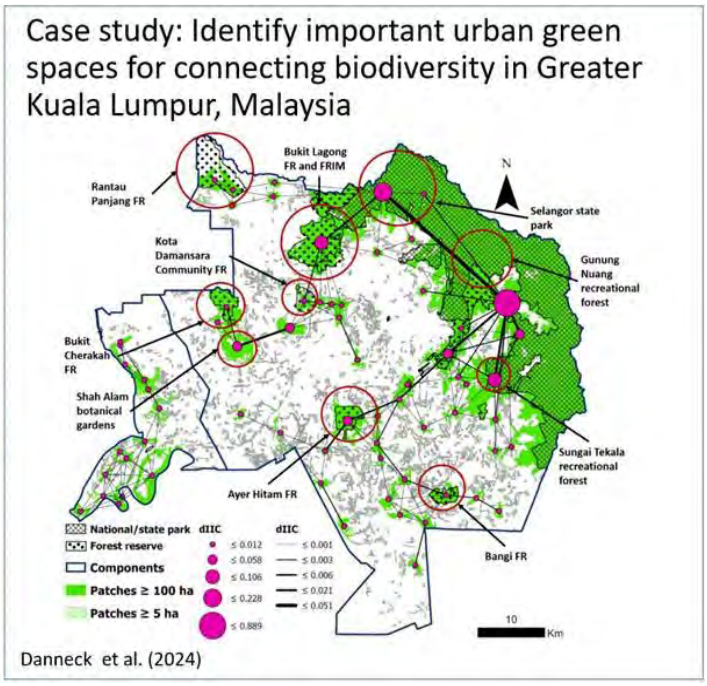


Figure 1. *Wildlife connectivity modelling case study from Danneck et al. (2024), for Greater Kuala Lumpur, summarising approach, outputs, inputs, methods and software used. dIIC values describe the importance of patches and links between patches for connecting wildlife in the landscape.*

Urban Ecosystem Services mapping (UES) and modelling and Multi criteria analysis (MCA)

Outputs: Maps of realised and hotspots of UES and priority areas for management actions

Inputs: Spatial data such as land cover, population density, and DEM; and biophysical parameters from literature from soil to climatei.e., evapotranspiration

Methods: Common process based models biophysical models (i.e., Universal Soil Loss Equation) to map ES, GIS hotspot analysis methods and MCA for suitability map

Software: InVest for UES and GIS software for MCA

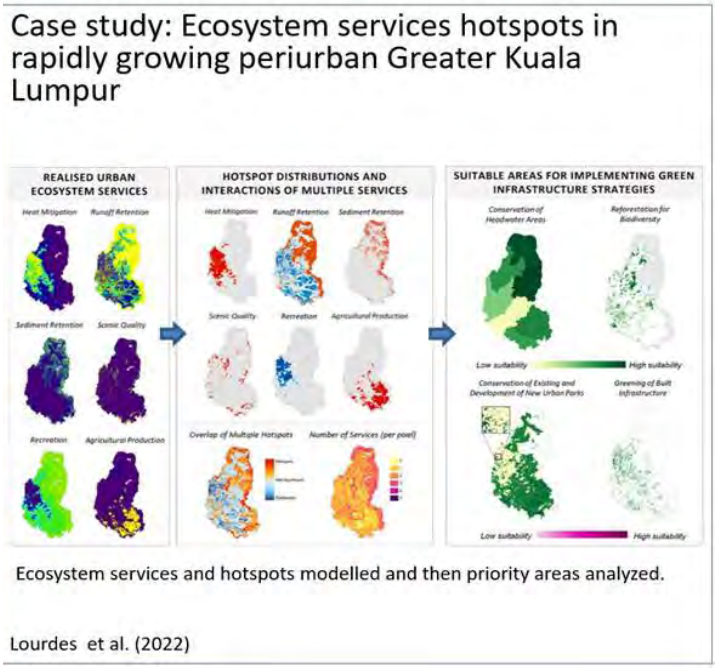


Figure 2. *Urban ecosystem services (UES) mapping case study of the Upper Langat catchment in peri-urban Greater Kuala Lumpur from Lourdes et al. (2022), summarising the approach, outputs, inputs, methods and software used. Six UES —heat mitigation, sediment retention, scenic quality, recreation, and agricultural production—were initially modelled. Following this, hotspots of multiple UES were identified, and finally, suitable areas for implementing green infrastructure strategies were pinpointed through multi-criteria analysis.*

Mapping social values for ecosystem services and development preference using Public Participation GIS (PPGIS)

Outputs: Spatial maps highlighting areas of social value distribution and zones of spatial agreement and disagreement among community groups

Inputs: Data from an online PPGIS survey and land cover information

Methods: Data gathered with questionnaire,social values analysed using SoLVES for 10 social values and 2 development preferences and areas of agreement/conflict indentified using cluster analysis

Software: Maptionnaire for social survey and SoLVES for mapping social values for ecosystem services

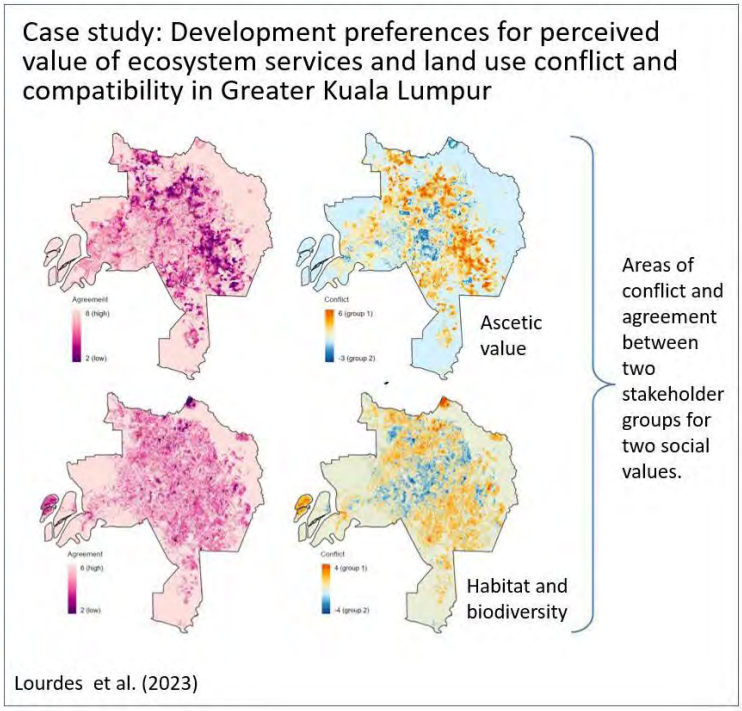


Figure 3. *Mapping social values for ecosystems and development preferences cast study from Lourdes et al. (2023) in Greater Kuala Lumpur summarising the approach, outputs, inputs, methods and software used. Areas of conflict and agreement regarding social values for ecosystem services and urban development were mapped for two stakeholder groups: one representing pro-environmental interests and the other advocating for pro-development perspectives.*

Urban ecosystem services provide multiple benefits that improve residents' quality of life and help mitigate environmental challenges arising from rapid urbanisation. Green and blue infrastructure, such as parks, forests, and water bodies, offer cooling effects, noise reduction, reduce stormwater runoff, flooding and erosion, enhance aesthetic and recreational opportunities, sequester carbon and support biodiversity. With the intensifying impacts of climate change—such as rising temperatures, increased flooding, and more frequent extreme weather events, particularly in Southeast Asia—ecosystem services in cities have an even more crucial role in climate change adaptation and to a lesser extent climate change mitigation through the sequestration of carbon in urban ecosystems.

While wildlife connectivity and urban ecosystem services are often modelled using process-based approaches driven by experts; these methods may overlook community preferences for the management and valuation of urban blue-green infrastructure. In contrast, Public Participatory Geographic Information Systems (PPGIS) can serve as a valuable tool for engaging community stakeholders and promoting a planning process that aligns with local needs and priorities. For instance, PPGIS can identify areas valued by communities for biodiversity through an online mapping social survey, which may differ from locations selected solely through expert-driven biophysical ecosystem services modelling. By integrating local knowledge, values, and preferences through participatory mapping, PPGIS supports more inclusive and responsive

urban planning decisions. These models can generate critical data that can offer urban planners' valuable insights into where NbS interventions could be prioritised.

8.3 Analysis of Existing Adaptation Efforts

Across Southeast Asia, mainstream urban planning rarely incorporates ecosystem service and connectivity modelling and PPGIS approaches, with examples being scarce (Lourdes et al., 2022; Lechner et al., 2020). Nature-based solutions (NbS) are often considered only at site-specific levels or in regional assessments that lack the resolution needed for detailed urban planning and design. Even where relevant data exists, much of it remains within academia or inaccessible, contrasting sharply with the integration seen in the Global North. Lourdes et al.'s (2021) review highlighted that most ecosystem service modelling in Southeast Asia tends to focus on broad regional assessments rather than planning-specific applications.

In comparison, cities in the Global North have made more consistent efforts to integrate NbS and urban ecosystem services into planning, albeit with variable levels of success (Lechner et al., 2020). In Europe, NbS approaches have been widely implemented through numerous research and demonstration projects. NbS approaches in Europe demonstrate the potential to enhance urban resilience by integrating ecosystem services into city planning, a practice that remains underutilised in Southeast Asia. The three case studies, Lourdes et al. (2022, 2023) and Danneck (2024) are pioneering examples of urban modelling approaches for connectivity, urban ecosystem services and PPGIS in Malaysia and Southeast Asia (**Figure 13**).

