SUSTAINABLE INFRASTRUCTURE IN THE TROPICS

STATE OF THE TROPICS

A STATE OF THE TROPICS REPORT **2017**

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FOREWORD

On June 29 2016 the United Nations celebrated the first ever International Day of the Tropics. The date marks the launch, two years earlier to the day, of the inaugural *State of the Tropics 2014 Report*. This landmark report, the result of an international collaboration between leading research institutions from across the world's tropical zone, offers a different perspective on the world. It demonstrates that the Tropics is a geo-political and environmental entity in its own right, and highlights the increasing importance of the region and the global implications of the immense social, economic and environmental changes the Tropics are experiencing. A new global dynamic was revealed in the pages of that report.

Since the report's release the world has embarked on an ambitious journey launching several major global initiatives to address the world's most pressing challenges. 2015 was a milestone year for global development with the United Nations 2030 Agenda for Sustainable Development, the Paris Agreement on climate change and the Addis Ababa Action Agenda on Financing for Development. These landmark agreements define a series of ambitious global goals that will guide actions on global development, economic policy, climate change and environmental protection in the coming decades.

Nations of the Tropics are at the forefront of these efforts. With almost half the world's population, more than half of its young people, many of its fastest growing economies, most of the world's biological and cultural diversity, and ecosystems services of global importance, what happens in the world's tropical zone over the coming decades will have global implications. The trajectory of the region will in large part determine whether the world meets its ambitious aspirations for global prosperity and equality.

The *State of the Tropics* report demonstrates that nations of the Tropics have made extraordinary progress across a wide range of social, economic and environmental indicators in recent decades. It also highlights the many significant and unique challenges the region continues to face.

The development of sustainable, resilient and inclusive infrastructure lies at the heart of addressing the region's most significant challenges. As the world heads towards 9.5 billion people by mid-century and races towards an urban future, feeding the world's population, meeting its housing needs, providing energy and access to basic services for all, while ensuring environmental sustainability and limiting climate change impacts will require significant new investment, innovation and approaches to infrastructure development and management.

Estimates of the world's infrastructure deficit in financial terms are breathtaking. Arguably as important though, is the need to invest in human and institutional capacity without which prudent and productive financial investment is not possible and the long term viability of infrastructure projects is compromised. As this report makes clear, most of the world's infrastructure deficit is in the Tropics which also faces significant and unique challenges relating to infrastructure development. The region's climate and environmental conditions, extreme weather events, its high rates of poverty, and limited human and institutional capacity, make planning, developing, operating and maintaining infrastructure in the Tropics particularly problematic.

However, where there are challenges there are also opportunities. People have lived and thrived in the Tropics for millennia and continue to develop innovative solutions to life in the region. By taking stock of the status and trends in infrastructure development across the Tropics this report identifies where progress has been made and where key gaps in infrastructure needs in different sectors remain. A series of case studies complement the report's analyses and highlight best practice examples and the critical role that local knowledge, innovations and capacity will need to play to realise effective infrastructure development in the region.

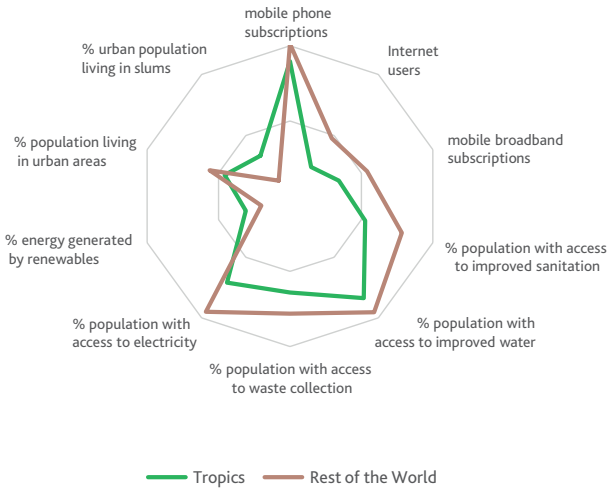
Infrastructure is a long-term investment. Many of the roads, dams, pipelines, telecommunications networks, and other essential facilities we are building today will last generations. Turning our minds and our efforts to getting it right now is critical. Developing infrastructure that is resilient, sustainable and inclusive by drawing on the human potential of the Tropics and building institutional capacity, improving governance and developing effective partnerships to develop tropical solutions for tropical challenges will be critical for meeting the region's and the world's ambitions for a prosperous and sustainable global future.

Professor Sandra Harding
Vice Chancellor & President, James Cook University
Convenor, State of the Tropics Project

KEY MESSAGES

Investment needs to be increased substantially to meet the world's significant infrastructure deficit, most of which is in the Tropics.

Major global trends including growing human populations, increasing affluence, and rapid urbanisation rates, alongside the impacts of global challenges such as climate change, will require massive investment in infrastructure in the next few decades to meet demand and global targets for sustainable development. An estimated US$3.5 trillion needs to be spent globally each year to 2030 to meet the world's growing requirements for energy, transport, telecommunications, water, and sanitation. Most of the infrastructure needs (almost 70% of the estimated global deficit) are in the world's tropical nations, where an estimated US$30 trillion will need to be invested by 2030 to bridge the gap. As the adjoining figure shows, nations of the Tropics trail the rest of the world in infrastructure in most sectors.



The Tropical Infrastructure Gap in 2015

Tropical nations share infrastructure development challenges and opportunities but in many cases are constrained by limited human and institutional capacity and poor governance. Effective partnerships promoting greater pan-tropical and cross-disciplinary collaborations are required to improve the enabling environment for infrastructure development and management.

The planning, delivery, operation, and maintenance of infrastructure in the Tropics is subject to unique challenges that require focused attention. Tropical climates and environmental conditions, including high heat, humidity, rainfall, and extreme weather events, expose infrastructure to conditions not experienced elsewhere. Many forms of infrastructure such as roads, energy networks and buildings are particularly vulnerable to extreme events, and compared with temperate regions are affected by higher rates of deterioration. Limited technical and institutional capacity in many tropical nations, compounded by ineffective governance (more so than access to resources and financial investment opportunities), constrains development and maintenance of adequate infrastructure in the region. The transfer of infrastructure, technology and policies developed in other parts of the world are often inappropriate for tropical conditions. These points underlie the critical need for tropical nations to acquire their own independent capacity to develop and manage sustainable and resilient infrastructure for their own local circumstances. Locally developed solutions and innovations offer considerable potential for sharing across nations and communities in other tropical contexts. Effective multi-stakeholder partnerships between nations, regions, and sectors in the Tropics will help build human and institutional capacity and improve governance, leading to greater potential for capitalising on tropical infrastructure solutions developed for tropical challenges.

Climate change is likely to disproportionately affect the Tropics exacerbating the inherent challenges relating to infrastructure development and management in the region.

With a disproportionate number of the world's poorest and most vulnerable communities, climate change impacts are set to affect tropical nations significantly. Tropical climatic conditions and extreme weather events are set to intensify with even higher rainfall and temperatures predicted, in some cases resulting in novel climates in equatorial regions that have not been recorded in human history. Small Island Developing States, coastal communities and the urban and rural poor are at the frontline of many of these impacts, particularly in relation to sea level rise and natural disaster risks. The need to "climate proof" infrastructure to help tropical countries adapt is an imperative, while the broader need to reduce future warming by investing in infrastructure and technologies that emit fewer greenhouse gases is a global priority.

There is considerable scope for developing renewable energy options in the Tropics, with several tropical nations already world leaders in certain sectors.

More than one billion people worldwide do not have access to any form of modern energy, while for another billion access is intermittent and unreliable. Most of these people live in rural areas of the Tropics. Energy generation lies at the intersection of development, poverty alleviation and climate change. The energy infrastructure deficit in the region is a significant challenge but it also offers an opportunity for tropical nations to develop more efficient, decentralised and renewable forms of energy generation that can 'leap-frog' inefficient and polluting infrastructure. Micro-hydro, solar photo-voltaic and biomass gasification as well as hybrid technologies such as wind-diesel and solar-diesel supported by energy storage technologies are evolving rapidly. Proportionately more of the energy generated in the Tropics is from renewable energy sources than in the rest of the world. Some tropical areas such as parts of South and Central America already rely mostly on renewable energy, while other constituencies such as Singapore and Australia are world leaders in research and development in renewable energy technologies ideally suited to tropical conditions.

Despite recent progress, many people still lack access to basic infrastructure relating to water, sanitation and waste management. The financial investment required to meet these needs is relatively modest compared to other sectors and significantly lower than the costs of addressing the negative outcomes of poor water, sanitation and waste management.

Access to clean water, sanitation facilities and waste management are among the most basic of human needs. Poor water quality, sanitation facilities and waste management practices impact human health and wellbeing, posing particularly acute risks to poor and vulnerable communities. Pollution and greenhouse gas emissions from poor practices also have major impacts on the environment. In 2015, almost half of the population in the Tropics had no access to improved sanitation infrastructure, while a third were not covered by adequate waste disposal services. Waste generation rates are notably lower in low income tropical nations, however, the waste that is generated is mostly disposed of by uncontrolled and unsustainable means. Progress relating to the provision of infrastructure supplying clean water has been comparatively better reflecting the greater attention this sector has had from the international development community. However, at 84% of the population with access, coverage is not universal and still lags behind the rest of the world. In part, the reason for relatively slow progress in these sectors relates to the poor investment returns for the private sector relating to the provision of this type of infrastructure and inadequate public investment. Nevertheless, the estimated total financial investment to provide universal coverage in the Tropics is around $385 billion – a relatively modest amount compared to the world's investment in other sectors. Significant opportunities also exist in developing and formalising the waste management sector in many tropical nations where a large informal reuse and recycling industry already exists.

Transport infrastructure facilitating the movement of goods and services and people is an important driver of trade, productivity and economic growth. Its sustainable development requires that it be safe, affordable, accessible, efficient and resilient while minimising carbon and other emissions and environmental impacts.

Transport infrastructure has developed significantly throughout the Tropics in the last two decades. The development of roads, air and sea ports and railway networks are an important facilitator of trade and economic growth in the region and investment in these facilities offer a high rate of return for government and private investors. Growth in air and sea traffic and improvements in technology have opened up new industries and export opportunities for many tropical countries, particularly for high value agricultural products. Nevertheless, the volume of air and sea freight and air passenger traffic originating from the Tropics remains a fraction of the global total. Many regions of the Tropics, particularly island nations of South-East Asia, Oceania and the Caribbean are highly reliant on port and sea freight infrastructure but quality remains low requiring significant new investment. A huge increase in road construction is projected over the next few decades in the Tropics. While roads are important for development there is a critical need to ensure planning and building of new roads optimises social and economic benefits while minimising environmental impacts. Tropical wilderness areas are especially vulnerable given that roads into new areas are often associated with increases in land colonisation, habitat disruption and overexploitation of natural resources.

Information and communication technology (ICT), including 'smart' infrastructure, offers great potential for innovation and development in the Tropics and is applicable to all other infrastructure sectors. However, digital literacy and equitable access remains a challenge in most tropical nations.

The rapid global growth of ICT infrastructure is mirrored throughout the Tropics with its contribution to improving financial inclusion, health and education outreach and productivity of primary industries particularly notable. Mobile phone uptake in the Tropics has been rapid and is the main source of connectivity for most people in the region. Access to the Internet, however, is highly variable in the Tropics despite a 10 percentage point increase since 2010. High speed, fixed line internet access is rare in the region although there is increasing access to mobile and satellite broadband. The rise of 'smart infrastructure' and its applicability across sectors offers significant potential for the development and scaling up of local innovations and solutions and options for 'leap-frogging' older, less efficient or polluting infrastructure.

Financing sustainable infrastructure development will require multiple financing sources including public and private, domestic and international.

The large infrastructure gap in the Tropics will require considerable investment from both public and private sources. Insufficient investment in many tropical nations to date is partly due to inadequate infrastructure planning and significant challenges in the enabling environment in terms of institutional capacity, technical knowledge and skills and governance structures which act as impediments to investment and development. New infrastructure initiatives such as the UN's Global Infrastructure Forum led by multi-lateral development banks aims to bring together multiple stakeholders to bridge the infrastructure deficit by identifying and addressing key requirements and highlighting opportunities for investment and cooperation, including through the facilitation of public-private partnerships. Currently, most private investment in the Tropics is within the ICT sector, and to a lesser degree in energy infrastructure. Investment in transport, sanitation, water infrastructure is considerably lower, reflecting in part the lower returns in these sectors. Within the transport sector, most private investment is channeled towards roads due largely to a growing dependence on roads for moving freight and increased car ownership across the region.

The rural – urban divide and rapid rates of urbanisation present particular challenges for equitable and inclusive infrastructure development in the Tropics.

Urbanisation is a major global trend that has particular resonance in the Tropics given the region's rapidly growing human populations, rural-urban mobility and young population demographics. Existing urban infrastructure deficits and the high proportion of informal settlements in many cities are magnified as the need for key infrastructure development is outpaced by increasing demand. For the one third of tropical city dwellers who live in a slum, securing tenure and ownership is a key to improving conditions and transforming slums into developed, formal settlements with adequate infrastructure. Despite the many urban development challenges in the Tropics there are many examples of innovative urban developments in the Tropics which offer opportunities for broader leadership in innovation and sustainability. Nevertheless, while urban infrastructure development is a major issue most of the tropical population remains rural. Logistical challenges and the higher economic costs of providing adequate infrastructure to rural communities means much of the world's infrastructure deficit is in tropical rural regions.

Balancing the economic and social benefits of infrastructure development while minimising environmental impacts and respecting cultural considerations is critical to ensuring infrastructure is sustainable, resilient and inclusive.

The tropical zone hosts most of the Earth's cultural and biological diversity including ecosystem services of global importance. Poorly planned, delivered and managed infrastructure has significant environmental impacts including habitat loss and degradation, pollution, and overexploitation of wildlife and natural resources. The lack of effective engagement with local communities, including taking into account local cultural considerations and needs, often results in the development of infrastructure that is not appropriate to local community needs and can be rendered useless and ultimately wasted.

The timely delivery of sustainable and resilient infrastructure in the Tropics is central to achieving the world's goals for sustainable development.