8.4 Barriers and Challenges

The technical complexity and resource requirements of developing and implementing GIS-based tools pose significant challenges, particularly in low- and middle-income countries in Southeast Asia. In these regions, financial, technical and human resources are often limited. Additionally, the availability of expertise in GIS and ecosystem modelling is limited, which presents another barrier to the effective development of tools, and application and understanding of such data.

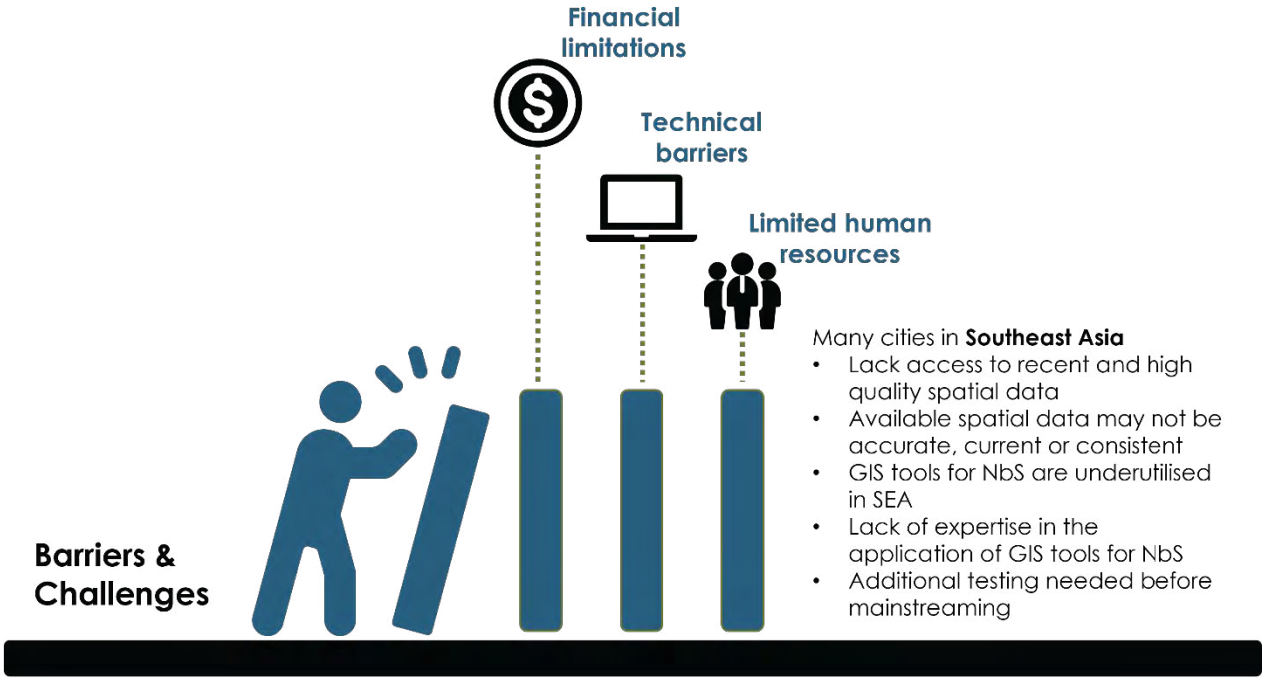
Many cities in Southeast Asia lack access to recent and high-quality spatial data, which impedes their ability to conduct detailed analyses. For example, in each of the three case studies, the project team developed a high-resolution land cover map detailing roads, agriculture, forests and other important land uses, which served as a foundational layer for applying the modelling approaches. Among the three approaches, ecosystem service modelling was the most complex, demanding various additional data inputs (Lourdes et al., 2022). For instance, calculating heat mitigation required estimates of evapotranspiration, shade, and albedo, while the sedimentation model needed parameterisation of the Universal Soil Loss Equation. Even when spatial data is available in Southeast Asia, it may not be accurate, current or consistent,

creating additional difficulties in capturing the rapid changes in urban landscapes.

8.5 Opportunities for Improvement

Traditional urban planning approaches in Southeast Asia often fall short in several ways: they typically overlook the spatial distribution of urban biodiversity and ecosystem services, fail to engage the public effectively, and rely on top-down decision-making processes that may not consider the needs of local communities. This lack of public engagement leads to decisions that are poorly informed by local contexts and may even exacerbate environmental issues. The limited integration of ecosystem services and biodiversity considerations in urban planning frameworks also hinders efforts to improve urban resilience. Addressing these challenges necessitates adopting GIS tools that can map, model, and incorporate ecosystem services and connectivity into planning processes, while supporting community participation, helping to create urban landscapes that are both ecologically viable and socially inclusive.

Integration of connectivity, urban ES and PPGIS into the urban decision-making framework remains limited in the region and was not fully realised in these studies. Additionally, while these studies implicitly address climate adaptation challenges, such as identifying priority areas for green space restoration to mitigate urban heat (Lourdes et al., 2022), there is a need for more explicit consideration of climate change issues. Future research could draw on European studies, like Raymond et al. (2023) in Helsinki, which examined spatial relationships between biophysical and social values for carbon sequestration and biodiversity. Using PPGIS, CO_2 flux modelling and biodiversity assessments, they identified areas in the city which were win-wins for carbon mitigation and



biodiversity. Finally, there is a need to develop methods for modelling future climate change and urban growth scenarios, as the biophysical and social characteristics of cities are likely to evolve. Currently, few models incorporate these dynamic factors, both in Southeast Asia and globally. For instance, the flood mitigation model by Lourdes et al. (2022) could be adapted to assess a range of rainfall scenarios under different climate change and urban development conditions.

8.6 Importance of Stakeholder Engagement

Stakeholder engagement is important and this was achieved in our work, particularly through undertaking a PPGIS social survey of 595 residents of Greater Kuala Lumpur to map resident social values for ecosystem services (Lourdes et al., 2024). PPGIS allowing residents to contribute spatial data on their preferences, perceptions, and priorities, thus making the planning process more inclusive, transparent and equitable. In Southeast Asia, where urban planning has traditionally followed a top-down model, the adoption of PPGIS could see a shift towards a norm or approach that values local knowledge and prioritises community wellbeing. Such inclusive engagement not only strengthens the legitimacy of planning decisions but also enhances the likelihood that NbS projects will be accepted, maintained, and supported by the community.

8.7 Case Studies and Best Practices

The integration of various modelling approaches offers a pathway toward more holistic and effective urban planning that considers both ecological and social dimensions. This integration allows urban planners to adopt a multifaceted approach, ensuring that both human and environmental needs are addressed in spatial planning. The three studies in Greater Kuala Lumpur illustrate how data-driven spatial planning could guide targeted interventions. Such modelling can identify the most significant benefits, demonstrating the value of a systematic approach to NbS planning. In Greater Kuala Lumpur, for example, PPGIS was used to map social values and preferences, revealing areas of agreement as well as potential land-use conflicts, which can inform balanced development decisions and ensure that diverse community needs are considered.

Notably, the models applied in the Greater Kuala Lumpur case studies utilised well-established approaches and software commonly used in the Global North, including Graphab for connectivity (Foltête et al., 2012), InVEST for ecosystem services (Sharp et al., 2020), and SolVES (Social Values for Ecosystem Services) with Maptionnaire for PPGIS (Sherrouse et al., 2022; 2011). Each of these tools has been widely recognised for modelling social and ecological values, yet they have rarely been applied in Southeast Asia, making these studies some of the few examples in the region. Rather than developing new methodologies, the emphasis should be on adapting these proven approaches to the unique contexts

of Southeast Asia. **Figure 1** outlines the key input datasets and parameters required to run these models. There is also significant potential for integration across Southeast Asia, as countries share common tropical ecosystems, climate, and environmental conditions, providing opportunities for a collective approach to developing spatial data and parameterising models (Lechner et al., 2020).

8.8 Call to Action

Urban planners and policymakers are encouraged to adopt an integrated, multidisciplinary approach that combines GIS approaches to optimise the impact of NbS. By merging these tools, urban planning can effectively address the ecological, social, and spatial dimensions of urban development, thereby creating cities that are more resilient to climate change and capable of providing a high quality of life for residents. Continuous investment in data collection, advanced GIS technology, and capacity-building initiatives across the region is essential to improve the accuracy, robustness, and usability of the data, and inclusiveness of urban planning processes. Finally, these integrated approaches should be standardised within urban planning frameworks, across cities in Southeast Asia.

8.9 Acknowledgment

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Chapter 9:

Connecting Urban Habitat in Tangerang Selatan to Support Biodiversity

Risty Khoirunisa, Eka Permanasari, Muhamad Risqi U. Saputra, Maria Hällfors and Alex M. Lechner

CHAPTER HIGHLIGHTS

Urbanisation in Tangerang Selatan

Rapid urban transformation resulting in more intense floods and heatwaves and biodiversity loss.

Current challenges in urban green connectivity

Many local residents are unaware of nature's contributions to people. Additionally, existing zoning practices do not prioritise biodiversity and regulations on green spaces are poorly monitored.

Keys to conservation and climate resilience

Participatory urban planning, integration of ecological considerations into land-use planning, investment in green infrastructure and public-private partnerships are essential.

Summary

- **Affiliation:** Monash University Indonesia
- **Beneficiaries:** Over 2 million residents (growth rate 3.04% per annum)
- **Project Type:** Research
- **Time Scale:** 2023 - 2026
- **Stakeholders involved:** Academia, local government, urban design associations and urban design companies
- **Funding:** USD 73,676 (EUR 70,000)
- **Sponsor:** Finnish Strategic Research Council
- **Impacts:** New insights into planning for biodiversity in Indonesian urban environments. Emphasise the importance of urban biodiversity to young scientists, planners and policy makers

Relevance of this chapter to SEACAR's themes

Summary

Urbanisation poses significant challenges to biodiversity, especially in rapidly developing Southeast Asian cities like Tangerang Selatan, Indonesia. As urban expansion fragments green spaces, maintaining ecological connectivity becomes essential for biodiversity. This study investigates the impact of rapid urban growth on biodiversity and proposes strategies to foster ecological and climate resilience in cities. Using connectivity modelling and movement analysis, the research identifies key challenges, including habitat fragmentation and increased species loss caused by land transformation that disrupts animal movement. Additionally, it examines shortcomings in policies that often overlook the integration of urban planning with biodiversity conservation. To address these issues, the study advocates for nature-based solutions implementation and cohesive policy frameworks that support biodiversity conservation in cities. By embedding ecological considerations such as green corridors and habitat connectivity into urban development, this approach aims to protect local ecosystems, sustaining ecosystem services to enhance urban resilience, which are crucial for climate adaptation.

9.1 Introduction and Context Setting

Urbanisation is a global phenomenon that has transformed landscapes, particularly in rapidly developing regions such as Southeast Asia (Lourdes et al., 2021). Indonesia is not an exception, especially growing cities such as Greater Jakarta. The continuous expansion of urban areas remains the most significant threat to biodiversity (Wood et al., 2022). As development disrupts natural habitats, fragmentation of green spaces intensifies, making it increasingly difficult to maintain connected landscapes for urban species.

Tangerang Selatan, a rapidly urbanising city on the outskirts of Jakarta, Indonesia, exemplifies the conflict between urban development and the need for ecological preservation. Home to over 1.3 million people (BPS, *Kota Tangerang Selatan dalam Angka*, 2023), this peri-urban area is undergoing significant transformation as rural landscapes give way to commercial and residential developments driven by private sectors. Although this urban expansion contributes to economic vitality, it also threatens biodiversity, particularly through habitat fragmentation. Beyond biodiversity loss, the rapid land transformation will lead to other challenges intensified by climate change including Urban Heat Island (UHI) effect, and an increased risk of urban flooding (Khoirunisa & Yuwono, 2023).

In rapidly urbanising regions like Tangerang Selatan, promoting ecological connectivity—facilitating the movement of species across landscapes—is crucial for preventing local extinctions and conserving biodiversity (Lechner et al., 2017; Danneck et al., 2023). Strengthening ecological connectivity can also help cities become more resilient to climate change because the ecosystem services provided by green spaces include mitigating Urban Heat Island (UHI) effect and urban flooding and supporting social cohesion as well as mental health. By emphasising ecological connectivity, cities can identify important

green spaces for conservation, create wildlife corridors that allow species to thrive, and sustain urban ecosystem services.

Benefits of strengthening ecological connectivity.

However, only a handful of studies focus on ecological connectivity in Indonesian cities and Southeast Asia, with none providing a detailed analysis of green corridor functionality or species-specific movement patterns. This lack of data represents a significant barrier to informed decision-making in urban planning and conservation efforts.

Recognising this need, Monash University Indonesia, in collaboration with the Finnish Environment Institute (Syke), under the MUST (Multispecies Justice Transition; https://mustproject.fi/home/), project funded by the Finnish Strategic Research Council, has undertaken a preliminary ecological connectivity model of Tangerang Selatan. The model aims to provide insights to guide urban planning and conservation efforts, balancing development with biodiversity and climate resilience.

9.2 Identification of Key Issues

Several critical challenges in Tangerang Selatan related to urban biodiversity include habitat fragmentation, loss of green spaces, increased species vulnerability, and insufficient integration of urban planning with biodiversity conservation plans to support climate resilience.

First, habitat fragmentation is a major concern (Lechner et al., 2020). The rapid development of commercial and residential areas has disrupted habitat continuity, fractured green spaces and impeded species movement (Luna et al., 2020; Wood et al., 2022). This fragmentation reduces genetic diversity, making species more vulnerable to diseases and environmental changes (Lechner et al., 2020) and ultimately disrupts the provision of urban ecosystem services (Lourdes et al., 2021) such as the regulation of urban climate and water cycle. These disruptions can increase cities' vulnerability to environmental changes driven by climate change. The ecological dynamics of native fauna species, such as *Lonchura leucogastroides* (Javan Munia) and *Pycnonotus goiavier* (yellow-vented bulbul), have also been affected (Nor et al., 2017; Izzati et al., 2019).

Our connectivity modelling described in **Figure 1** shows the connectivity between habitat patches for small and medium terrestrial mammal subgroups, using Graphab, an ecological connectivity modelling software, and the ecological characteristics identified in a previous connectivity modelling study (Danneck

et al., 2023). For small terrestrial mammals, such as plantation squirrels, the minimum patch size is set at 5 hectares, with a maximum dispersal distance of 1000 metres. In contrast, medium terrestrial mammals, such as palm civets, require a minimum patch size of 100 hectares and a maximum dispersal distance of 5000 metres. This model highlights the distinct spatial needs of each subgroup, emphasising the importance of adequate patch size and connectivity between patches to support species movement and habitat resilience. The delta Integral Index of Connectivity (dIIC) value was used to quantify and analyse connectivity. The size of the purple circles represents the relative importance of each patch, with the thickness of black lines indicating connection strength between patches (**Figure 1**). Red lines denote optimal (least-cost) paths that animals are likely to take between two patches. In the small terrestrial mammal subgroup, fragmentation is represented by the component boundaries which show that certain patches and groups of patches are not connected. In contrast, patches for medium terrestrial mammals are all connected, however, as larger patches (exceeding 100 hectares) are scarce in Tangerang Selatan, there is very little habitat available (see **Figure 1**).

Figure 2 visualises species movement within the urban matrix between habitat patches, with red zones marking "pinch points" where infrastructure like roads and buildings restrict species movement, restricted movement heighten the risk of mortality for species that are shifting around in urban landscapes.

Second, urban expansion driven by private development and economic interests has accelerated the loss of green particularly affecting smaller terrestrial mammal subgroups. These areas of spaces in Tangerang Selatan.

Issues of Urban Biodiversity in Tangerang Selatan

- Disrupted habitat continuity
- Fracturing green spaces
- Impeding species movement
- Reduces genetic diversity
- Increase vulnerability of species to diseases and environmental changes

- Accelerated loss of green spaces
- Conversion of green areas into roads, industrial sites and residential buildings
- Increase species mortality risks from movement in urban matrix between green spaces

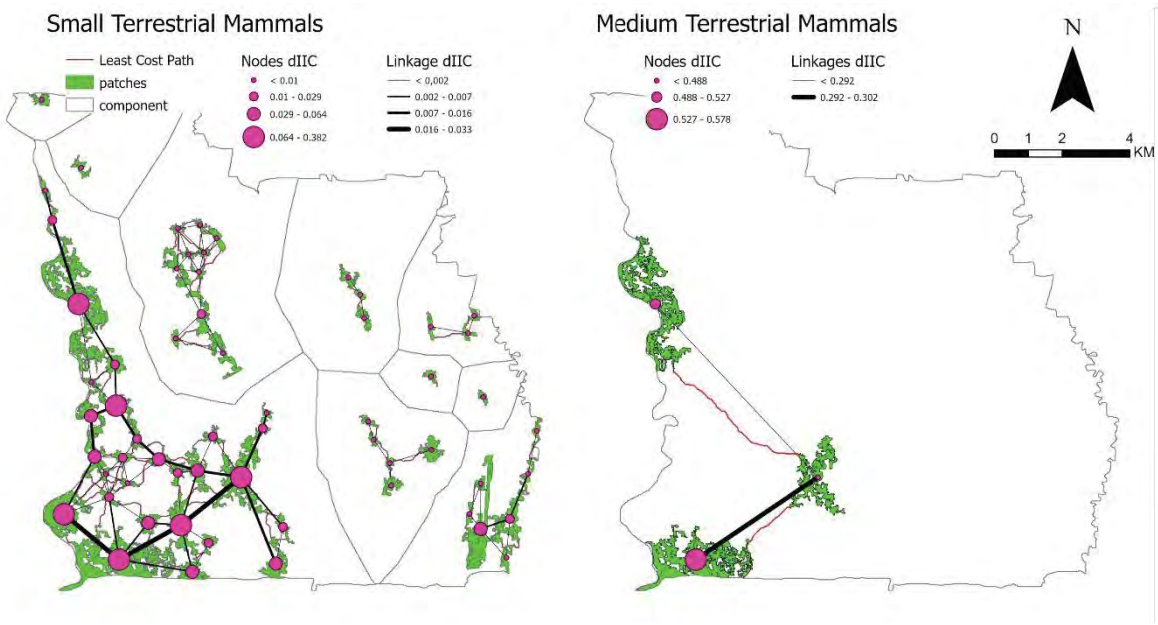


Figure 1. *The visualisation shows habitat connectivity between patches for small and medium terrestrial mammals in Tangerang Selatan, Indonesia. The red box highlights an example of a fragmented habitat area.*