Most of the world's aspirations for a sustainable and equitable future will play out in the world's tropical zone. As this report demonstrates, although the region has made extraordinary progress on a range of infrastructure development indicators in recent decades, significant challenges remain. Enduring poverty, growing inequalities, poor health and education outcomes, and environmental degradation remain major obstacles to sustainable development in many tropical nations. With rapidly growing human populations, changing demographics, many rapidly growing economies, and as a host of most of the world's cultural and biological diversity, the importance of the region is set to increase. The development of sustainable, resilient and inclusive infrastructure is central to addressing the region's challenges and meeting global development goals.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INTRODUCTION

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Introduction

Sustainable, resilient and inclusive infrastructure lies at the heart of global development. Appropriately developed and managed, infrastructure is a powerful catalyst for promoting economic growth, social inclusion and environmental stewardship. The development of sustainable infrastructure can be transformative for communities and nations, lifting people out of poverty and providing access to services, products and markets to facilitate trade and productivity, promote health and wellbeing, and improve education outcomes.

Although the world has made notable progress in recent decades in delivering key infrastructure, significant gaps persist. Meeting the challenge of bridging these deficits is likely to increase as the world faces several major transformative trends. Growing human populations, increasing affluence, rapid urbanisation, and global challenges such as climate change, make the timely development of sustainable infrastructure one of the most pressing challenges of our time. Estimates of the global infrastructure deficit vary but all agree it is immense, with recent predictions suggesting the world will need to spend up to $60 trillion by 2030 to meet key infrastructure needs (McKinsey & Company 2011; OECD 2015). The importance of infrastructure development is highlighted by several recent global initiatives centred around three primary challenges: stimulating economic growth, promoting sustainable development, and addressing the impacts of climate change (Bhattacharya et al. 2016). These challenges are reflected in ambitious global targets as set out in the UN's groundbreaking 2030 Agenda for Sustainable Development (United Nations 2015c), the Addis Ababa Action Agenda on Financing for Development (United Nations 2015a), and the landmark Paris Agreement on climate change (United Nations 2015b).

The challenges and opportunities for investment in infrastructure provide are broadly recognised by both the public and private sectors. New infrastructure initiatives such as the UN's Global Infrastructure Forum, led by multi-lateral development banks in close collaboration with the United Nations, aims to bring together multiple stakeholders to bridge the infrastructure deficit by identifying and addressing key requirements and highlighting opportunities for investment and cooperation, including through the facilitation of public-private partnerships.

The most significant global challenges relating to infrastructure development are shared, but their relative importance and how they may be addressed differ within and between nations and regions. In general, developing and emerging economies face different priorities and have different constraints and challenges. Starting from significantly lower baselines their infrastructure deficits are more acute with many nations lacking basic facilities and services such as adequate transport, reliable energy supplies, and water and sanitation facilities that are taken for granted in more developed economies. While there are significant investment opportunities in developing nations, significant challenges in the enabling environment in terms of institutional capacity, technical knowledge and skills, and governance structures act as impediments to investment and development. More developed economies face somewhat different challenges including ageing infrastructure, high costs of infrastructure development and uncertainty over long term economic growth prospects impeding investment.

Although they play out differently between nations and regions there are shared challenges and responsibilities, including the impact of universal transformative trends such as urbanisation, the logistical and financial challenges of provision of adequate infrastructure to people in rural areas, and the pervasive impacts of climate change that require infrastructure that facilitates mitigation and adaptation.

This report explores these issues from a tropical perspective. It takes stock of the current and historical status of infrastructure development across the tropical zone by sector and explores the particular challenges and opportunities nations and regions of the Tropics face in terms of improving the provision of adequate services and facilities to their populations. In doing so, the report demonstrates that the region is becoming increasingly important, and highlights that the extent to which nations of the Tropics develop sustainable, resilient and inclusive infrastructure will in large part determine whether the world achieves its ambitious development goals.

What is Sustainable and Resilient Infrastructure? **BOX 1.1**

Infrastructure includes the physical and organisational structures required by societies and economies to function effectively and productively. It includes 'hard' infrastructure elements such as transport services (road, rail and port facilities), water supply, sanitation and waste management facilities, energy networks, telecommunications, food production facilities and educational and health facilities.

It also includes 'soft' infrastructure that is essential to facilitating the enabling environment for hard infrastructure development. It includes the financial services, institutional capacities, technical knowledge and skills and governance structures required for planning, delivering, operating and maintaining infrastructure effectively.

Sustainable infrastructure encompasses social, economic and environmental considerations. It is socially inclusiveness and respectful of human rights and cultural diversity and sensitivities. It is designed to meet the needs of the poor by increasing access, supporting poverty reduction, and reducing vulnerability of communities to natural hazards and the impacts of climate change. Infrastructure that is economically sustainable provides meaningful employment, helps boost a country's productivity and seeks to build the capabilities of local suppliers and developers. It does not burden governments with unpayable debt or users with high charges. Environmentally sustainable infrastructure mitigates carbon emissions during construction and operation and contributes to the transition to a lower-carbon economy. It minimises environmental impacts, and aims to maintain or enhance biodiversity and ecosystems services including the provision of clean water, air and soil.

Resilient infrastructure refers to durability and its ability to withstand changes and impacts in order to continue performing over time. High heat, humidity and rainfall, alongside natural hazards such as extreme weather events, flooding and drought in the Tropics, present particular challenges for the design, building and maintenance of infrastructure. This also makes resilient infrastructure particularly relevant in the context of climate change risks, such as sea-level rise and the increase in the intensity or frequency of extreme-weather events.

Infrastructure for Tropical Development

The timely delivery of sustainable and resilient infrastructure is fundamental to realising the UN's 2030 Agenda for Sustainable Development and achieving the Sustainable Development Goals (SDGs). Infrastructure development can help reduce poverty and hunger, improve health outcomes and wellbeing, promote access to education, and assist in realising gender equality. It can provide access to clean water and sanitation and access to affordable, reliable and clean energy. Building, operating and maintaining infrastructure is a powerful stimulant for economic growth and the creation of employment. Sustainable infrastructure can promote responsible consumption and production patterns, support environmental protection efforts and help tackle climate change. As such, the development of sustainable infrastructure cuts across all of the SDGs (Figure 1.1), and is specifically addressed in Goal 9 which calls on the international community to build resilient infrastructure and promote inclusive and sustainable industrialization and innovation (United Nations 2015c).

FIGURE 1.1 **Sustainable and resilient infrastructure development is critical to the implementation of the Sustainable Development Goals. Adapted from Bhattacharya et al. (2016).**

Infrastructure is also an important element of several other major international initiatives relating to development, economic growth and environmental sustainability. The implementation of the Paris Agreement will be dependent on developing infrastructure to promote climate change mitigation and adaptation. In many nations, the rapid rate of urbanisation outpaces the capacity to deliver adequate infrastructure while its provision to people in rural regions is often logistically difficult and cost prohibitive. The New Urban Agenda addresses these important challenges (United Nations 2016b). As emphasised in the Sendai Framework for Disaster Risk Reduction resilient infrastructure is fundamental to preventing and addressing the impacts of natural disasters which have a disproportionate impact on the world's most vulnerable communities (UNISDR 2015). Related to this, the importance of infrastructure in promoting sustainable development and resilience in least developed countries and small island developing states, most of which are in the Tropics, is highlighted in the UN's Istanbul Programme of Action (United Nations 2011), and the SAMOA Pathway (United Nations 2014).

Other recent multi-lateral initiatives including those promoted by the G20 through the Global Infrastructure Hub, the World Economic Forum and various multilateral development banks also emphasise the role of new infrastructure development. The Addis Ababa Action Agenda promotes the need to ensure that all countries and sectors have access to necessary financing and technical expertise and that all infrastructure investment is resilient and aligned with sustainable development. To this end, the establishment of the new Global Infrastructure Forum, facilitated by the UN and led by the multilateral development banks, is designed to become a platform for coordination across infrastructure initiatives and for inclusive dialogue.

These landmark agreements and initiatives will guide actions on global development and economic policy in the coming decades. At a time of great global change and as the world redefines the global development agenda they offer an opportunity to place the planet on a path towards a more sustainable and equitable future with the development of sustainable, resilient and inclusive infrastructure playing a central role.

Tropical challenges need tropical solutions

Most of the world's aspirations for a sustainable and equitable future will play out in the world's tropical zone. As the landmark *State of the Tropics 2014 Report* demonstrates, nations of the Tropics have made extraordinary progress on a range of development indicators in recent decades (State of the Tropics 2014). However, significant challenges persist. Enduring poverty, growing inequalities, poor health and education outcomes,

and environmental degradation remain major obstacles to sustainable development in many tropical nations. With rapidly growing human populations, changing demographics (the region will accommodate more than half the world's population and two-thirds of its children by 2050), economies on the whole growing 20% faster than the rest of the world, and as a host of most of the world's cultural and biological diversity, including ecosystem services that underpin human health and wellbeing, the importance of the region is set to increase.

The development of sustainable and resilient infrastructure is central to addressing the region's challenges and fulfilling its potential but the planning, provision, operation and maintenance of infrastructure in the Tropics are subject to unique challenges that require focused attention. Infrastructure in the Tropics is exposed to environmental conditions, including high heat, humidity, rainfall, and extreme weather events, not experienced elsewhere. Roads, bridges, harbours, electricity networks and buildings are particularly vulnerable to extreme weather events such as tropical cyclones and flooding. Compared with temperate regions, tropical climates can affect infrastructure through higher rates of deterioration. The transfer of infrastructure, technology and policies developed in other parts of the world are therefore often inappropriate for tropical conditions, pointing to the need for increasing opportunities, capacity and investment for developing and scaling up local infrastructure design and innovations.

The onset of climate change is likely to exacerbate the challenges tropical nations face. Indeed, with many of the world's poorest and most vulnerable communities, climate change is likely to disproportionately affect the Tropics. Tropical climatic conditions and extreme weather events are set to intensify with even higher rainfall and temperatures predicted, in some cases resulting in novel climates in equatorial regions that have not been recorded in human history (State of the Tropics 2014). The latitudinal expansion and intensification of climate in the tropical region presents a range of challenges for sustainable development in the region (Ziembicki & Lockie 2016). Small Island Developing States (SIDS), coastal communities and the urban and rural poor in the Tropics are at the frontline of many of these impacts, particularly in relation to sea level rise and natural disaster risks (UNISDR 2015). These countries will need significant investment to "climate proof" infrastructure by improving design and maintenance. These adaptation measures to climate change are critically important to tropical communities but the broader need to mitigate future warming by investing in infrastructure and technologies that emit fewer greenhouse gases is a global priority. Such "greener" infrastructure will play a key role in meeting goals under the Paris Agreement and will require larger investments in clean energy, smart grids, better energy storage and efficiency, transport with lower emissions, and where possible carbon capture and storage. Green and blue infrastructure in this regard will also play an important role (Box 1.2).

Other major transformative trends and challenges impacting infrastructure development in the Tropics include rapid urbanisation and the challenge of delivering infrastructure to rural and remote communities. By 2050, the world urban population is expected to nearly double with two-thirds of the world's population living in cities (United Nations 2016b). Over 70% of the global demand for infrastructure over the next 15 years is expected to be in urban areas (United Nations 2016b). Social and economic exclusion and spatial segregation is a universal feature of cities and human settlements and so ensuring that infrastructure develops equitably, not only within and between nations, but within cities is equally important. Similarly, the larger infrastructure deficit in rural areas, largely due to additional logistical and financial challenges of delivering and managing infrastructure in rural areas, and often compounded by poor political representation, is needed. Most of the world's infrastructure deficit is in tropical rural regions.

Human and Institutional Capacity and Pan-tropical Partnerships

Many of the world's most pressing infrastructure development needs are in the developing and emerging economies of the Tropics. The region includes all 37 UN member Small Island Developing States (SIDS), 43 of the 47 Least Developed Countries (United Nations 2016a) and the majority of nations with the lowest incomes as defined by the World Bank (Figure 1.2). In these nations effective governance and human and institutional capacity issues significantly constrain investment and the ability to develop infrastructure for local needs.

Image: Jeddah, Saudi Arabia. Mark Ziembicki

Green and Blue Infrastructure in the Tropics

BOX 1.2

In the context of human settlements, green infrastructure refers to all natural, semi-natural and designed vegetation within our cities, towns, and peri-urban areas. It can refer to landscape features at various spatial scales including areas of remnant vegetation, public parks, gardens, recreation areas, and trees along streets, as well urban greening architectural innovations such as green roofs and green walls. Blue infrastructure elements are related to water and may include water courses, lakes, or coastal assets such as mangroves, coastal wetlands and artificial engineering initiatives that promote natural coastal resilience (see also Case Study #4). Together they form green-blue infrastructure.

Green and blue infrastructure is generally designed to improve urban sustainability, promote biodiversity conservation, and maintain and/or restore landscape functions including through the provision of natural and cultural ecosystem services. Such services include water protection, carbon storage, noise reduction, flood and landslide prevention, aquifer recharge, heat-island-effect mitigation, air-quality improvement, health-related disease prevention, and an increase in healthy urban lifestyles.

Human settlements and the natural environments of the Tropics may be particularly benefited by well-designed and delivered green and blue infrastructure initiatives. High heat, humidity and rainfall, compounded by extreme weather events and the region's existing large infrastructure deficit, makes human communities and infrastructure in the region particularly vulnerable to the negative repercussions of flooding, storm surges and heatwaves. Additionally, the region's high biological diversity is disproportionately threatened by a broad range of threats (State of the Tropics 2014). With climate change impacts set to bring even hotter and wetter conditions in the future, alongside the region's rapidly growing and urbanising populations, the imperative for effectively incorporating green-blue infrastructure with the built environment to improve resilience of natural and human communities in the Tropics has never been stronger.

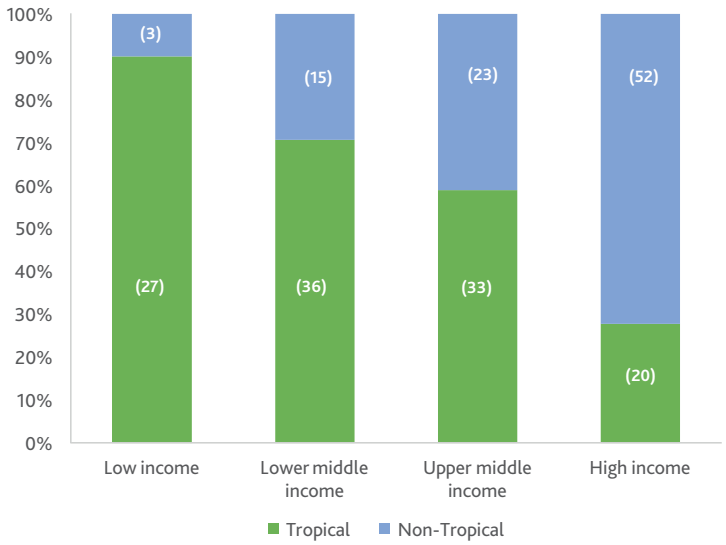

FIGURE 1.2 **The proportion and number (in parentheses) of nations in the Tropics and outside the tropics according to income level as defined by the World Bank (Fantom & Serajuddin 2016).**

The challenge of infrastructure maintenance in the Tropics is also considerable (PRIF 2013). The failure to manage and maintain existing infrastructure assets has contributed in part to the large infrastructure deficit the region faces. The premature deterioration of infrastructure has significant social, economic and environmental impacts. The lack of preventative maintenance is also economically costly given that preventing the deterioration of existing infrastructure usually provides a better financial return than investment in new infrastructure.

Having an educated population with the necessary skills, knowledge and experience to plan, build and maintain major infrastructure assets, alongside developing their own capacity in science and technology to generate innovation is essential. An assessment of the availability of skilled personnel (including research and development professionals and trained technicians) indicates that most tropical nations have a significant deficit in technical capacity, skilled workers and researchers (Figure 1.3 and 1.4).

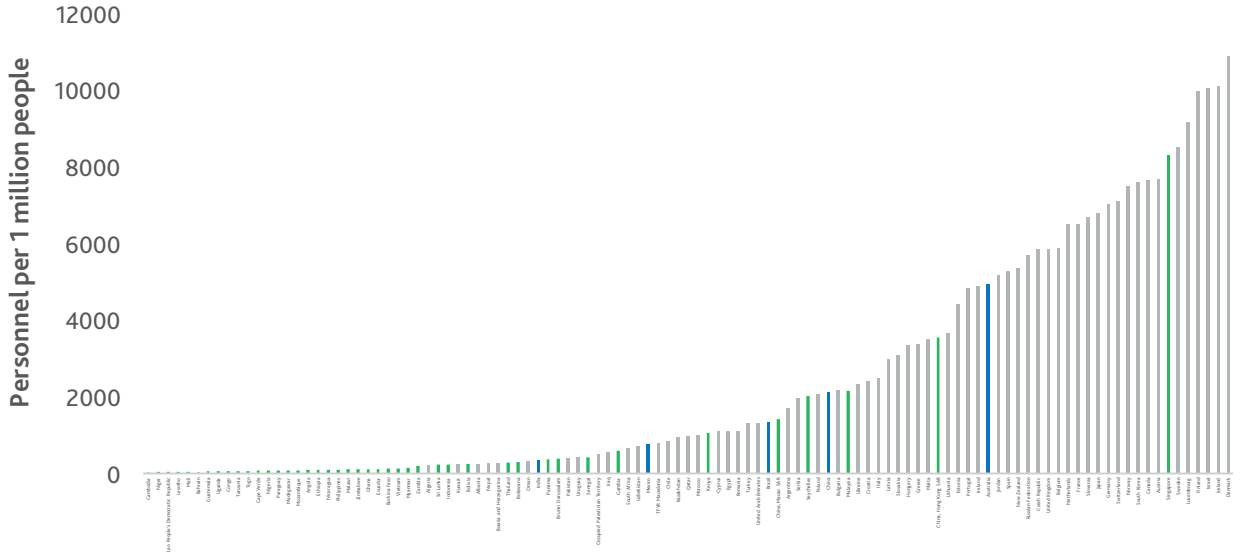

FIGURE 1.3 Number of Research and Development personel per nation based on latest available data (UNESCO, 2017).

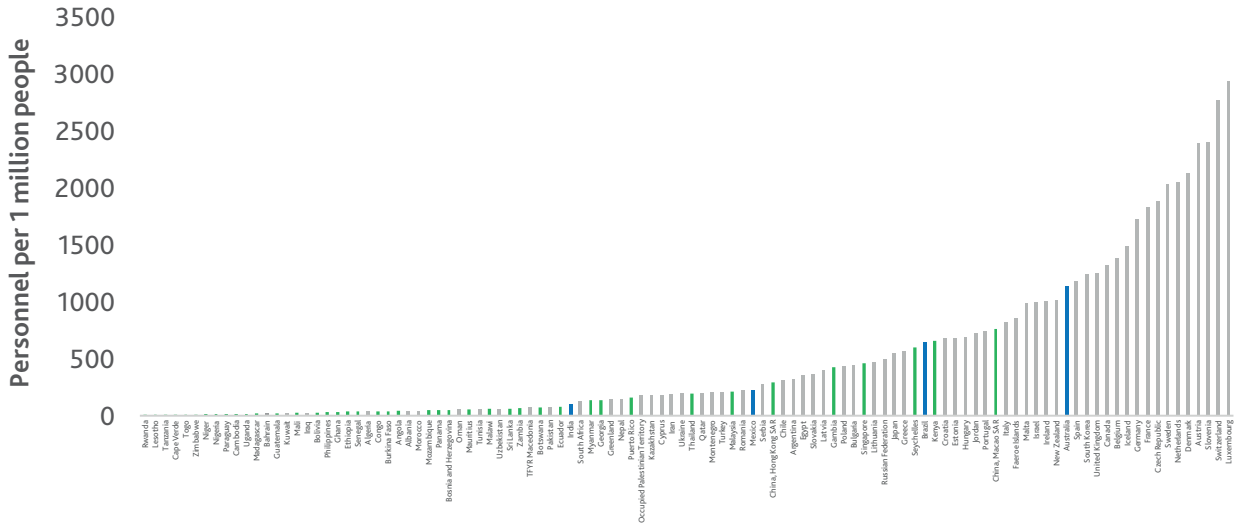

FIGURE 1.4 Number of trained technicians based on latest available data (UNESCO, 2017).

The need and potential for developing local solutions and innovations relating to infrastructure that are appropriate for tropical conditions and local socio-economic contexts underlies the importance of developing human and institutional capacity in developing and emerging economies. The value of drawing on expertise from multilateral development banks, the higher education and research sectors, international organisations and the private sector through building collaborative, multi-stakeholder partnerships between institutions, governments and communities in the Tropics cannot be overstated. Examples of how effective engagement and multi-stakeholder partnerships in two different contexts in the Tropics can work are a focus of Case Studies 1 and 2 in this report.

Such partnerships and engagement at local levels can help drive local innovation and foster the broader application of solutions developed in one part of the region to other parts of the tropical zone. New technologies, increasing connection and opportunities for inter-disciplinary and inter-sectorial partnerships also offer unprecedented opportunity to leapfrog poor practices and technologies by skipping over old types of developments that were inefficient and unsustainable. Throughout the report several examples in different sectors of such opportunities are highlighted, many of which emphasise the potential impact that the development of smart infrastructure can have in redefining how we develop and manage all types of infrastructure in the region (Box 1.3).

Financing and Policy Priorities for Sustainable Infrastructure

The Tropical Infrastructure Gap

Most of the world's infrastructure deficit is in the Tropics. Based on calculations developed from McKinsey & Company (2011) datasets and methods, and drawing on human population estimates for the Tropics, it is estimated that around 69% of the global infrastructure gap occurs in the tropics. This equates to an estimated US$2.3 trillion per annum needed to meet infrastructure needs in the Tropics by 2030, including US$764 billion for energy, US$234 billion for telecommunications and approximately US$385 billion for basic water and sanitation infrastructure.

These estimates, however, are conservative. The Asian Development Bank has recently estimated that $1.7 trillion per annum will need to be spent in Asia alone – particularly if the costs associated with climate change adaptation and mitigation are included (ADB 2017). This compares with an estimate approaching 5.4 trillion annually by 2025 for the entire Asia Pacific region (PWC 2014) where it is expected that the infrastructure market will grow by 7% to 8% a year in the decade to 2025. But even these higher estimates for Asia are likely to be conservative because they refer to baseline costs relating to core or hard infrastructure. They exclude social infrastructure requirements (e.g. health and education facilities), costs associated with training and skill development related to infrastructure operation and management, and do not account for disaster recovery spending which can be substantial. For example, Haiti is estimated to have lost 32% of its GDP in damage to housing, agriculture and critical infrastructure following Hurricane Matthew, which came in the wake of even larger losses due to the 2010 earthquake. The estimates also don't take into account the value of natural infrastructure and ecosystem services, or the role of green and blue infrastructure.

Financing Infrastructure Development

Record low interest rates, availability of finance and rapid technological change offer a historic opportunity to use infrastructure development to promote inclusive economic growth, eliminate poverty and tackle climate change. The way that infrastructure is funded varies around the world and is constantly evolving. Currently, large nation-building infrastructure may be financed in a number of different ways including through public funds, private investment, loans, debt restructuring and donations, or some combination of those. There is an overall global trend for governments to seek private-sector involvement in projects rather than relying entirely on public funding, concessional loans, donations or foreign aid. High-income nations generally finance infrastructure through national budgets combined with private investment. Low and middle-income countries often have to rely on other sources such as multilateral lending institutions, international development aid, and donor organisations. The challenge for tropical countries, particularly those with large infrastructure deficits, high rates of debt and low private investment, is to find an optimum balance in funding sources for infrastructure development as well as create a policy environment which encourages private investment.

Multi-lateral lending agencies play an important role in financing infrastructure projects in the Tropics. Not only do they provide funds but also a governance framework for implementation. Traditional lenders such as the World Bank, the African Development Bank and Asian Development Bank are now being supplemented by new initiatives such as the Asian Infrastructure Investment Bank, the G20's Global Infrastructure Hub, the New Development Bank, the Asia Pacific Project Preparation Facility, the World Bank Group's Global Infrastructure Facility and the Africa50 Infrastructure Fund (United Nations 2015a).

In 2015, countries agreed on a series of bold measures to overhaul global finance practices and generate investments to tackle economic, social and environmental challenges. The Addis Ababa Action Agenda aims to guide financial practices across a broad range of policy issues including technology, infrastructure, taxation, foreign aid, climate change, social inclusion, health, and small and medium enterprises (United Nations 2015a). Through this process, countries agreed to establish a Global Infrastructure Forum to identify and address infrastructure gaps, highlight opportunities for investment and cooperation, and work to ensure that projects are environmentally, socially and economically sustainable (United Nations 2015a). The Addis Ababa Action Agenda especially calls on targeting those countries that face the largest infrastructure deficits, particularly those that are least able to address it for enhanced support, through financial support and capacity building (United Nations 2015a; UNECOSOC 2016).

Investment in infrastructure is considered a strong driver of economic growth, however, increased investment does not always lead to stronger growth. High rates of depreciation of infrastructure assets due to poor maintenance, unnecessary discard and underutilisation are common in tropical countries. Corruption also hinders sustainable infrastructure development. Research suggests that widespread corruption is often associated with high public investment in infrastructure projects, but lower spending on maintenance and operation (Tanzi & Davoodi 2000). Public investment and aid programs focused on delivering new infrastructure, without considering the funding needed for ongoing maintenance, may therefore have a limited impact on longer term economic growth.

Data quality and availability

Poor data availability and accessibility limits capacity to make informed decisions regarding infrastructure investment and development, monitoring of infrastructure performance and the evaluation and minimisation of risk associated with infrastructure projects (Giovannini et al. 2014). There are significant gaps in data availability particularly at national and regional scales. The need for disaggregated data, to account for differences in gender, age, etc. is also important but lacking for most countries and territories in the Tropics.

A major focus of the 2030 Agenda for Sustainable Development is development of data collection protocols and capacity, as well as making information available to researchers, governments, the private sector and local communities in a meaningful way. The Global Partnership for Sustainable Development Data is a multi-stakeholder, open network aiming to harness the data revolution for Sustainable Development.

It is also important to acknowledge the importance of considering the quality of infrastructure when measuring its availability and coverage. Assessing infrastructure quality adds complexity to data collection. For example, just because a community has nominal access to an improved water source such as a tap or pipeline does not necessarily mean it functions or is used. A further example relates to electricity particularly in regard to efficiency. An important indicator in this respect for the power sector is the percentage of electricity lost in transmission and distribution. In 2013, for example, developing Asia still lost about 8% of generated electricity (ADB 2017).

The Smart Infrastructure Revolution **BOX 1.3**

Digitally enhanced or smart infrastructure is the combination of existing physical infrastructure with digital infrastructure such as sensors, networks, IoT, robotics, artificial intelligence and data management. Digitalisation cuts across all physical infrastructure sectors and has huge potential for revolutionising how infrastructure is delivered, managed and maintained. Smart infrastructure offers the opportunity to enhance the provision of services by getting more out of existing infrastructure through increased efficiency, capacity, reliability and resilience. Improving our knowledge of the performance of existing infrastructure through digitalisation, alongside new evolving technologies and innovations, will also allow future infrastructure to be designed to be more efficient, resilient and sustainable.

The rise of smart infrastructure is already having significant impacts across infrastructure sectors. In transport, for example, sensors are being used in road networks to detect traffic density, control lane use and driver speeds and to reroute vehicles to avoid congested areas. Similar applications in railway networks, and the application of digitalisation advances to air traffic control systems, are significantly boosting efficiency and capacity. The water management and energy supply sectors are developing methods to increase the efficiency of supplies. The benefits of applying smart infrastructure to many of the tropical world's infrastructure development challenges is enormous but will require significant investment, human capacity building and collaboration between sectors to realise its potential.

About the report

This report takes stock of the current and historical status of infrastructure development across different regions of the Tropics. It presents a broad ranging, statistical analysis of a set of indicators relating to infrastructure based on data collated from existing datasets from several authoritative, multi-lateral sources including UN agencies, the World Bank and other repositories. The report considers the status and trends in infrastructure development by sector including energy facilities, water and sanitation, waste management, information and communication technologies, transportation and human settlements.

About the case studies

Complementing the report's analyses are a series of thought-provoking case studies that highlight critical infrastructure development issues and best practice examples of innovative sustainable projects in the Tropics. The case studies, contributed by a range of experts working on infrastructure development across the region, cover multiple sectors and locations. They include practical, real world examples of impactful research, governance models, and grass roots initiatives that have relevance beyond their specific locations.

Regions of the Tropics

With most of the world's biological and cultural diversity, and a range of socio-political and economic systems, the world's tropical zone is defined by its diversity. Nonetheless, the region is united by shared characteristics and challenges. To facilitate meaningful analyses and reporting it makes sense to develop groupings that ideally have some degree of commonality or internal homogeneity. There are a number of ways that this could be undertaken, including by climate (wet/ dry/ temperate tropics) and by national borders. As the majority of data available are reported on a national basis it makes sense that 'nations' are the basis of regional aggregations. The regional groupings are listed below and the nations that comprise each region are listed in Appendix 1.