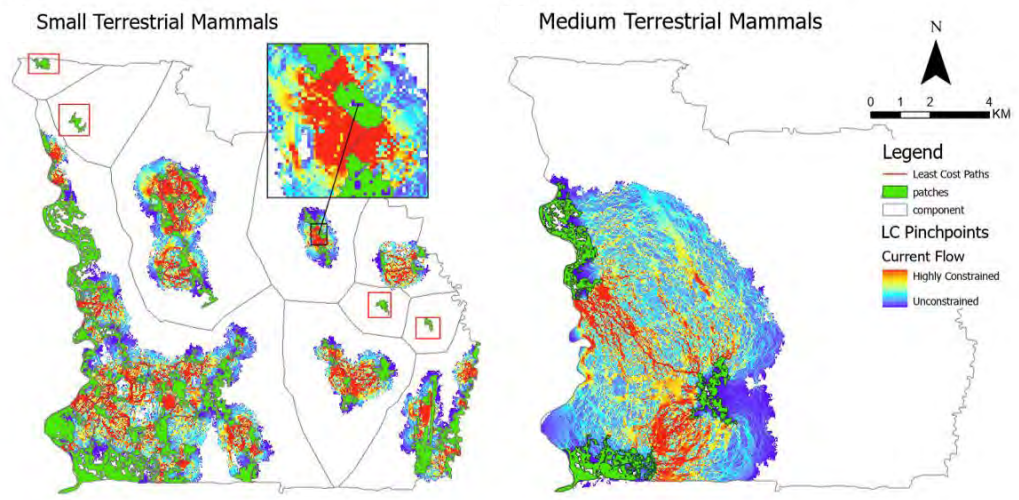


Figure 2. *Visualisation of species movement between habitat patches for small- and medium-sized terrestrial mammal guilds in Tangerang Selatan, Indonesia, based on Danneck et al. (2023) parameterisation using pinchpoint/bottleneck analysis. The red areas indicate locations where congestion occurred.*

Fitri and Pangaribowo (2022) report that green spaces in the area declined to 17% between 2010 and 2020, with significant reductions observed in the Serpong area. This decrease is primarily due to the conversion of green areas into roads, industrial sites, and residential buildings, which increases species mortality risks for animals attempting to cross these areas, as shown in **Figure 2**. The decline in species diversity ultimately leads to ecosystem degradation and reduces community resilience (Lechner et al., 2020).

Given the ongoing fragmentation of urban areas like Tangerang Selatan and other cities

across Indonesia, integrating ecological connectivity into city planning is critical. Currently, the lack of integrated urban and biodiversity planning poses a significant challenge across Indonesian cities. Thus, government intervention is necessary; policies that prioritise the preservation of critical green spaces within urban planning should be established to balance development goals with ecological sustainability. Ensuring ecological connectivity supports biodiversity and is pivotal for enhancing climate resilience, allowing urban areas to better adapt to environmental changes and extremes. Moreover, these green spaces offer numerous co-benefits, including ecosystem services like mitigating the urban heat island effect, which improves overall urban liveability and climate resilience (Lechner et al., 2020).

9.3 Analysis of Existing Adaptation Efforts

The city of Tangerang Selatan in conjunction with private developers has undertaken various efforts to address the impacts of urban development such as the revitalisation of green spaces and the creation of policies that preserve green spaces. Tangerang Selatan has built urban parks and green spaces development across the city. Notably, several commercial and property developments have achieved platinum certification by the Green Building Council Indonesia (GBCI), a designation that mandates the inclusion of substantial green spaces (**Figure 3**).

Furthermore, parks such as the Taman Kota BSD 1 and Taman Kota BSD 2 (**Figure 4**) are examples of large green spaces that likely contribute to species connectivity in the city. However, while these parks offer some biodiversity benefits, they are often isolated from each other, limiting their effectiveness as wildlife corridors, as depicted in **Figure 1**.

Figure 3. *Graha Unilever, Green Office Park Kavling 3, Jalan BSD Boulevard Barat, BSD City, Tangerang 15345, Indonesia, an example of a platinum-certified Building in Tangerang Selatan (https://gbcindonesia.org/).*

Figure 4. *Taman Kota BSD and Taman Ayodya are some examples of urban parks in Tangerang Selatan.*

The city has also developed policies aimed at conserving, creating green areas and preventing them from further loss. These policies include zoning regulations that restrict development in ecologically

sensitive areas However, the enforcement of these policies in Indonesia is often inconsistent and overridden by economic pressures to prioritise development over green conservation (Faisal et al., 2022). Finally, these existing policies do not have a strong biodiversity conservation focus and are not underpinned by evidence-based connectivity analyses, and thus the city may be green, and still not support ecological processes.

9.4 Barriers and Challenges

Despite these efforts, several barriers and challenges hinder the conservation of biodiversity and enhancement of connectivity in Tangerang Selatan. In a recent workshop that we organised (**Figure 5**), the main challenge that was identified was the lack of public awareness. Many urban residents may not fully appreciate the role that connected habitats play in maintaining biodiversity and the broader ecosystem services that benefit humans, for example, climate adaptation and resilience.

Existing urban planning policies and regulations often prioritise human needs, with little consideration for wildlife. Consequently, ecological and climate considerations are often inadequately integrated into urban planning, leading to the loss of critical habitats and ecological corridors. Additionally, the implementation of existing regulations regarding green spaces is not well-monitored. Faisal et al. (2022) points out that, despite the development of green infrastructure policies, there is a lack of optimisation in planning, causing policy development to be uncoordinated and overlapping between ministries and government agencies.

Figure 5. *Photos from workshop activities focused on identifying challenges, key species, and critical ecosystems in South Tangerang and its surrounding areas.*

9.5 Opportunities for Improvement

To address these challenges, several strategies can support biodiversity conservation in Tangerang Selatan. The connectivity model has pinpointed fragmented habitats that could be reconnected (see **Figure 1**), providing valuable insights for identifying critical areas to integrate into city planning to support biodiversity and maintain ecosystem services, which are essential for urban resilience. Studies in Kuala Lumpur, Malaysia emphasised the vital role of green corridors in facilitating the movement and dispersal of urban species (Aziz & Rasidi, 2014; Danneck et al., 2023).

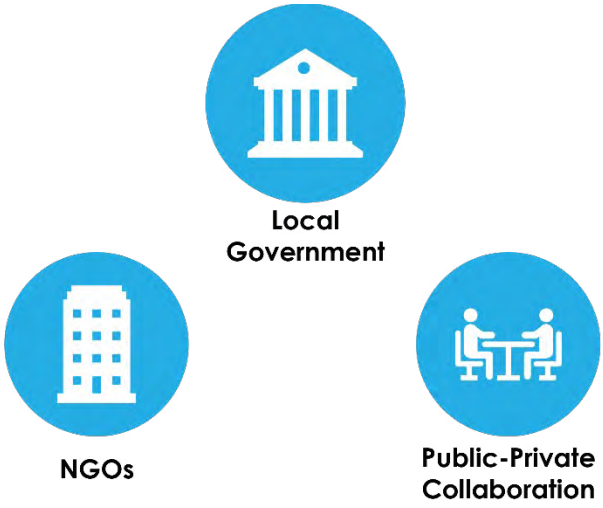
Promoting NbS, such as green roofs and urban forests could also further enhance connectivity, particularly within the matrix (i.e., non-habitat urban areas) (Raymond et al., 2017; Lechner et al., 2020). Adopting a NbS approach offers multiple eco-

benefits, especially in terms of climate change adaptation and mitigation. Ultimately, integrating connectivity into urban planning, raising public awareness, strengthening policy and regulatory frameworks, and leveraging advanced technologies like remote sensing and geographic information systems (GIS) offer significant long-term opportunities.

9.6 Importance of Stakeholder Engagement

Our work is underpinned by engaging with biodiversity experts in the region. Their expertise is essential for developing these ecological models, as in Indonesia, the scarcity of field data makes expert input particularly crucial. This represents a significant gap, which can be partly overcome by engaging experts who mostly reside in universities or academic institutions.

Local governments also play a crucial role in contributing data and insights on existing policies and can later implement recommendations from this project. Additionally, NGOs and local communities, including World Wide Fund for Nature (WWF) Indonesia, Wildlife Conservation Society (WCS) Indonesia and Burung Indonesia can provide valuable knowledge and resources that support and enhance conservation strategies by offering diverse perspectives. Finally, collaboration between public and private sectors (Schewenius et al., 2014), such as developers, is also essential for implementing and sustaining conservation strategies, particularly in Tangerang Selatan, given the significant role of private developers and master-planned developments associated with new cities (Widita & Lechner 2024).