- Central and Southern Africa
- Northern Africa and Middle East
- Caribbean
- Central America
- South America
- Oceania
- South East Asia (including China)
- South Asia

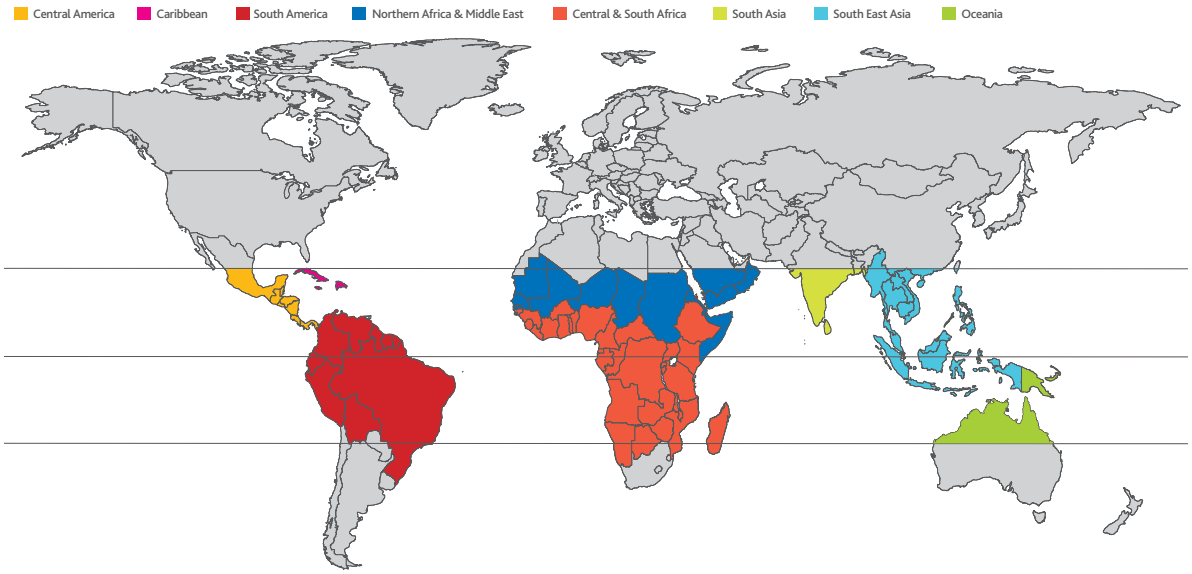

FIGURE 1.5 Tropical regions of the world used in the State of the Tropics analysis.

Nations of the Tropics

In assessing which nations and territories should be included in the report two processes were applied. The first used a population-based decision tool to assess whether nations partially in the Tropics should be included, and the second reviewed data availability to assess whether sufficient data are available to warrant a nation's inclusion in the report.

The geographic area that is the Tropics is clearly defined as the region between the Tropics of Cancer and Capricorn. However, national borders do not neatly align with these latitudinal lines and there are a number of nations and territories that straddle the zone.

The following practical approach has been applied to select nations and territories to be included in the Report:

- The nation/territory is entirely within the tropical zone;
- Nations partially within the Tropics are included if:
  - The majority of the population (i.e. more than 50%) lives in the Tropics (e.g. Brazil, India); or
  - The proportion of the population living in the Tropics is 5% or more of the region's population living in the Tropics (e.g. Australia, China).

Using this decision tool 134 nations and territories were assessed as being tropical nations (See Appendix 1).

About the State of the Tropics Project:

Given the critical, central role of an effective enabling environment there are important opportunities and roles for the higher education sector and research institutions. The State of the Tropics consortium provides a platform to identify and address critical challenges and opportunities faced by nations of the tropics. By bringing together communities with other stakeholders from multiple institutions and sectors, the consortium aims to identify and facilitate action on critical research requirements for sustainable development in the Tropics

In early 2011, a group of leading research institutions with an interest in tropical issues identified a need to examine the

condition of life in the Tropics. The group met in Singapore in mid-2011 to scope a project that would draw on shared expertise to report trends across a broad range of environmental, social and economic indicators. The intent was to shed light on a simple question: Is life in the Tropics getting better?

Reflecting the broad international scope of the project are the key institutions involved. These include:

- James Cook University – Australia
- Escuela Superior Politiécnica del Litorial (ESPOL) – Ecuador
- Mahidol University – Thailand
- The National Institute of Amazonian Research (Instituto Nacional de Pesquisas da Amazônia or INPA) – Brazil
- Liverpool School of Tropical Medicine – United Kingdom and Ghana
- Nanyang Technological University – Singapore
- Organisation for Tropical Studies – Costa Rica
- University of Hawaii (Mānoa) – United States
- University of Nairobi – Kenya
- University of Papua New Guinea – Papua New Guinea
- University of South Pacific – Fiji

On 29 June 2014, the in augural State of the Tropics 2014 Report was launched. That report assessed a broad range of environmental, social and economic indicators. It shined a light on the people and issues of the tropical world, and contributes to efforts to improve the lives of the people and environments of the Tropics.

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Image: Cape York Peninsula. Mark Ziembicki

THE CAPE YORK REGION PACKAGE

Professor Allan Dale, The Cairns Institute, James Cook University

Key Messages

- The deficit in reliable strategic infrastructure to provide connectivity between communities is frequently a major barrier to social and economic development in tropical regions.
- Maximising economic and social benefits from the development of major infrastructure relies on effective public engagement in, and review of, the design, prioritization and implementation of programs.
- The Cape York Region Package (CYRP), a shared $260.5 million investment by the Australian federal and Queensland state governments on an 80:20 basis, showcases the benefits of new engagement approaches in an economically marginalised tropical region.

Tropical Context

Cape York Peninsula is a remote Aboriginal and pastoral domain in north-eastern tropical Australia. The vast region has an area of approximately 128 880 square km, but as at 30 June 2011, it only had an estimated residential population of 16 977. It is expected that the population will reach approximately 20 658 by 2031 (QDSDIP 2014). Most of the landscape comprises Indigenous lands, extensive pastoral estates and conservation areas. Indeed, the region contains some of Australia's most significant biodiversity and cultural diversity, including proposed World Heritage sites. By Australian standards, however, the economic viability of Cape York is vulnerable (Dale et al 2015). There are 11 economically marginalized and remote Indigenous Aboriginal communities scattered around the Cape York Peninsula coastline. Cape York Peninsula is also the only land-based gateway into the Torres Strait Islands and an important link onwards north into Melanesian Papua New Guinea.

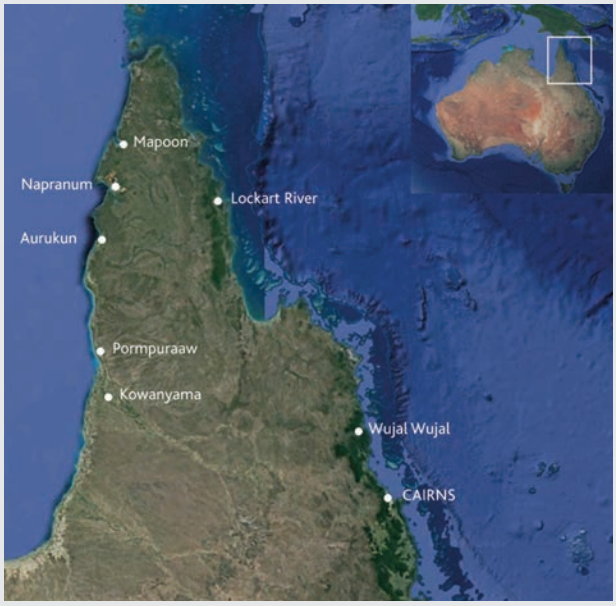

Figure CS1.1 Cape York, Northern Australia. Image: Google

In this tropical regional landscape, development opportunities and social aspects of communities in the region are greatly influenced by a tropical monsoonal climate with very distinct wet and dry seasons (QDSDIP 2014). Due to remoteness and the significant disruption caused annually through tropical monsoons and cyclones, the economy depends heavily on welfare and, currently, marginal remote and extensive pastoral and wilderness-based tourism. Mining on the west coast is the one major (but very localised) economic driver, though much of the industry labour force is drawn from outside the region and the profits are largely exported elsewhere. Indigenous participation in the emerging regional economy is at an extremely low percentile of total population. Workforce participation and employment opportunities have remained limited, with the region experiencing high rates (20%+) of unemployment among Indigenous people. Cape York also has low levels of food, energy and water security. It is a net importer of food and energy with many communities still operating from diesel generators, making it vulnerable to fossil fuel cost spikes (Dale et al. 2016). Significantly elevated freight costs and wet season disruptions further limit food security and generally contribute to high living costs and mobility problems throughout the region.

Background to the project

The lack of a cohesive transport corridor from north to south and connectivity to coastal Indigenous communities has been a major barrier to regional development. For many years, the region's economic development organisations, Indigenous Traditional Landowners, industries, Local governments and Queensland state and Australian federal government agencies have seen strategic investment in resolving this freight and transportation deficit as being essential to economic development. Consequently, cooperation between the regional community, the Peninsula's Local governments and the State and Federal governments led to a highly collaborative approach to the design of, and investment in, solutions.

In 2013, the (then named) Cape York Infrastructure Package – subsequently rebadged as the Cape York Region Package (CYRP) was announced, and reaffirmed by the Australian Government in 2014. It reflects a $260.5 million commitment to a five-year

program of works jointly funded by the Australian and Queensland Governments, based on 80:20 funding arrangements, to upgrade critical (mainly transport) infrastructure on Cape York Peninsula. The package consists of (QDTMR 2016):

- $200 million program of works over five-years to seal some priority gravel sections of the backbone freight route - the Peninsula Developmental Road (PDR);
- $10 million over four years for sealing works on the Endeavour Valley Road (EVR) through to the Hope Vale Aboriginal community; and
- $50.5 million for other priority community infrastructure identified by the Cape Indigenous Mayors Alliance (CIMA).

The 570 km Peninsula Developmental Road (PDR) connects Lakeland to Weipa. The state-controlled section comprises 527 km, from Lakeland to the Rio Tinto boundary, of which sections totalling 144 km were sealed prior to the start of the CYRP. Over the first two years of the CYRP, 68.4 km of bitumen seal was completed, with a further 51.6 km of bitumen seal planned to be delivered in 2016-17.

Since 2014-15, a total of 7.1 km on the EVR has been sealed, with a further 3.4 km planned to be completed. Infrastructure works being undertaken in the eight CIMA communities include upgrades to roads, boat ramps and water and sewage plants.

The core objective of the five-year CYRP (2014-15 to 2018-19) has been to stimulate economic growth and to resolve critical social inequities, while protecting and promoting the region's internationally significant wilderness and environmental values. It is considered that sealing more sections of the PDR will deliver huge benefits to Cape York residents, Indigenous communities and visitors, with a focus on (QDTMR 2015):Reducing road closures during the tropical wet season;

- reducing road closures during the tropical wet season;
- reducing ongoing road maintenance costs;
- improving safety;
- improving access to local roads;
- improving access to the Cape for freight, tourists and other road users; and
- providing a platform for future economic development.

Other benefits include:

- improving community infrastructure; and
- providing employment, training and business development opportunities for Indigenous and (Cape York) local people and businesses.

The real innovation in the CYRP, however, has been the high level of inter-governmental collaboration at all levels that has resulted in combined state and federal commitments to significant regional community engagement in the design and delivery of the infrastructure spend. Both Governments joined together with key regional institutions in the establishment of a CYRP Sub-working Group. Together with the Queensland Department of Transport and Main Roads (QDTMR), the Australian Department of Infrastructure and Regional Development (DIRD) and the Department of Prime Minister and Cabinet (DPM&C), the Queensland Department of Aboriginal and Torres Strait Islander Partnerships (DATSIP), the Department of State Development (DSD), and the Department of Infrastructure, Local Government and Planning (DILGP), this group also involved Cook Shire Council, the Cape York Indigenous Mayors Alliance (CIMA) and key regional development agencies (Regional Development Australia Far North Queensland & Torres Strait Inc and Cape York Sustainable Futures) – all of whom supported the responsible government agencies to engage effectively with the wider Cape York community through regular CYRP Taskforce meetings.

The overarching engagement framework has enabled the regional community to: (i) influence the design and prioritization of the infrastructure program; and (ii) provide feedback on the proposed infrastructure procurement arrangements to help maximize regional, local and Indigenous outcomes from procurement.

Because of the annual tropical wet season, infrastructure works are limited to between May and December, but within each of the five years of the program, these community engagement arrangements have enabled feedback on both forward planning and past efforts in program delivery. At the outset, this feedback has ensured a priority focus on the development of the central Peninsula Developmental Road, and a secondary focus on supporting priority transport and other local infrastructure needs within the eight Indigenous communities represented by CIMA.

A second layer of engagement within this framework involved detailed project-level negotiation following the registration of the Native Title Cape York United Number 1 Claim (QUD673/2014) registered over Cape York Peninsula (Claim), which includes the PDR. The key principle of the Claim is that "Traditional Owners for each area continue to speak for their traditional lands and waters according to their traditional laws and customs" (CYLC 2015). Cape York Land Council (CYLC) is the solicitor on the record for the Claim and has the authority to act on behalf of the named Native Title Claim applicants.

Consequently, negotiations took place between TMR and CYLC regarding an Indigenous Land Use Agreement (ILUA) (QDTMR 2016) and a Cultural Heritage Management Agreement which consented to certain acts being undertaken so the PDR could proceed validly with respect to native title. The ILUA and the Cultural Heritage Management Agreement were authorised under the Native Title Act 1993 (Cth) and then executed by the State and members of the Claim and has been lodged for registration at the National Native Title Tribunal.

The second component of the CYRP, the $10 million sealing project on the Endeavour Valley Road, is the result of extensive collaboration between TMR's Commercial Unit RoadTek and the Hope Vale Aboriginal Shire Council (HVASC). This resulted in TMR signing a Memorandum of Understanding with the HVASC for the provision of road construction and maintenance services to assist in the delivery of the project. Currently in its third year of operation, HVASC employees are working on the project and receiving training in road construction.

Within the Cape's remote Indigenous communities, the major ($50.5 million) package of priority community infrastructure works was identified and developed by the CIMA, representing

the Aurukun, Kowanyama, Lockhart River, Mapoon, Napranum, Northern Peninsula Area, Wujal Wujal and Pormpuraaw local Indigenous Councils, in consultation with QDTMR and DIRD. In nominating the priorities for their local communities, the CIMA Mayors considered each project on its economic impact, creation of training and employment opportunities and the impact on social well-being of the community and cultural significance.

Successes

With just over halfway through its planned five year program of works, the CYRP is currently running both on time and on budget. One of the keys to its success to date has been based on: (i) effective cooperation between federal and state governments; (ii) both levels of government effectively engaging with the Cook Shire and CIMA Councils, the regional community, local Indigenous Traditional Landowners and the delivery industry; (iii) all parties taking a reflective and adaptive approach to the planning and delivery of the program, building long-term partnerships for the future; (iv) QDTMR's proactive engagement with principal contractors to assist with sourcing of Indigenous trainees, employees and businesses; (v) the mentoring role provided by RoadTek to HVASC workers on the EVR and to the Indigenous businesses and employees working on the PDR; and (vi) the innovative use of tailored, incentivized Key Result Areas on the PDR projects namely (QDTMR 2017): KRA 1 Indigenous Training and Non-Indigenous training and upskilling; KRA 2 Implementation of an Indigenous Economic Opportunities Plan; KRA 3 Local Industry Participation.

Notably, QDTMR arranged for a successful north-west Queensland Indigenous business (Myuma) to share the story of their journey in developing Indigenous business sustainability with Hope Vale Aboriginal Shire Council, prior to works commencing on the EVR project. In early 2015, Myuma was also invited by the CYLC to share their story with Cape York Traditional Landowners. QDTMR subsequently sponsored two Traditional Landowners to visit the Myuma Training Site in Camooweal to observe business processes and gain a better understanding of effective program and project delivery to support sustainable Indigenous business capability and promote Indigenous training and employment opportunities.

There is a high level of community satisfaction with the design and works priorities set by the program. Most important, however, has been the focus on securing Indigenous, regional and local community benefit through delivery. With a significant increase in Indigenous, regional and local contractors securing works, the local employment outcomes from the project have been outstanding, surpassing previous major infrastructure efforts.

In 2014-15 and 2015-16, 68.4 km of the PDR was sealed, with 51.6 km of sealing works being undertaken in 2016-17. In 2015 (QDTMR 2016):

- 22 Indigenous trainees were employed on the PDR.
- 15 Indigenous businesses gained work through almost 25% of the contract work
- More than 80 Indigenous workers were employed on the projects (at the peak of construction).

As at 30 November 2016 (QDTMR 2017):

- 87 Indigenous workers, including 35 new entrant trainees, were employed on the sealing and gravel production projects on the PDR. This equates to 27 per cent of the workforce
- 18 Indigenous businesses/joint ventures were working on, or sub-contracted to, PDR projects.
- *The figures above are a point in time only and can vary depending on the work taking place and the stage of the various projects.

Current partnership arrangements will also greatly increase the chance of local, regional and wider political support for continuing the program into the future.

Lessons learned

This case study delivers several lessons that can be applied to other parts of the Tropics. These include:

- Remote communities in the Tropics can benefit from effective engagement with central agencies from the design to delivery phases;
- Structured engagement with Indigenous land holders can greatly reduce risks in project approval and delivery and equally benefit landholders;
- An active focus on securing Indigenous and local benefit from procurement processes can both increase support for infrastructure and boost regional development; and
- Quality processes for cultural heritage assessment and ongoing engagement with Traditional Owners can reduce the impacts on cultural heritage from major infrastructure development.

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IMPROVING INFRASTRUCTURE GOVERNANCE: THE SENTINEL LANDSCAPE APPROACH

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Rebecca Riggs, Tanah Air Beta and James Cook University

Key Messages

- Spatial Development Initiatives (SDIs) leverage broad-based development across the rural regions of tropical countries via coordinated infrastructure investments.
- Governance of SDIs must be coordinated, collaborative and committed to optimising long term sustainability by effectively managing their assets.
- The sentinel landscape approach provides an entry point and mechanism for institutions, including universities, to engage with stakeholders *in situ*, contributing to processes and policies enhancing landscape governance.

Across the tropics, infrastructure is driving environmental, social and economic change in rural landscapes – *they are transforming social-ecological systems*. Large-scale investments in resource exploitation are transforming livelihoods, while also placing enormous pressure on terrestrial and marine ecosystems. These investments are often programmatic, part of regional or national development strategies and are termed spatial development initiatives (SDIs[1]) (Ascher, 1999). SDIs are used as a development strategy throughout the tropical developing world. They have a longer history of use in Africa than elsewhere and centre around infrastructure, aiming for broad-based development (Kuhlmann et al., 2011). Their execution relies upon coordinating hard and soft infrastructure development among a variety of stakeholders in a geographically explicit space. The main drivers of SDIs are typically industrial; i.e. they are companies with the capital and political connections needed to acquire large or valuable tracts of land for their development. In contrast with outreach programs that aim to alleviate poverty, SDIs aim to induce transformative change: supporting economic growth and productivity in specific regions, promoting investment, generating employment and establishing access to new markets (Galves Nogales, 2014; Kuhlmann et al., 2011; Weng et al., 2013). The logic for development is that development initiatives will geographically consolidate around market-driven business opportunities – a process referred to as densification. Densification also means enhancing the development benefits through both backward and forward linkages to improve supply chains, facilitating the ability of local small and medium enterprises to provide more goods and services locally.

Recent SDIs in tropical countries have taken the form of industrialised agriculture or extractive industries, including oil palm and rubber plantations, pulp and paper production, and mining. The supporting infrastructure of SDIs have the potential to deliver benefits to the 1.4 billion people living in extreme poverty, more than two thirds of whom reside in rural areas of developing countries (IFAD, 2010). New roads, ports, electricity and communication networks can provide access to markets, healthcare and education (De & Iyengar, 2014). However, poor design and implementation of SDIs can lead to economic disparities, corruption, elite capture, and rent-seeking thereby diminishing opportunities for inclusive and just development. Further marginalisation of already vulnerable groups must be avoided and rectified (Colchester et al., 2006; Subedi, 2012). Serious concerns have been raised over the rate change in areas of high ecological significance; the environmental consequences of infrastructure development and deforestation in frontier areas are widely recognised (Andersen, 2002; Barbier, 2004; Laurance et al., 2014). As SDIs are situated in places where institutions and policies that govern access to land and resources are poorly implemented or weak, ensuring governance is nurtured is vital if SDIs are to achieve optimal outcomes (Chomitz et al., 2007). The arrangements, capacity and process by which institutions make decisions must be coordinated, committed and collaborate to reconcile conflicting objectives and deliver optimal social and ecological outcomes.

The integrated landscape approach to governing SDIs

As SDIs are a long-term process involving multiple stakeholders, they cannot be governed by a single institution. Stakeholders representing all facets of society have a role in determining their implementation, from local Indigenous groups to global development banks. Governance of SDIs is therefore about power and relationships. It is "the interactions among structures, processes and traditions that determine how power and responsibilities are exercised, how decisions are taken, and how citizens or other stakeholders have their say" (Graham et al., 2003). The primary challenge for SDIs is therefore ensuring meaningful engagement from stakeholders across scales, reconciling conflicting objectives and building consensus among stakeholders towards desirable social and ecological goals. Policies must concurrently target specific regions, key economic

1. We define an SDI as a targeted intensification of economic activity in an explicit space (adapted from Gálvez Nogales, E. 2014)

sectors and households. Collaborative governance, referred to as effective polycentric or multi-level governance is fundamental for building trust between stakeholders, ensuring fair and equitable outcomes and overcoming divisions between opposing institutions (Nagendra & Ostrom, 2012).

How can institutions achieve effective collaborative governance of SDIs? Engineering a 'grand design' is unlikely to maximize the benefits or manage the conservation and development trade-offs in an equitable, just and sustainable fashion (Sayer et al., 2008). Emphasis must be on building a sustainable process, not focusing solely on an endpoint. We must establish a way to manage and govern change in the landscapes that are targets of SDIs, so that governments and stakeholders can achieve sustainable infrastructure development.

Drivers of SDIs are turning to Non-Government Organisations (NGOs) and research institutions to broaden their engagement and build their capabilities at a *landscape* level. The term *landscape* is used to describe a diverse social-ecological system bounded in space where problems need solving. Building capabilities at a *landscape* level therefore requires an integrated and transdisciplinary approach, known as *integrated landscape approaches* (Reed et al., 2016). Specifically, a landscape approach is defined as "a long-term collaborative process bringing together diverse stakeholders aiming to achieve a balance between multiple and sometimes conflicting objectives in a landscape or seascape" (Sayer et al., 2016). NGOs, research institutions, private organisations and governments can use this approach to engage with stakeholders across scales and across sectors, creating platforms for decision-making and reconciling trade-offs. Once a platform for engagement is established, stakeholders can build a management coalition to govern the implementation of SDIs, ensuring accountability, transparency and representation from the entire landscape.

The role of academic institutions

Evidence shows integrated landscape approaches are not simple; they require adaptive management and 'muddling through' (Lindblom, 1959). Yet their recognition and utility in reconciling social and ecological trade-offs is growing (Reed et al., 2016). What differentiates landscape approaches from a traditional approach is their underlying commitment to working across sectors to strengthen processes required for long term engagement. As SDIs can take decades to fulfil their initial objectives, NGOs and research institutions looking to improve social and environmental outcomes must be prepared for long term commitment. At the James Cook University Development Practice Program, we apply a *sentinel landscape approach* to supporting conservation and development institutions in tropical developing countries. Working with partners based in a landscape, our team aims to influence processes and deliver outcomes on-the-ground while ensuring learning, reflecting and contribution to policy. We aim to meet the needs of the practitioners and people living in the landscape while continuing to learn from and improve integrated landscape approaches to implementing SDIs.

> *If researchers position themselves strategically within landscape management processes and adopt an action-research approach, they can gather data and influence the process at the same time. In this way, research can help meet the needs of practitioners and policymakers, while practitioners and policymakers will help in answering relevant research questions (Kusters, 2015).*

A sentinel landscape approach places research institutions in a unique position to influence change. They are an opportunity for deep engagement and reflect the need to do research *in* development, rather than *on* development or even research for development. Rather than transfer skills from one place to another it reflects our pedagogy to cogenerate knowledge, learn together for change, and increase our collective emotional intelligence and empathy. The moral imperative of making progress toward the 2030 agenda means partnering ourselves collaboratively for people, planet, and prosperity. The sentinel landscape approach is an entry point and development laboratory from which to learn. As landscape practitioners, the aim is to build capacity at a local level while having access to resources and capabilities to guide policy and processes at a larger scale. Just as infrastructure gives rise to multi-dimensional impacts at different temporal and spatial scales, we need a holistic approach to understanding and managing change in landscapes. Sustainable infrastructure development requires a collaborative approach to governance. Governments, private companies, civil society and research institutions all have a role to play.

Gorontalo Indonesia

A trans-Sulawesi development corridor is subjecting forested areas to new land-use pressures. Our sentinel landscape in Pohuwato Regency is home to competing land-uses, rural poverty, transmigration villages, and the development corridor is catalysing fast change. Highway development is meant to help deliver new public-private agribusiness partnerships as part of the national economic stimulus plan MP3EI. Large scale agricultural endeavours, including oil palm and corn plantations, are spreading into forest land, catalysing community migration to the area. These communities welcome development opportunities yet also add to the demands on the natural environment. James Cook University has worked with Burung Indonesia (a local NGO) as they initiate ecosystem restoration concessions to reconcile some development pressures on local biodiversity hotspots. Ecosystem restoration concessions are a landmark among policy makers, and James Cook University is working on the ground to help untangle some of the local priorities and needs as they compete with global environmental values. The opportunities to take different, more inclusive and environmentally friendly development pathways are significant and deserve attention.

In Pohuwato Regency of Gorontalo Province roads have expanded and improved. Since 2010, hundreds of kilometres of new "good condition roads" and improvements to poor roads have led to rapid large-scale changes in the agricultural economy of the province. However, poor quality local infrastructure remains a challenge; poor quality roads often wash away and bridges collapse leaving people cut off from essential services. The underlying drivers for the development corridor are major investments in agribusinesses in response to demand for food and stock-feed in Korean and Japanese markets. Locals respond that their livelihoods and wellbeing are improving with better connectivity. Information technology and agricultural extension is transforming livelihoods, and the social-ecological system is in transition. There is an opportunity in this case for greater investment in mediating this transition through a rigorous application of a landscape approach.

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Image: Indonesia. David Gilbert

2

ENERGY

SUMMARY

- Globally, 85% of people had access to electricity in 2012, compared with 70% in the Tropics with access especially limited in rural areas
- Coal and gas are the dominant fuel sources for energy production in the Tropics
- Off-grid renewable energy systems supported by storage technology devices may be a cost-effective solution for rural and remote areas
- Development of renewable energy infrastructure in tropical countries is essential to meet global target of less than two degrees warming.
- The role of private investment in bridging the energy infrastructure gap is important but current investment levels are highly variable and largely remain focused on non-renewable options

2

For the majority of people on Earth, having light at night, being able to stay warm and keeping food cold is as simple as turning on a switch. However, more than one billion people worldwide do not have access to any form of modern energy, while for another billion access is intermittent and unreliable (World Bank, 2015). Most of these people live in rural areas of the tropics.

In terms of infrastructure development, energy generation lies at the intersection of development, poverty alleviation and climate change. Access to electricity is an important aspect of sustainable development playing a vital role in helping communities overcome poverty, promoting economic growth and employment opportunities, and supporting the provision of social services such as education and healthcare. However, electricity generated by fossil fuels is the largest contributor to greenhouse gases produced by human communities. The changing nature of how people are producing and using energy in the Tropics will play an increasingly influential role in the world's aspirations for achieving global sustainable development targets and reducing the impacts of climate change.

The energy sector comprises energy extraction, conversion, storage, transmission and distribution (Bruckner et al., 2014). Energy infrastructure includes power stations, powerlines, transformers and other components of electrical distribution. The extent and condition of energy infrastructure is reflected in how people access and use energy.

Indicators

Access to electricity (% of population)
Modern energy services are considered crucial to human wellbeing, economic development, and environmental sustainability. Access to reliable forms of energy is an essential ingredient to ending extreme poverty. Electrification data are collected from industry, national surveys and international sources (World Bank, 2015). Data are disaggregated by rural and urban dwellers.