9.7 Call to Action

To ensure the long-term sustainability of biodiversity and climate resilience in Tangerang Selatan, immediate and coordinated actions are essential. Landscapes that are highly fragmented, under the lack of a comprehensive urban green space network are likely widespread across Indonesia as cities continue to expand. New models for explicitly characterising biodiversity and its needs are required, along with innovative approaches to engaging urban planners and policymakers to prioritise biodiversity in all aspects of urban development and climate adaptation plans. This includes integrating ecological considerations into zoning regulations, land-use planning, and infrastructure development. Biodiversity often receives limited attention when supporting data is lacking for decision-making; however, such data should be incorporated into planning processes.

Collaboration between the public and private sectors is crucial to implementing and sustaining conservation and climate adaptation initiatives such as investment in green infrastructure (Schewenius et al., 2014). Particularly, in private new cities such as Tangerang Selatan, public-private partnerships can mobilise resources, share expertise, and drive innovation in creating green infrastructure and preserving ecological corridors. Integrating biodiversity conservation into urban planning helps nature and supports ecosystem services, thereby strengthening urban climate resilience.

9.8 Acknowledgment

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Chapter 10:

Project HeatSafe: The Impacts of Heat Stress on Workers' Health, Wellbeing and Productivity in Singapore

Jason Kai Wei Lee and Pearl Min Sze Tan

CHAPTER HIGHLIGHTS

Rising ambient temperature

Environmental heat and humidity are reaching threshold/unsafe levels for outdoor workers in tropical and subtropical countries due to global warming.

Impacts of heat stress on workers

Heat stress can cause psychological strain, impair cognitive capacity and decision making, while reducing productivity.

Case study: Heat adaptation interventions for outdoor workers

The intervention package includes heat stress education, scheduled breaks, provision of cold water and optimised work attire.

Summary

- **Affiliation:** The National University of Singapore and Singapore ETH Centre
- **Beneficiaries:** Predominantly outdoor workers
- **Project Type:** Research
- **Time Scale:** 2020 - 2024
- **Stakeholders involved:** Singapore Ministry of Manpower (MOM) and Workplace Safety and Health Institute (WSHI)
- **Funding:** USD 3.3 million (SGD 4.3 million)
- **Sponsor:** The National Research Foundation, Prime Minister's Office, Singapore
- **Impacts:** Contributed to the Singapore Ministry of Manpower's "Enhanced Measures to Reduce Heat Stress for Outdoor Workers", which was released in October 2023

Relevance of this chapter to SEACAR's themes

Summary

How much impact and influence does heat stress have on health, work productivity and the economy? Project HeatSafe is the first large-scale study in Singapore and the region aimed to investigate the impact of rising heat levels on the health, productivity and wellbeing of workers in tropical climates such as Singapore, both on an individual level and a macroeconomic and national level.

Funded by Singapore's National Research Foundation, Project HeatSafe was coled by the National University of Singapore and the Singapore-ETH Centre. Key partners include Singapore's Ministry of Manpower (MOM), and the Workplace Safety and Health Institute, as well as overseas institutions such as the Health and Environment International Trust, Tsinghua University, Vietnam Military Medical University, Institute of Technology of Cambodia and Seoul National University.

Project HeatSafe sought to understand the complex threats that extreme heat exposure poses to human health, wellbeing and work productivity in tropical countries such as Singapore, and to find sustainable and scalable heat adaptation solutions to reduce the growing impacts of heat stress. Given its strategic location and expertise in heat stress management, Singapore is well-placed to lead the way in developing and deploying solutions to counter the complexities of increasing heat stress, helping individuals, communities and society thrive in this warming world.

10.1 Introduction

Rising ambient temperatures and humidity due to global warming is an occupational hazard to workers in climate-vulnerable industries, such as construction, manufacturing and gig work (Fatima et al., 2021; Flouris et al., 2018; Morrissey et al., 2023; Shi et al., 2022). Prolonged physical labour in hot/humid conditions, coupled with the requirement to don protective clothing or equipment that impedes heat loss can result in significant occupational heat strain (i.e., physiological consequences of heat stress) that compromise workers' health and productivity (Cheung et al., 2016; Flouris et al., 2018; Kjellstrom et al., 2019; Morrissey et al., 2023). The effects of global warming are amplified in tropical and subtropical countries where environmental heat and humidity levels are reaching threshold/ unsafe levels (IPCC, 2023; Kjellstrom et al., 2017).

10.2 Impact of heat stress on workers

We sought to understand the impact of heat stress on workers via a series of research studies:

10.2.1 Physiological Strain

In studying the effects of occupational heat stress on both indoor and outdoor construction workers, a total of 79 indoor and 76 outdoor construction workers were profiled during a 9-hour work shift.

Overall, both indoor and outdoor construction workers experienced low physiological strain, despite varying Wet

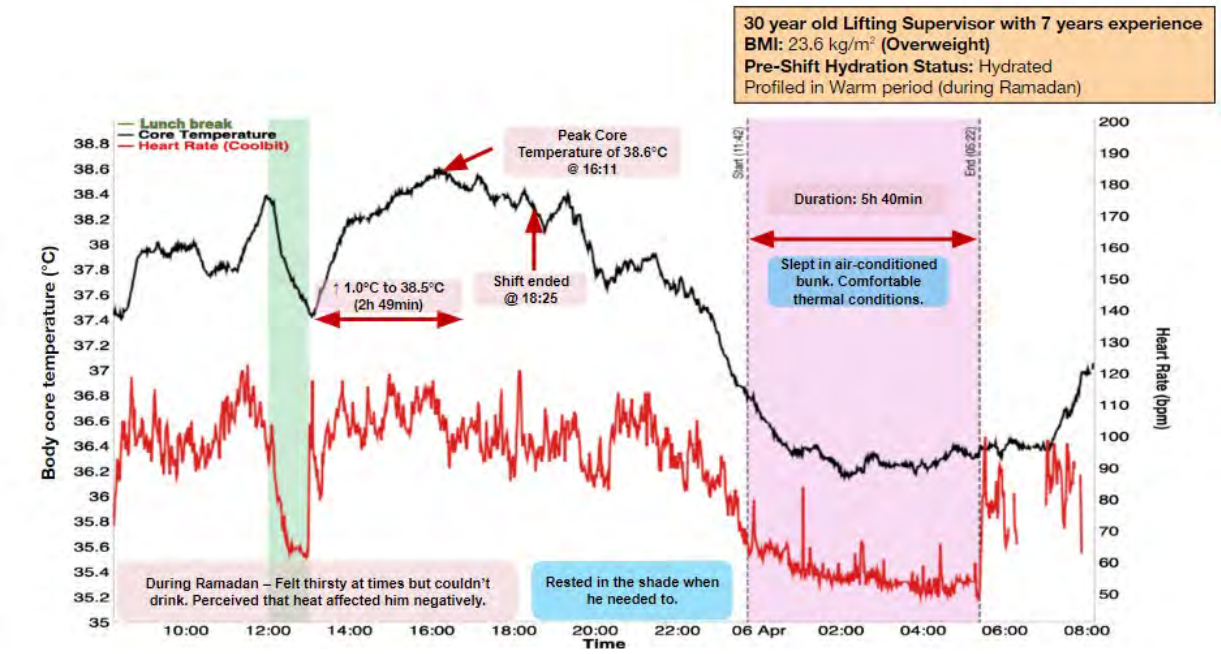


Figure 1. *Psychological strain experienced by a worker during the 9-hour shift.*

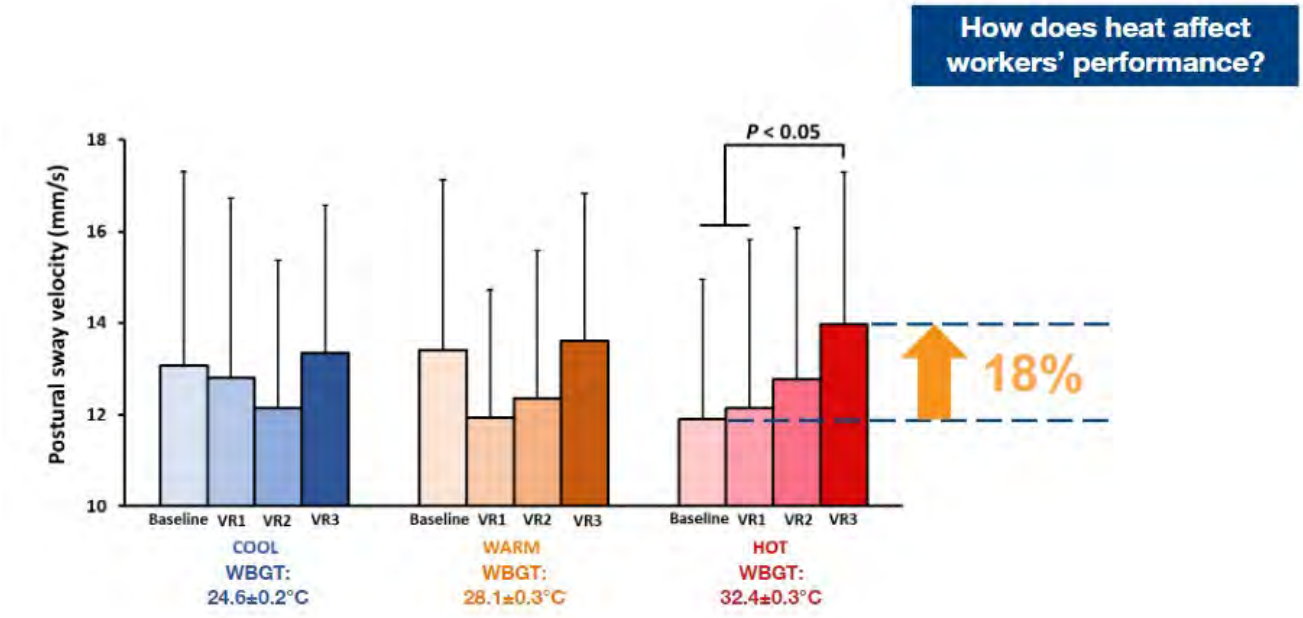


Figure 2. *How does heat affect workers' performance?*

Bulb Globe Temperature (WBGT) levels, likely due to their ability to self-pace. However, some workers exhibited prolonged high thermal strain, specifically with a body core temperature exceeding 38°C. An example of the physiological strain experienced by one such worker is illustrated in **Figure 1**.