Electricity production by sector (% of total)
Electricity is primarily generated through the use of coal, gas, water (hydro-electricity), nuclear and a number of renewable sources such as solar energy wind power, geothermal, biofuel, and tidal. Greenhouse gas emissions from electricity generated by fossil fuels are a major contributor to human induced climate change. A focus on developing renewable energy in the tropics is essential if the globe is to meet its target of less than 2 degrees of global warming by the end of the century (UNFCCC, 2015). Exploring the changing nature of how energy is produced is essential for planning a sustainable future for the Tropics and the world. This indicator demonstrates the degree to which regions of the tropics have developed infrastructure relating to different types of fuel sources and the share of renewable energy in the overall energy mix.

Investment in energy with private participation (Total investment and number of projects)
In many nations, particularly in the tropics, central governments may not be able to afford to develop and maintain the necessary infrastructure to improve access to modern forms of energy. Private investment will need to be an important component contributing to energy access for the future, however governments have a key role in ensuring private investment is ethical, sustainable and promotes equality as well as profitability.

International goals and agreements — BOX 2.1

Throughout the world there is growing momentum to set ambitious infrastructure targets to provide universal access to safe, sustainable energy. Energy is centrally placed amongst the Sustainable Development Goals (SDGs) proposed for the 2030 Agenda. SDG 7 focuses solely on energy with several ambitious targets (Bruckner et al., 2014).

SDG #7 *Ensure access to affordable, reliable, sustainable and modern energy for all*

- By 2030, ensure universal access to affordable, reliable and modern energy services
- By 2030, increase substantially the share of renewable energy in the global energy mix
- By 2030, double the global rate of improvement in energy efficiency
- By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology
- By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support.

Supporting the Sustainable Development Goals is the Sustainable Energy for All Initiative (SE4All), a United Nations and World Bank supported program which by 2030 aims to:

- Ensure universal access to modern energy services.
- Double the global rate of improvement in energy efficiency.
- Double the share of renewable energy in the global energy mix.

The Sustainable Energy for All initiative also acts in support of the 2014-2024 Decade of Sustainable Energy for All as declared by the UN General Assembly.

Alongside these initiatives, in November 2015, 189 nations who were represented at the United Nations Climate Change Conference negotiated the *Paris Agreement*. This agreement came into effect when nations representing more than 55% of global greenhouse gas emissions signed the agreement in April 2016 in New York. This agreement has the goal of limiting global warming to less than 2 degrees Celsius (oC) compared to pre-industrial levels. The agreement calls for net anthropogenic greenhouse gas emissions to reach zero before the end of the 21st century (United Nations, 2015). Given that most greenhouse gas emissions are produced to create electricity, in order to reach the above goals and achieve zero emissions, all nations will need to transform the way energy is produced.

Trends

Access to electricity

Access to electricity allows water to be pumped for crops, enables children to study after dark, families to access the Internet to support income generation and for food and medicine to be refrigerated. Globally, the proportion of people with access to electricity rose from 76% in 1990 to 85% in 2012. This growth in access was overwhelmingly in urban areas (Schnitzer, 2014).

In the Tropics, just over 70% of people had access to electricity in 2012, up from 56% in 1990 (Table 2.1). Although access has improved considerably, it remains much lower than in the rest of the world where nearly 95% of people have access (IEA, 2015) For further perspective, 76% of all people without access to electricity (more than 800 million people) live in the Tropics.

Regionally in the Tropics, the largest increases were in South East Asia and South Asia. Access in Central and Southern Africa, Northern Africa and the Middle East and Oceania remains low (Table 2.1). When tropical Australia and Hawaii (USA) are removed from the analysis, Oceania has the lowest electricity access in the Tropics. Unlike other under-served regions, access to electricity has barely kept up with population growth in the region, growing only 7% since 1990. Developing infrastructure to expand electricity access in Oceania faces unique issues given significant logistical challenges associated with small populations dispersed across tens of thousands of islands (Dornan, 2014).

Of the tropical regions, South Asia has demonstrated rapid improvement. India was the largest contributor to global improvements with more than 40 million people gaining access to electricity in tropical India between 2010 and 2012. Despite this improvement, tropical India still has the largest number of people without access to electricity in the world (more than 150 million). The Caribbean, Central America and South America all have relatively high rates of access to electricity with many nations comparable to, or exceeding, the global access rate.

TABLE 2.1 **Access to electricity in the Tropics 1990-2012. Data are the percent of the population with access to electricity. Electrification data are collected from industry, national surveys, and international sources (World Bank, 2016b).**

REGION	1990	2000	2010	2012
	%	%	%	%
The Tropics	**56.40**	**62.67**	**68.43**	**70.87**
Central & Southern Africa	20.36	23.97	29.67	33.29
Northern Africa & Middle East	24.64	28.21	31.47	35.23
South Asia	49.69	60.61	73.87	77.61
South East Asia	74.53	83.51	90.38	92.19
Caribbean	74.06	77.72	80.90	82.11
Central America	89.47	92.33	93.93	94.54
South America	90.61	94.76	96.58	98.14
Oceania	40.19	39.51	40.49	42.92
Rest of World	**87.39**	**90.36**	**93.61**	**94.61**
World	**75.65**	**79.31**	**83.08**	**84.58**

Rural and Urban access to electricity

Globally, fewer people have access to electricity in rural areas than in urban centres. Although tropical regions display considerable variability, lower rates of urbanisation in the Tropics compared with the Rest of the World mean that most of the underserved population lives in tropical rural areas (Figure 2.1). In 2012, just over 30% of rural dwellers in Central and Southern Africa and Northern Africa and the Middle East had electricity access compared with 70% and 67% in urban areas respectively. South East Asia and South Asia exhibited similar patterns, with Oceania (when tropical Australia and Hawaii are excluded from analyses) having among the lowest energy access rates outside of cities. In Papua New Guinea, for example, it is estimated that less than 20% of people living outside of urban areas have access to electricity. In Central America, South America and the Caribbean there is less variation between rural and urban areas reflecting higher rates of urbanisation and greater access to electricity grids, particularly to hydro-electricity, in rural areas of South America (Figure 2.3).

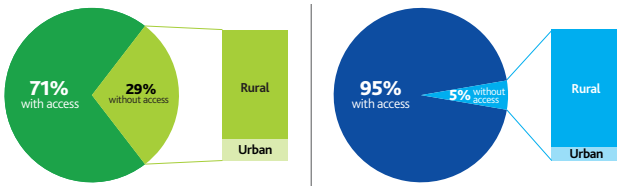

FIGURE 2.1 **Percentage of the population with access to electricity in The Tropics (left) and the Rest of the World (right). The proportion of people without access to electricity are disaggregated by urban and rural dwellers (World Bank, 2016b).**

Reliable Access

Although access to the electricity grid has improved in the Tropics this does not necessarily ensure constant or reliable supply. It is estimated that beyond the 1.1 billion people who do not have access to electricity, a further billion do not have access to reliable electricity (World Bank, 2015). Unreliable access to electricity is a particular problem in Central and Southern Africa and South Asia. Nigeria, for example, a nation with major oil and gas reserves, will have power outages, even in urban areas, on up to 50 days per year due to limited generation and transmission capacity, poor maintenance and inefficient supply chains (World Bank, 2015). In other areas of the Tropics, rapid economic growth has created challenges in meeting increased demand for electricity. In rural India, 24-hour electricity supply is rare, despite improvements in access (largely based on coal expansion). Further development of distribution infrastructure is essential; as ongoing demand will continue to outstrip supply. The challenge will be meeting this shortfall of electricity access without having to rely on large-scale expansion of fossil fuel based electricity generation.

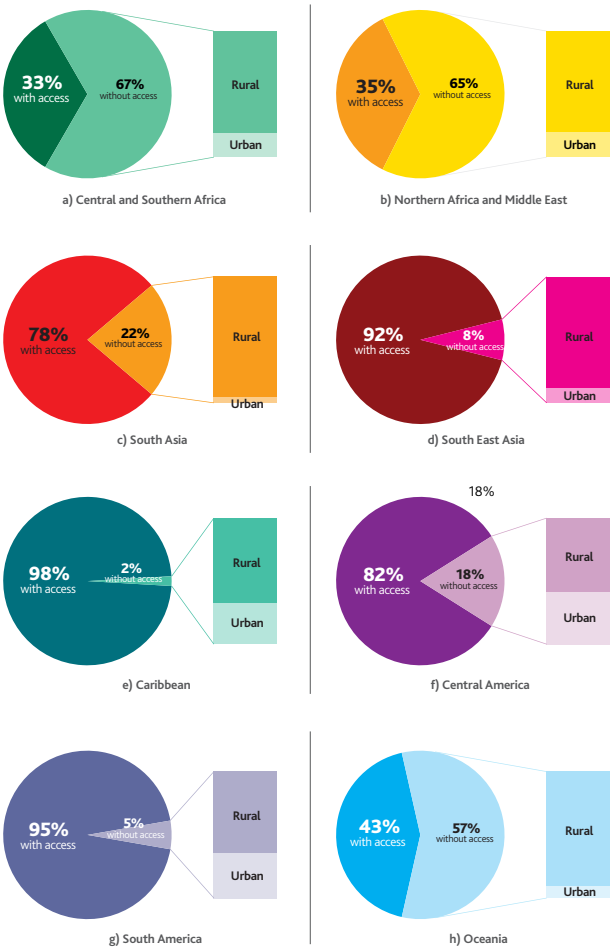

FIGURE 2.2 Proportion of the population with access to electricity in 2012 disaggregated by rural and urban areas by region of the tropics (World Bank, 2016b)

Energy production and renewable energy

Electricity can be generated from several fuel sources. How each nation chooses to develop their electricity supply sector is based on a range of criteria including supply risks and price, and numerous social, political and environmental considerations.

Currently, the main fuels used to generate electricity are coal, gas, water (hydro-electricity), nuclear and a number of renewable sources, such as solar and wind power. Globally, total electricity generation almost tripled between 1980 and 2012 while per capita production increased by 140%.

Coal and gas still account for the vast majority of energy production: 40% and 22% respectively in 2012 (Figure 2.4). According to the International Energy Agency (IEA) hydro-electricity accounted for 18% of global electricity in 1980. Despite increasing output throughout the 1980s and 1990s (primarily due to developments in China and Brazil), its contribution to the overall energy production mix as a proportion dropped to 14% in 2012. Although it remains a small proportion of overall energy production, the contribution of renewable energy (excluding hydro-electricity but including solar, biofuels, geothermal, wind, waste and marine) increased from 0.2% in 1980 to 3.7% in 2012.

All regions in the Tropics have increased their electricity production dramatically since 1980 (Figure 2.5). However, there is a great deal of variation in the energy production mix between regions largely as a result of inherent differences in available resources, existing infrastructure, capacity, socio-economic circumstances and political contexts. Although the relative share of coal and gas use for power generation has increased in the Tropics, their proportional contribution to the overall energy mix is similar to that outside the tropics. Hydro-electricity on the other hand is notable for its significantly greater and increasing role in electricity generation in the Tropics, particularly in South America and Central and Southern Africa. Although considered a renewable source of energy production the increase in hydroelectricity has come with a rapid expansion of dam building which has its own set of social and environmental issues (World Bank, 2016b). Other renewable energy uses have shown comparable patterns of increase in the Tropics to the rest of the world. By comparison, nuclear energy contributes very little to the energy mix in the Tropics but has increased slightly, particularly in South Asia where it has been driven by nuclear power development in India.

FIGURE 2.3 The Earth by night. Tropical regions of Africa, South America and Oceania show low rates of electrification. Image credit: NASA

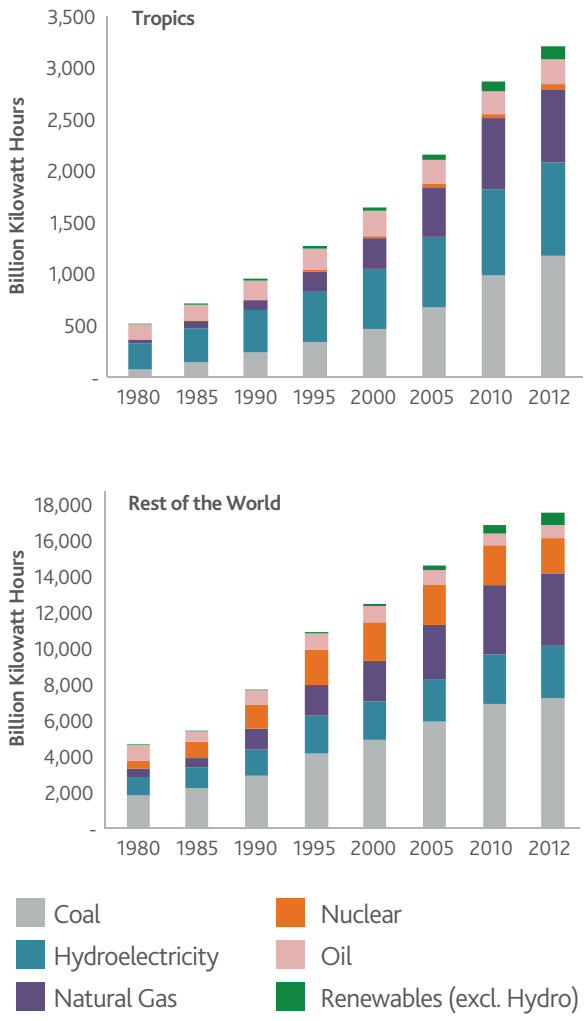

FIGURE 2.4 **Total electricity production contribution of fuel sources to electricity production in A) The Tropics and B) Rest of the World (IEA, 2015).**

Although hydro-electricity dominated the production of electricity in Central and Southern Africa and South America, oil has become increasingly important in both of those regions in recent years. This is due to growing output from Nigeria, Mozambique, Angola and Tanzania in Africa (IEA, 2015,) while in South America, domestic policies in Brazil have resulted in expansion in offshore oil extraction (IEA, 2015). In Oceania, South Asia and South East Asia, coal remains the most important source of energy production fueled by extensive coal fired power production in India, China and Australia. Data from Oceania should be interpreted with caution as data on fuel sources are only available from Australia and United States (Hawaii), however other sources suggest that most nations in Oceania are dependent on imported oil, although hydro-electricity is important in Papua New Guinea (EIA, 2016). Oil and gas were the most important fuel sources in the Caribbean and Central America due to substantial oil resources in Mexico and the USA.