10.2.2 Cognitive Capacity and Decision-making

In a Virtual Reality task, 18 healthy men were instructed to complete welding and plank-walking tasks, which are typically performed at construction sites, under three different WBGT conditions: 25°C,

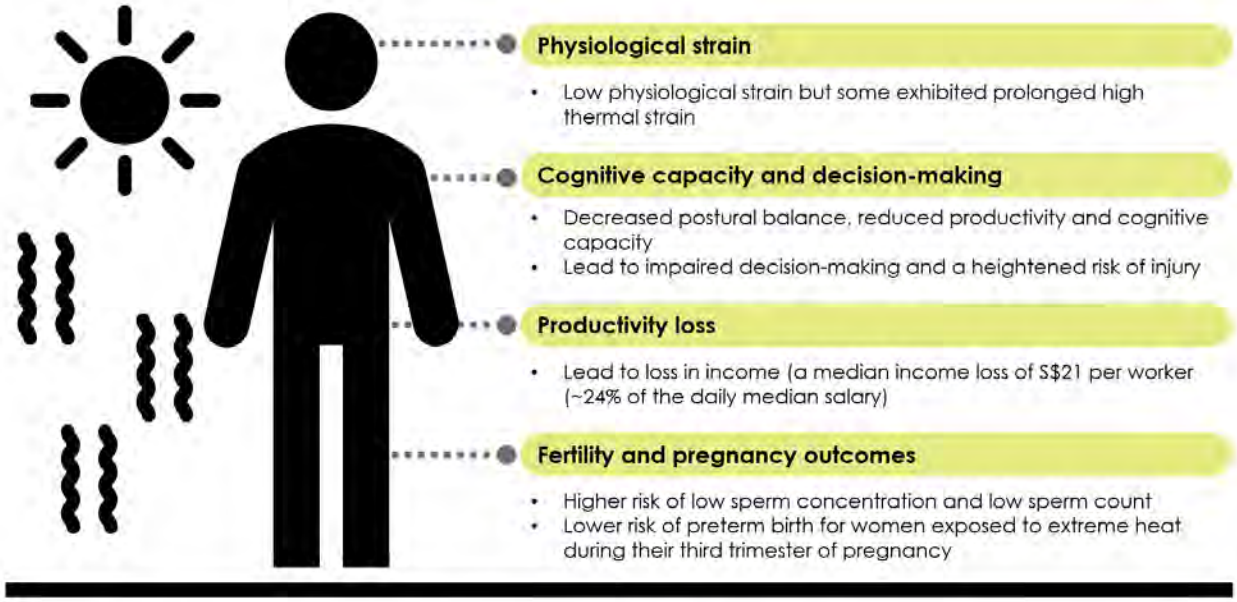
28°C and 32°C. These WBGT ranges were selected to simulate Singapore's current cool and warm environmental conditions, as well as the projected hot environmental conditions in the future.

A combination of high body core temperature, elevated skin temperature, and increased heart rate was linked to a decrease in postural balance during attention-demanding tasks. This can contribute to reduced productivity and cognitive capacity, leading to impaired decision-making and a heightened risk of injury (**Figure 2**).

10.2.3 Productivity Loss

Surveys were conducted with 355 workers and 214 employers in Singapore. It is estimated that for every hot day, the reduced productivity of workers during working hours (i.e., presenteeism) resulted in a median income loss of S$21 per worker, which accounted for about 24% of the daily median salary of the surveyed workers.

Figure 3. *Impacts of heat on productivity loss and economy loss.*



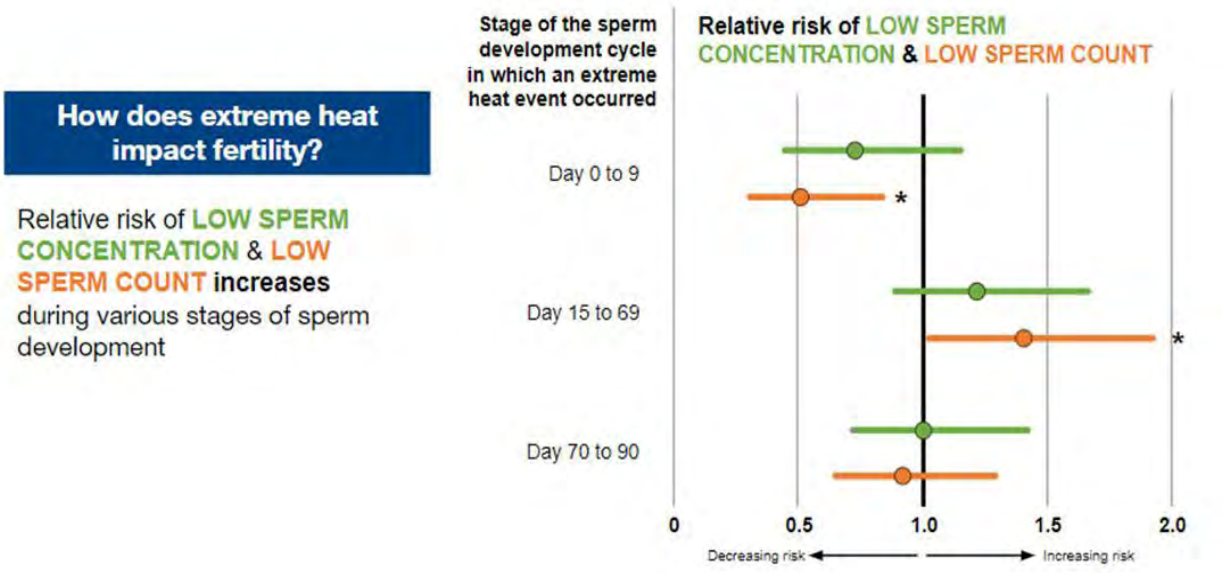


Figure 4. *How does extreme heat impact fertility?*

Approximately 70% of surveyed employers did not view the productivity losses of workers due to heat as a problem for their companies. However, they acknowledged the importance of educating workers about the impact of occupational heat strain on their health, wellbeing, and work performance. Other recommendations from employers include implementing specific heat adaptation measures at workplaces, such as regular work-rest cycles and water breaks, investing in cooling uniforms, and installing alert systems to notify workers of high temperatures (**Figure 3**).

10.3 Impact of chronic extreme heat on fertility and pregnancy outcomes in Singapore

The study of extreme heat's impact on local fertility outcomes for both women and men has not been extensively explored in tropical countries like Singapore, in contrast to countries with distinct seasons. To address this gap, sperm samples from 818 men were collected to analyse the risk of low sperm quality. The study found a higher risk of low sperm concentration and low sperm count in men who were exposed to extreme heat 15 to 69 days before their semen was collected (**Figure 4**).

The team also analysed birth records of over 30,000 mothers across the three pregnancy trimesters to assess the risk of preterm birth and small-for-gestational-age birth. Interestingly, there was a lower risk of preterm birth for women who were exposed to extreme heat during their third trimester of pregnancy (**Figure 5**).