It is clear that despite recent increases in renewable energy sources and infrastructure, fossil fuels continue to contribute most to electricity generation worldwide. In order to achieve the UN's 2030 goal of 'affordable, reliable, sustainable and modern energy for all' production will need to continue increasing. The challenge for the Tropics, as for the rest of the world, is to increase the contribution of renewable sources alongside improving the efficiency of fossil fuel based generation, in order to meet emissions targets.

In the short to medium term, improved efficiency in the production and consumption of energy is considered the most economically viable and available means of reducing greenhouse gas emissions and improving energy security (IEA, 2015). Increased efficiencies result in lower CO_2 emissions and lower costs. During a period of increasing demand for fossils fuels due to rapid development, efficiency goals are critical for sustainable development. In the long term, however, planning must occur that will allow tropical nations to access and use safe, reliable and renewable energy that is most appropriate for each country's particular circumstances.

Decentralised Solutions

The traditional approach to increase access to electricity of underserved populations is to extend the central electricity grid (Schnitzer et al 2014). Doing so, however, is expensive, and tends to rely on relatively few, large, and remote power stations. Decentralised energy, distributed generation or off grid power solutions refer to energy production systems which are produced close to where they are used, produce smaller amounts of electricity, are often not connected to national power grids and increasingly, are powered by renewable energy (although diesel generation remains important). Local generation can reduce transmission costs, reduce power losses, require smaller initial investment and have a smaller carbon footprint. Micro-grids employ various generation techniques including diesel, solar photovoltaic, micro hydro, and biomass gasification, as well as hybrid technologies such as wind-diesel and solar-diesel, often supported by energy storage technologies.

In many countries, diesel generators represent a significant proportion of total installed power capacity. For example, up to as much as 50% in the Democratic Republic of Congo and 17% in West Africa as a whole. However, the cost of diesel-based generation can be several times higher than electricity generated from larger power plants (Beér, 2007). This has incentivised a focus in the developing world on renewable, off grid solutions such as solar and micro-hydro (Foster and Steinbuks, 2008).

Geography also represents an additional constraint to the development and reliability of the electricity market in the Tropics. In countries where electricity is mainly generated through hydroelectric power stations, availability and reliability of power is highly dependent on weather conditions. During periods of poor rainfall or heavy flooding, power shortages

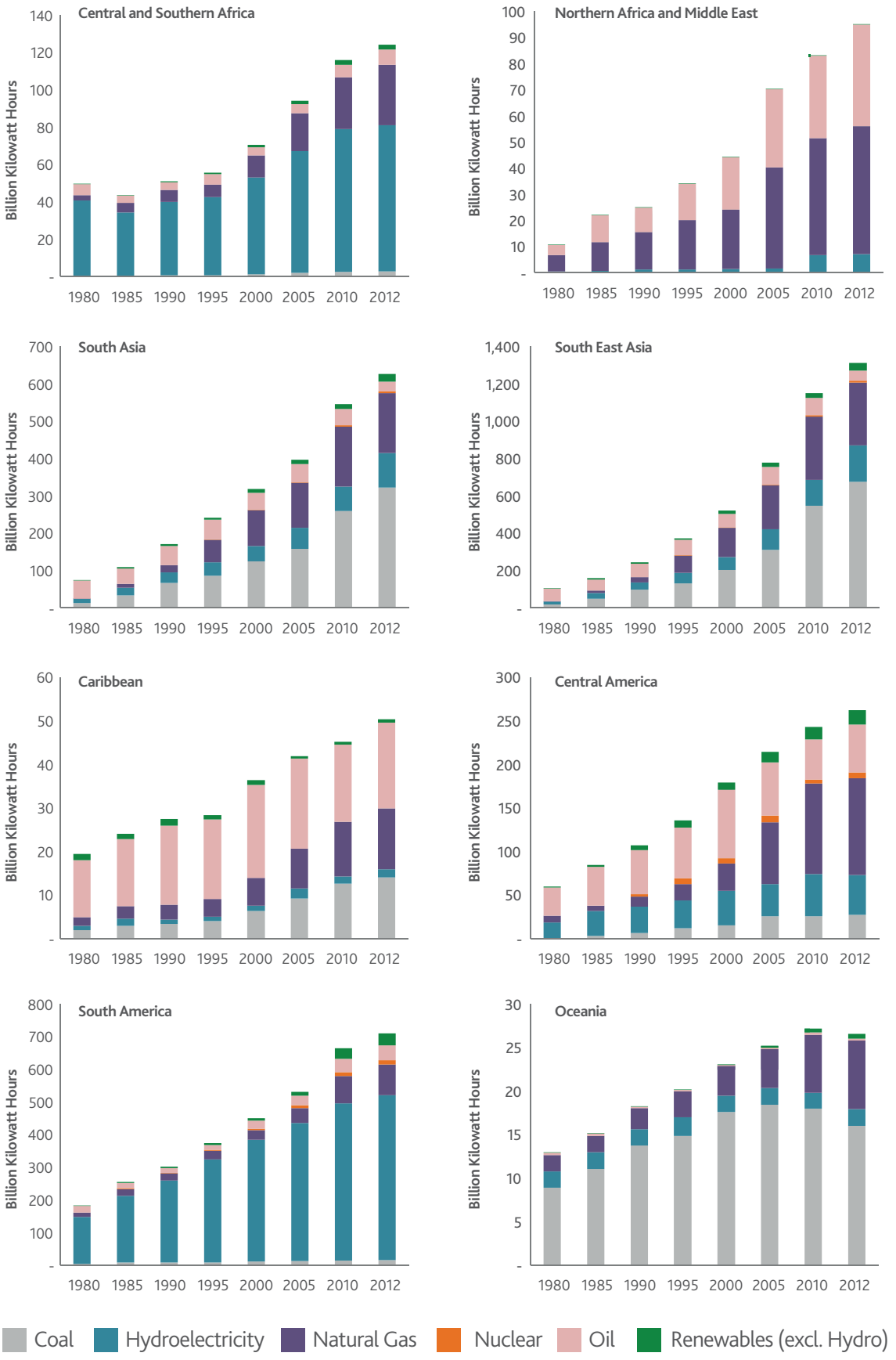

FIGURE 2.5 Total electricity production and contribution of fuel sources to electricity production between regions in the Tropics (World Bank, 2016b)

"The challenge we face is big, perhaps bigger than many people imagine. But so is the opportunity. If the world can find a source of cheap, clean energy, it will do more than halt climate change. It will transform the lives of millions of the poorest families."

"A cheap, clean source of energy would change everything."

Bill Gates, 2016

and disruptions can be a frequent occurrence. These uneven weather events add up to the cost of generating and transmitting electricity in countries with challenging geographic conditions. Potentially, having a local, smaller scale source of energy generation could reduce the costs and risks associated with distributing energy over large distances.

Role of the private sector

Universal and sustainable access to electricity in the Tropics will require significant investment. Estimates from the Global Tracking Framework (Schnitzer, 2014) suggest that a doubling or tripling of historical capital flows will be needed to achieve the 2030 Agenda and Sustainable Energy for All targets (Box 2.1). Other estimates are even higher; the World Energy Outlook suggests that a fivefold increase in capital is needed (World Bank, 2015). Given energy infrastructure is considered a public good, responsibility for provision generally falls to the public sector. However, the investment required is far beyond what central governments in developing nations are able to contribute and private sector capital will be necessary to reach these goals. Multilateral lenders such as the World Bank, African Development Bank and the Asian Development Bank provide finance for energy infrastructure as part of their mandates, yet have limited resources compared with the scale of the energy infrastructure deficit.

Public-Private Partnerships (PPPs) are a key way in which governments secure financing and expertise for infrastructure development (IEA, 2015). The World Bank compiles details of PPPs in infrastructure development in low and middle-income countries. The energy sector generally has the largest number of PPP projects as well as the greatest overall investment (Vandenberg, 2015). Although in the Tropics on the whole, the total amount of investment is greater for Information and Communication Technology infrastructure (World Bank, 2016a).

Available data on PPPs do not include information for high-income nations so global estimates are not available, however coverage is sufficient to explore the variation of investment in energy infrastructure across developing countries in the Tropics (Chao and Kasper, 2015). Total investment in public-private partnerships for energy infrastructure varies considerably across the tropics and over time (Figure 2.6). The vast majority of investment in the past two decades has been in South America and increasingly, South Asia. Investment with private participation in South East Asia has been consistently high. Comparatively, Central and Southern Africa, Northern Africa and Middle East and Oceania have had very low investment, despite the significant need for new energy infrastructure.

The total number of new investments in energy projects in the Tropics has actually declined since the mid 1990s (Figure 2.7). However, the scale of the investment indicates that although there are fewer projects, these projects are likely to be larger than previously. It is also likely that these data do not capture many small-scale, off-grid projects.

In South East Asia, new energy investments are driven by comparable investments in Malaysia, Indonesia, Philippines and more recently Vietnam. In South Asia, the vast majority of investment was in India. In South America, investment amounts were driven by Brazil, although there were significant investments in Peru and Colombia as well.

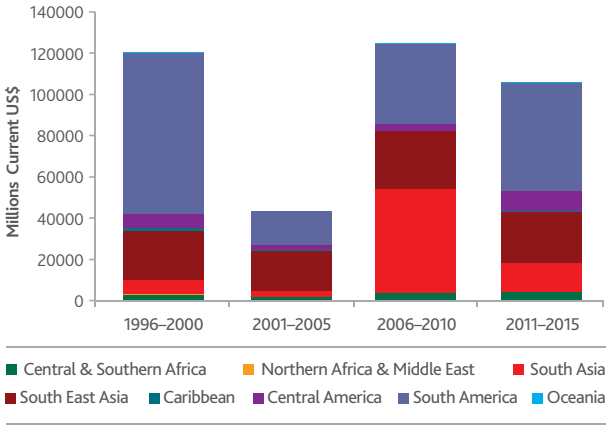

FIGURE 2.6 **Total investment in energy infrastructure with private participation by tropical region (World Bank, 2016a)**

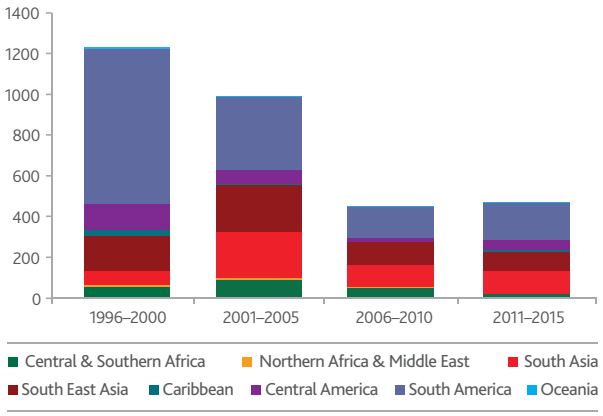

FIGURE 2.7 **Total number of energy projects with private investment across the tropical regions (World Bank, 2016a)**

Despite international goals and agreements focusing on developing renewable energy infrastructure, coal fired energy development has received the largest investment from the private sector in the Tropics since 1990 (Figure 2.8). The dominance of coal is driven by large investments in India where around 70 projects are recorded (World Bank, 2016a). There has also been significant investment in hydroelectricity (mostly in South America) and natural gas. Natural gas investments are spread throughout the Tropics, including in Africa, South America and South East Asia. Aside from hydroelectricity, onshore wind power generation has the largest investment of any renewable technologies driven in large part by many new projects in Brazil (71 projects); India (54 projects); and Mexico (15 projects) (World Bank, 2016a).

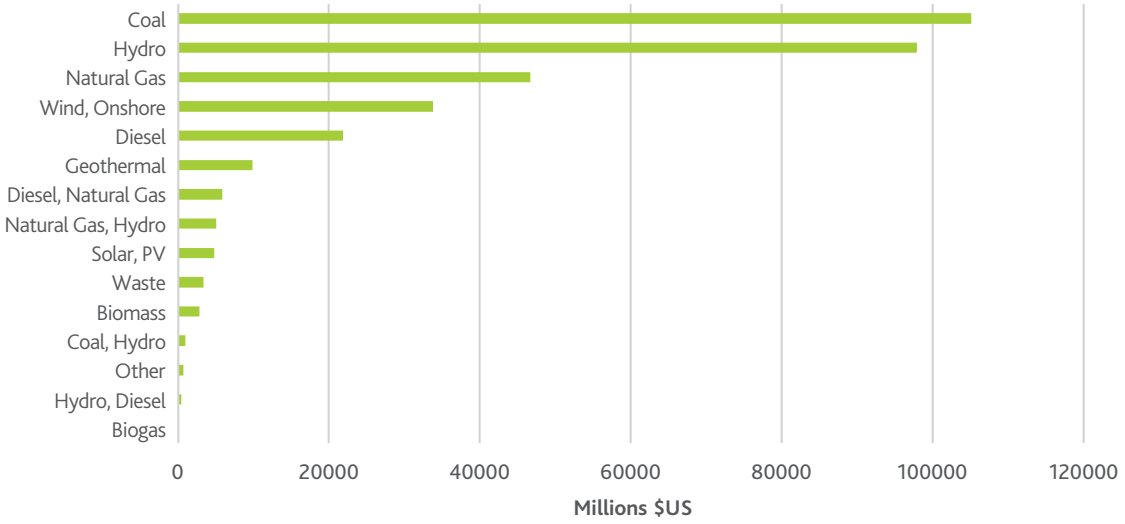

FIGURE 2.8 **Total investment (Millions USD) across energy technologies in the Tropics (World Bank, 2016a)**

The Asian Development Bank estimates energy infrastructure requirements in Asia alone will exceed $4 trillion in 2010-2020 (World Bank, 2016a). It is clear that private investment will be needed to meet this estimated shortfall. Tropical nations will need to create the appropriate financial and governance arrangements to encourage private investment in public good infrastructure such as renewable energy.

Relationship with other sectors

Energy influences the socio-economic condition of people and their communities in a number of ways. Access to electricity can be transformative in terms of health, education, income and the environment.

Health

Universal access to modern energy services in health facilities and at home is an essential requirement for improving health and wellbeing (Vandenberg, 2015, Adair-Rohani et al., 2013). Reliable electricity enables refrigeration to be used for storing medication and vaccines while also preserving fresh food. The presence of electricity in health care facilities can improve the range of potential primary care interventions. In the home, modern electricity is used to run air conditioningand reduces exposure to a wide range of hazardous pollutants created by burning fuel wood or coal for heat and cooking. It also reduces the need to collect fuel wood, which improves health and wellbeing of women and children. People of those countries with higher access to electricity have higher life expectancy and better quality of life.