Based on survey responses from over 300 women, the team observed indications of protective measures adopted by pregnant women. The proportion of pregnant survey respondents who increased their use of air-conditioning on hot days rose by 30% from the first trimester to the third trimester. In terms of behaviour,

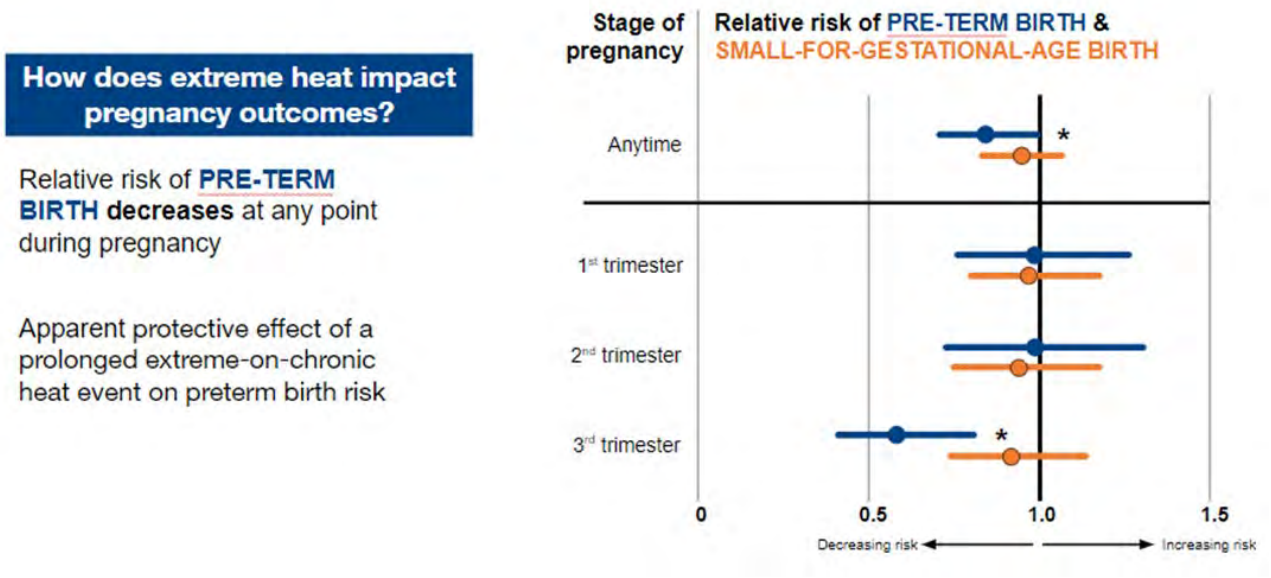


Figure 5. *How does extreme heat impact pregnancy outcomes?*

the proportion of respondents who spent less time outdoors on hot days increased by 12% from the first trimester to the third trimester, and the proportion who exercised less on hot days also increased by 11%. However, women who already had children were less likely to adopt these two protective behaviours.

10.4 Macroeconomic impact of heat on labour productivity losses of industries

Through an interdisciplinary approach, which combined various data sources incorporated into a supply-driven Input-output (IO) model, the study evaluated the macroeconomic impact of heat on labour productivity among the 42 industries of the Singaporean economy. These industries were further classified into four major sectors: services, manufacturing, agriculture and construction.

In 2018, the total average annual percentage reduction in productive working time due to heat in all four sectors averaged 11.3%, resulting in a total economy-wide output loss of S$1.18 billion. This percentage is projected to rise to 14% by 2035, leading to an economy-wide output loss of S$2.22 billion (**Figure 6**).

10.5 Case study: Heat adaptation interventions for outdoor workers

An intervention study was conducted at an outdoor construction site in Singapore in May 2023. Findings from previous phases of Project HeatSafe were taken into consideration when designing the heat adaptation intervention package. Recommendations by the Singapore Workplace Safety and Health Council were also incorporated. The intervention package was designed to be scalable, sustainable and economically viable and consisted of:

Heat stress education:

Educational videos were developed to raise awareness among supervisors and

workers about heat stress and heat-related injuries. The videos cover key topics such as what heat stress is, how to recognise its symptoms, and ways to prevent it. To ensure accessibility and understanding, the content was made in multiple languages that are commonly spoken by workers in Singapore. Videos are available from https://www.heatsafe.org/resources.

Scheduled breaks:

Three additional 15-minute rest breaks under shade during the workday.

Provision of cold water:

Increased access to cold water points and the use of an insulated bottle sleeve to keep workers' bottles cold.

Optimised work attire:

Provision of a set of work attire with enhanced heat dissipation properties. Workers participated in both a control (i.e., normal work routine, practices and attire) and an intervention condition, one week apart. While the physiological and perceptual responses of workers were similar between the control and intervention conditions, workers in the intervention condition clocked a higher step count (+10%) and step rate (+14%) during the work shift. This suggests a possible increase in work productivity. Findings from the focus group discussions revealed positive perceptions of the intervention and workers were supportive of their implementation. Our findings demonstrated the feasibility and potential benefits of implementing a multicomponent heat adaptation intervention package at construction sites in Singapore (**Figure 7**).

10.6 Conclusion

The findings from Project HeatSafe provide a multifaceted perspective on how heat stress can lead to detrimental impacts and consequences at both the individual and macroeconomic levels. These effects range from compromised decision-making, cognitive capacities and productivity to influencing health and wellbeing, including fertility and pregnancy outcomes.

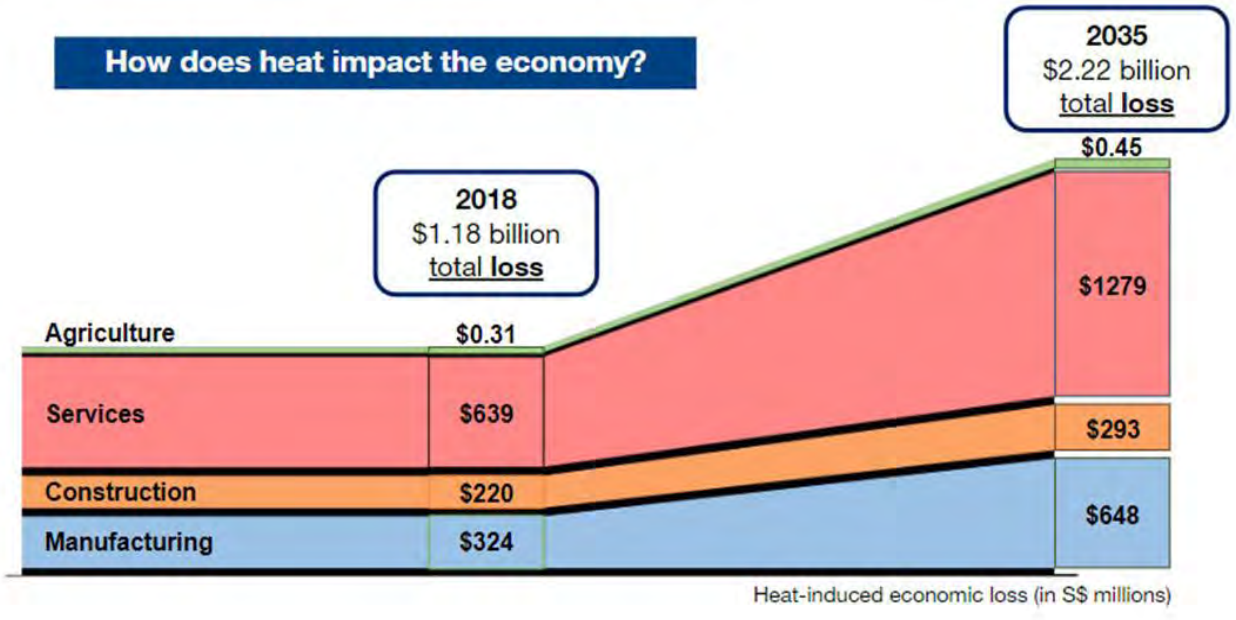


Figure 6. How does heat impact the economy?

Additionally, the study sheds light on the broader implications for labour and economic productivity at a macroeconomic scale.

In October 2023, the Singapore Ministry of Manpower (MOM) proactively released "Enhanced Measures to Reduce Heat Stress for Outdoor Workers." Formulated in consultation with the Singapore Ministry of Health's Heat Stress Expert Panel, which includes Associate Professor Jason Lee among its members, many of the heat adaptation recommendations aligned closely with the findings obtained from Project HeatSafe. **Figure 8** is a summary of the enhanced measures rolled out by MOM.

In field studies of this nature, it is ideal to identify and profile sites that are representative of the general situation in the country or region. However, there could have been self-selection bias in our sample, where worksites and workers who have a greater appreciation of the risks of occupational heat stress may be more likely to participate in the study. The findings from HeatSafe should hence be considered conservative.

In Southeast Asia, one group of workers who deserve greater attention are those who provide delivery services. They are often paid per piece and may overlook heat adaptation strategies as they go about their work in the outdoor heat. See: https://www.bbc.com/storyworks/theclimateandus/nationaluniversityofsingapore

10.7 Call to action

The Heat Resilience & Performance Centre at the Yong Loo Lin School of Medicine of the National University of Singapore (NUS) launched the Network's Southeast Asia Heat Health Hub at the 2023 UN Climate Conference (COP28), to stimulate greater collaboration and alignment in heat health research and policy initiatives to save lives in a region plagued by chronic heat and seeing impacts intensified due to climate change. Uniting the region against extreme heat, the Southeast Asia Heat Health Hub ignites collaboration, accelerates knowledge sharing, and amplifies capacity building to shield populations from heat-related health risks, aligning with the global mission to mitigate the devastating impacts of extreme heat and ensure a resilient future for all. The focus will be to address key areas such as urban heat, heat on workers and understanding the cultural and traditional perspectives and practices in heat management. This platform can be leveraged to scale up the work done in Project HeatSafe to benefit all in Southeast Asia. The inaugural Southeast Asia Heat Health Forum was held in Singapore in January 2025, and we invite partners to join us in this mandate (https://ghhin.org/2025southeastasiaheathealthforum/).

Acknowledgement

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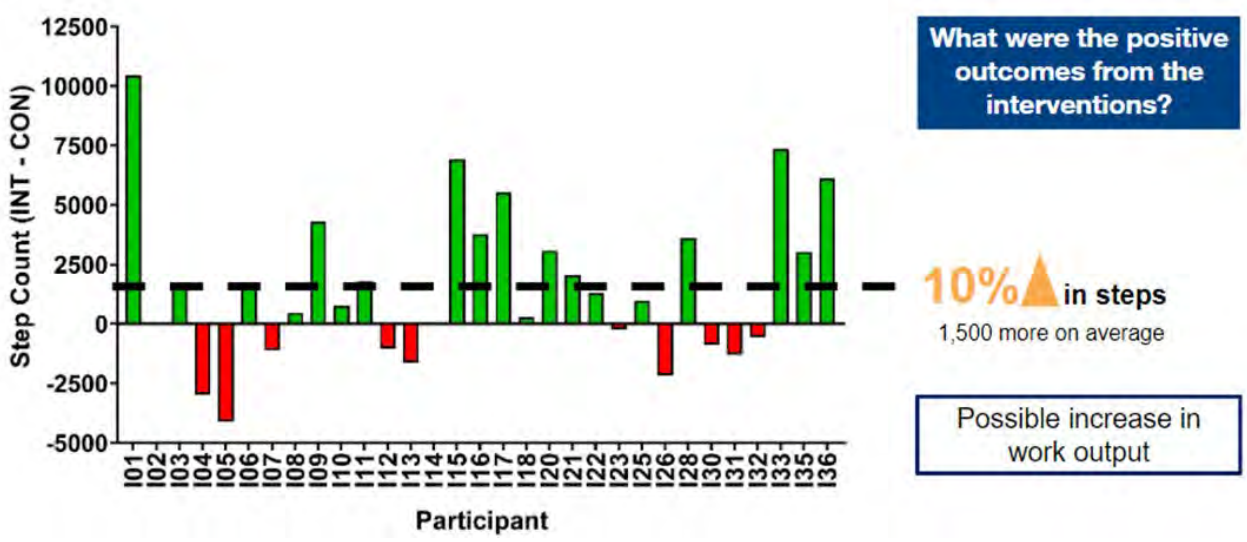

Figure 7. *What were the positive outcomes from the interventions?*

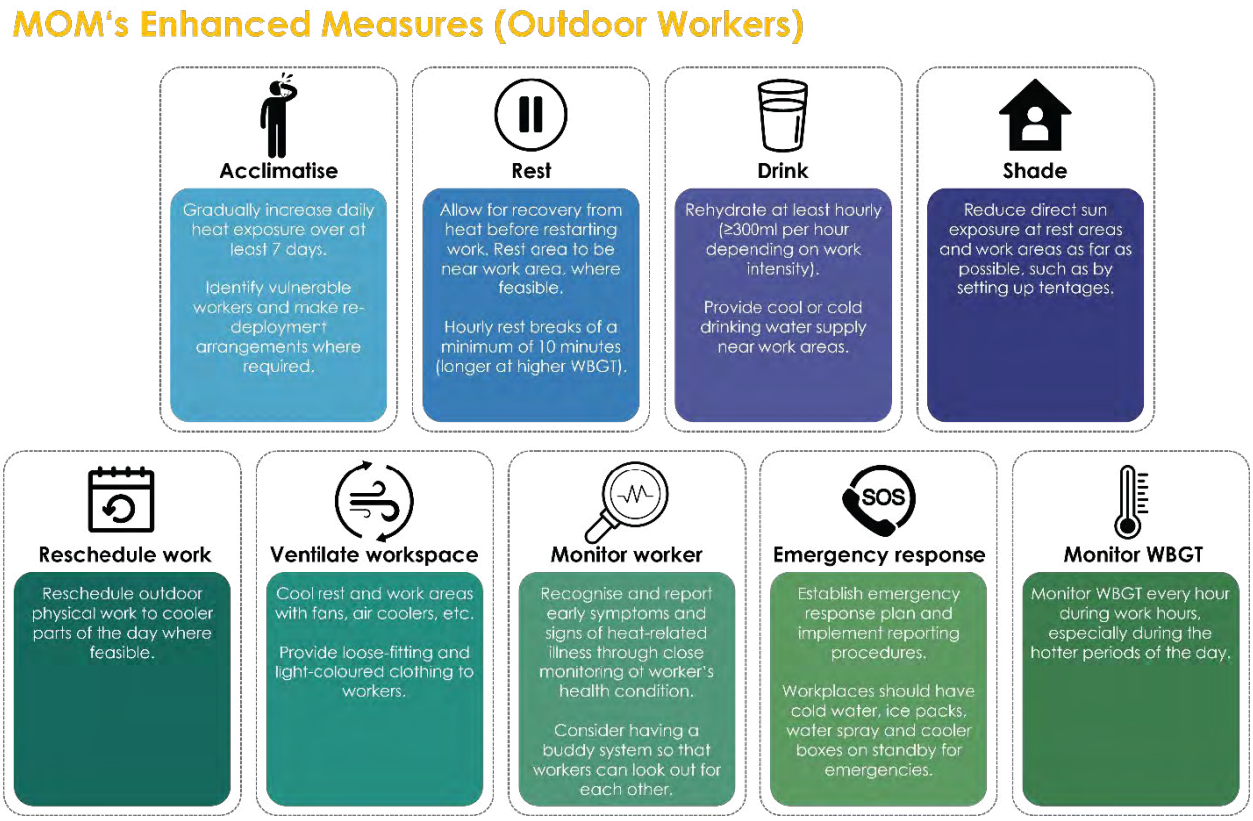

Figure 8. *Enhanced measures formulated by the Ministry of Manpower*

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CONCLUSION

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Key Takeaways of the Chapters

This report showcased ten on-the-ground projects or research initiatives that align with SEACAR themes to initiate, carry out, and scale up climate A&R efforts in Southeast Asia. It hopes that the methods and steps that the chapter contributors have taken will continue to catalyse and inspire people from all walks of life to better understand the potential of NbS and AI in community development and national planning.

These chapters highlight that local communities and multi-sectoral collaboration are crucial for applying NbS and AI in climate A&R efforts. Regardless of scale, such initiatives increase the resilience of cities, communities, and nature against the changing climate and disasters, underscoring the vital importance of adaptation. For example, Section 1 (Regional Perspectives) in this report highlight the flexible potential of combining NbS and AI to improve urban infrastructure planning and underscore AI's critical role in weather forecasting for enhancing regional disaster preparedness, particularly for floods and heatwaves. Additionally, Section 2 (Local Actions) demonstrate that climate adaptation efforts incorporating NbS have preserved urban ecosystem services essential for climate adaptation, reduced urban heat stress, mitigated flood impacts, and enhanced livelihoods, food and water security, while also reducing pollution. Section 3 (Knowledge for Action) pinpoints the impacts of urban heat island effects and heatwaves on human well-being and economic productivity, as well as highlight the geospatial tools and techniques, complemented by public participation to facilitate urban NbS planning.

While AI is already being deployed to support disaster risk response and management, there is still significant opportunity to leverage AI for increasing the adaptive capacity of local communities. We can learn from leading countries in climate adaptation such as the Philippines, for example, in leveraging AI to assess the potential socioeconomic and environmental impacts of climate risks on a municipality-level.

A Vision for Progress of Southeast Asia Climate Adaptation and Resilience Efforts

Given the well-documented impacts of climate change on communities' livelihoods, scaling up NbS and leveraging AI applications is crucial for enhancing climate adaptation and resilience efforts. As highlighted in the report, climate adaptation and resilience efforts demand multidisciplinary commitments, as they impact diverse aspects of life, including agriculture, trade, education, urban planning, rural development, and food and water security.

We hope different sectors can collaborate to address this critical issue through cross-sectoral communication, awareness programmes, policy reforms and prioritising A&R efforts in national planning, including greater budget allocation.

Call to Action: Our Invitation to You

The Alliance believes that the most impactful solutions can only come from rich and collaborative action. Hence, we invite stakeholders from all walks to reach out and engage with the SEACAR Alliance. Potential avenues of engagement include:

- **Joint knowledge sharing** – Contribute experiences and insights to the Alliance's annual co-publication, and partake in interviews, workshops, and roundtables to elevate the A&R profile in Southeast Asia.

- **Provide topic leadership** – Lead in coauthoring or contributing extensively to selected topics for the annual co-publication, and champion dialogues and discussions with regional stakeholders.

- **Be a resource partner** – Assist the Secretariat with funding or manhours, back an A&R pilot project in the region and magnify the importance of climate A&R by broadening its network or spotlighting it at key climate events. Active participation with the Alliance offers myriad advantages. This includes access to a vast regional knowledge pool on climate A&R, collaborative data and idea exchanges with key regional stakeholders, and the opportunity to expand your network and platform across various sectors in Southeast Asia.

Help us chart a climate-resilient course for Southeast Asia.

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From our inception in 2009 to manage urban rejuvenation in George Town, Penang, to our presence in cities across Malaysia today, Think City has achieved over a decade of experience and knowledge in the urban landscape. Each milestone has strengthened our mission in making cities better places for people to live in, observing the United Nations' Sustainable Development Goals as our guide. Think City's mission is to make cities more liveable, environmentally and socially resilient, and sustainable. Visit https://thinkcity.com.my/

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WWF is one of the world's largest and most experienced independent conservation organisations, with over 6 million supporters and a global network active in more than over 100 countries. WWF's mission is to stop the degradation of the Earth's natural environment and to build a future in which humans live in harmony with nature, by conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption. Visit www.panda.org/news.

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