Education

Education is widely recognised as one of the most essential components for sustainable development and shows a large return on investment in terms of economic growth. Access to electricity can have a huge impact on education. It eliminates the need to collect fuel wood, which increases the opportunity to attend school and other educational opportunities. Electricity enables study after dark and families can use television, radio, computers and other information and communication technologies for educational purposes (Adair-Rohani et al., 2013). Evidence from India indicates that access to electricity has a positive impact on school enrollment and literacy rates (Kanagawa and Nakata, 2008).

Income

Generally, it is people living below the poverty line who do not have access to electricity and it is argued that the lack of access to modern energy is a contributing factor for people remaining poor (Kanagawa and Nakata, 2008). One of the most important aspects of access to electricity is its impact on income generation, particularly for small and medium enterprises. Higher electricity consumption per capita is correlated with faster economic growth. Electricity access lowers production costs, increases profit margins and helps develop and modernize businesses (Kanagawa and Nakata 2008). Something as simple as a light can allow entrepreneurs to work at times convenient to the household. Income generating activities can be combined with household duties, having a particularly positive effect on the incomes of women (Kooijman-van Dijk and Clancy, 2010).

Environment

The relationship between energy and the environment is an important and complex one. At a household level, having access to electricity can reduce the use of wood for cooking (thus preserving local forests) and contribute to better air quality. Electricity generated from larger plants generates less greenhouse gas and is cheaper to run than diesel generators. However, while there are obvious local scale social and environmental benefits, on a global scale, the energy supply sector is the largest contributor to global greenhouse gas emissions. Latest available estimates from the Intergovernmental Panel on Climate Change (IPCC) suggest 35% of total anthropogenic greenhouse gas emissions are attributed to the energy sector (Bruckner et al 2015). Currently in the Tropics, new investments in energy generating technology still favour coal, oil and gas. Energy generation will play a central part in reducing greenhouse gas emissions and stabilising global temperatures. As technology improves there are opportunities for tropical nations to develop renewable solutions that are suited to a tropical environment and prevailing social and economic conditions.

Image: Rwanda. USAID and Power Africa

Looking forward

Access to clean, reliable energy is a major infrastructure challenge for the Tropics and a key focus of the 2030 Agenda for Sustainable Development. Without access to electricity, it is unlikely that other development projects such as schools and health clinics can achieve their goals. Currently in many parts of the tropics, particularly rural areas, people are more likely to have a mobile phone than electricity at home to charge it.

Countries of the Tropics with low or variable access to energy face a wide range of choices when planning the future of their energy sector. There is no doubt that to achieve global goals for sustainability and halt the impacts of human induced climate change, the energy sector worldwide will require some transformation. Large scale efficiency will need to be found in existing grids in cities and industries, and alternate source of energy will need to be used in places where existing access is low. As renewable energy becomes more and more cost effective it will allow tropical nations to explore diverse supplies of energy to meet increasing demand.

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Image: Cambodia. Mark Ziembicki

HOW RWANDA'S CLINICS HAVE GONE OFF-GRID AND ONTO RENEWABLE ENERGY

Assistant Professor Taha Selim Ustun, Carnegie Mellon University

Rwanda is located in the poorest region in the world, sub-Saharan Africa. Despite this, it is making advances with off-grid renewable energy solutions for rural areas that could be a model for similar economies. Rwanda has harnessed its endowment with enormous, untapped renewable energy generation potential to address the problem of how to get energy into remote parts of the country.

The approach being taken accepts that extending the electricity grid to remote areas is fraught with problems. It is expensive, transport costs are high, and accessibility is difficult. In sub-Saharan Africa, grid-extension costs $23,000 per kilometre (Deichmann et al., 2011).

A project to get clinics in remote areas of Rwanda onto reliable sources of renewable energy has recently been stepped up a notch with the introduction of technology that smooths distribution ((Blumenthal, 2008).

Small-scale generation for remote areas

Off-grid electrical systems, where power is derived from renewable energy, have the potential in Rwanda for taking advantage of several types of small-scale generation.

This has become more feasible with the development of new technologies that have revolutionised the possibilities for making these systems highly resilient and economically sustainable. Examples include smart meters with wireless communication and sophisticated technology for fine-grained monitoring and control.

Rwanda is taking advantage of developments such as this to crack the problem of getting electricity to remote clinics.

Uninterrupted access to electricity is a key requirement for improving care in health facilities. But access to either grid or off-grid electricity is still one of the grand challenges for rural health centres in the region. One-quarter of health facilities are not connected to any source of electricity. On average, three-quarters of facilities have no reliable source of electricity (Adair-Rohani et al., 2013). This leads to a poor health care service delivery.

83% of Rwanda's population live in rural areas (United Nations, 2014). This makes healthcare in these areas all the more important. And ensuring that healthcare centres have power is vital. To overcome this obstacle decentralised power sources such as photo voltaic (PV)systems are becoming popular in rural areas because of their cost effectiveness compared to grid extensions. PV systems basically convert solar energy to direct current electricity using semi-conducting materials. But these have not proved adequate in matching supply with demand because:

- Health centres operate on a first-come first-serve basis. If health centres continue to use connected electronic devices without proper management, the chances of blackouts will increase and patients will suffer.
- Unused energy from fewer patients than expected also presents a problem as energy is wasted. Making batteries available to store energy can be a way to ensure less is wasted, help avoid shortages and manage excess demands. But this option is expensive.

Figure CS3.1 shows the ad-hoc scheduling of energy services in PV-power health clinics. Between t_0-t_1, the power demand exceeds available solar power. The t_1-t_2 window sees no load. This results in some services not being delivered, unnecessary use of batteries, and hence a shorter life-time, and less orderly operation.

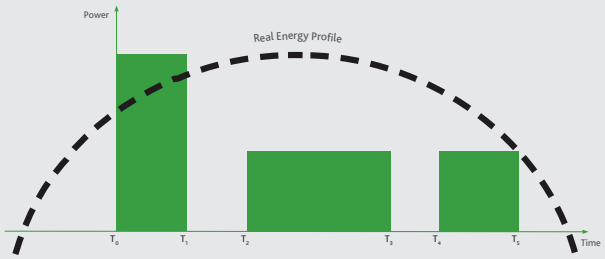

Figure CS3.1 Existing ways scheduling show overutilization of the energy generated by solar systems.

Smart scheduling has done the trick

Smart scheduling is used to match consumption of active services with the available solar power. This results in minimum use of batteries or other energy sources.

The idea lying behind is as follows: the central controller estimates daily solar profile of the PV panels by pulling solar radiation information from online servers. Then when a physician wants to undertake an operation that requires electricity he sends a request to the central controller. This request includes power consumption and the duration of the operation.

In our prototype, the final decision lies with the system. Different services have different priorities. So, a surgery room may be given the highest priority during system planning. If an emergency occurs and a surgery room is fed into the system, it will be given the highest priority.

But human intervention is possible. The central controller is a photo voltaic (PV) inside the clinic. This means that a clinic administrator or the highest ranking physician can tap into the system, remove some services from the list and add some others. The central controller checks the available solar power and the loads that are already being served. If there is sufficient excess

energy, the request is confirmed and the energy is delivered. If there is not sufficient energy the controller schedules the request to when there will be enough energy. This may happen due to solar radiation, hence the generation, increasing or a service that was already receiving energy load being terminated.

In this way, facilities are used in a smart way and solar generation is used as it is generated.

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WATER, SANITATION AND WASTE MANAGEMENT

SUMMARY

- 514 million people in the Tropics do not have access to improved drinking water infrastructure, including more than one out of three people in the tropical regions of Africa and the Middle East and Oceania.
- Just over half of all people in the Tropics have access to improved sanitation facilities meaning 1.5 billion people still go without.
- Oceania is the only region of the Tropics where sanitation coverage declined, highlighting that infrastructure investment has not kept pace with population growth.
- 36% of people in the Tropics do not have access to regular waste removal with the proportion as high as 63% in Northern Africa & the Middle East.
- Globally, unregulated or illegal dump sites serve about 4 billion people and hold over 40% of the world's waste. Most of these sites are in the Tropics.
- Urban solid waste is projected to increase by more than 70% globally to 2025 with tropical developing countries facing the greatest challenges in managing future waste.
- Significant new investment will be required in water, sanitation and waste management infrastructure to meet global development goals relating to these sectors by 2030.

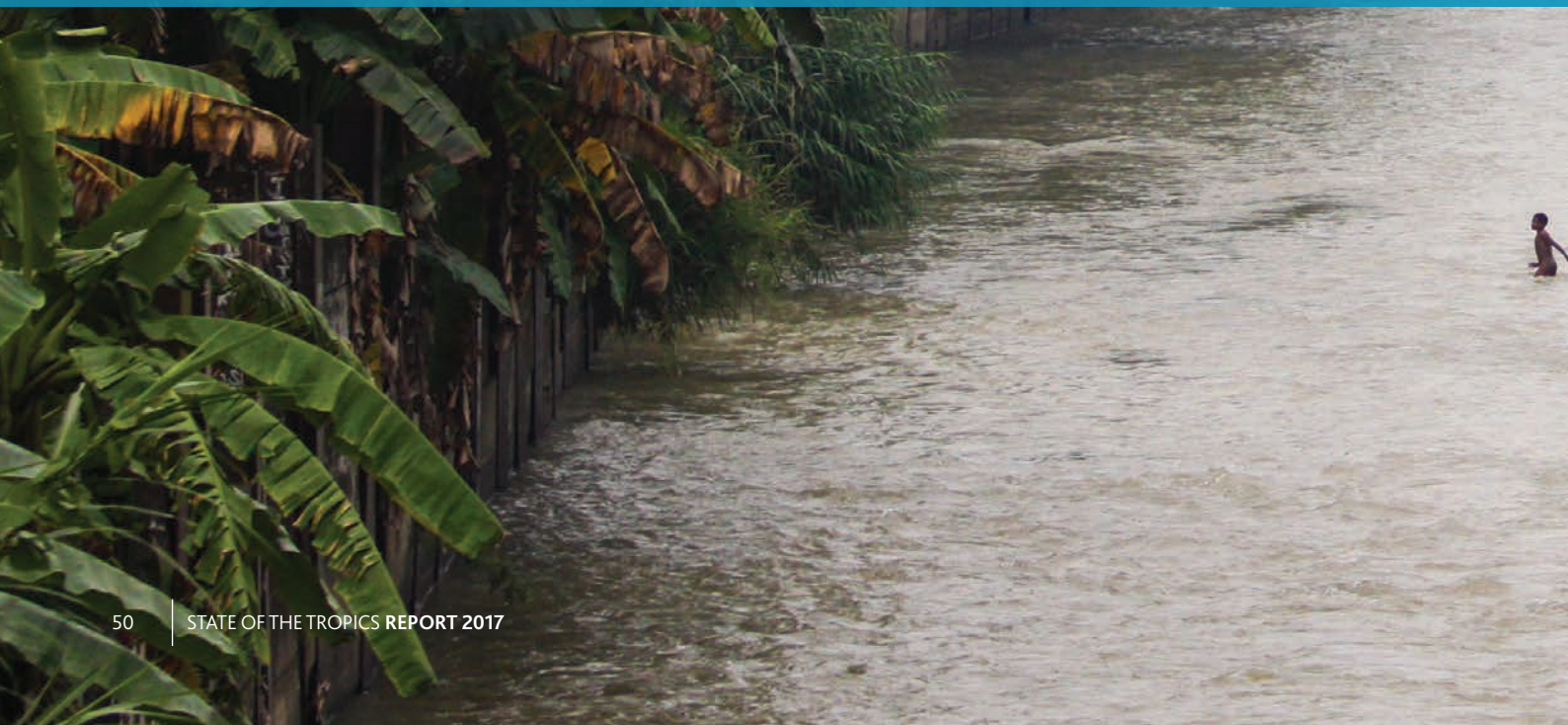

Image: Lae, Papua New Guinea. Mark Ziembicki

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Access to clean water, sanitation facilities and waste management are among the most basic of human needs. Infrastructure relating to provision of these essential services has been a major focus of international development initiatives for decades. However, while there have been substantial improvements in most parts of the world significant gaps remain. The importance of these basic services is reflected by their prominence in the 2030 Agenda for Sustainable Development; SDG 6 relates specifically to water and sanitation which aims to ensure availability and sustainable management of water and sanitation for all. SDG 12 promotes responsible consumption and production and includes targets relating to waste management.

The importance of water, sanitation and waste management infrastructure is also recognised in its broader impacts on other important aspects of development. Poor water quality, sanitation facilities and waste management practices impact human health and wellbeing, posing particularly acute risks to poor and vulnerable communities. Pollution and greenhouse gas emissions from poor practices have major impacts on the environment. Rapidly growing human populations alongside increasing urbanisation rates and the impacts of climate change in the tropics will magnify challenges relating to water, waste management and sanitation, especially in developing nations. Tackling these issues in a comprehensive and integrated manner will go a long way to achieving many of the global goals for sustainability.

Global initiatives & the UN 2030 Agenda

BOX 3.1

Provision of adequate water and sanitation infrastructure has been at the forefront of international development initiatives for several decades. Although there has been progress in this time many people still live with no access to these basic necessities. Waste management has received comparatively less attention, though waste generation rates continue to increase rapidly as the world races towards an urban future. The importance of these basic services are reflected in a number of SDG targets and global initiatives aimed at bridging the significant infrastructure gaps in these sectors.

SDG #6: ***Ensure access to water and sanitation for all***

- By 2030, achieve universal and equitable access to safe and affordable drinking water for all
- By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations
- By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally
- By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity
- By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate
- By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes
- By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies
- Support and strengthen the participation of local communities in improving water and sanitation management

SDG #11: ***Make cities and human settlements inclusive, safe, resilient and sustainable***

- By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management.

SDG #12: ***Ensure sustainable consumption and production patterns***

- By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.

The WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP) provides regular estimates in meeting global, regional and national targets for the provision of access to clean water and sanitation and hygiene facilities. Alongside initiatives such as those developed by the World Toilet Organisation to highlight the impacts of poor sanitation, these programs aim to reduce the infrastructure deficit relating to these basic human needs.

The Global Waste Management Partnership is a network of a broad range of stakeholders including governments, businesses, academia, NGOs and other organisations aimed at promoting international collaboration around waste management. Key initiatives include developing a knowledge platform for gathering and sharing information about waste management to drive informed policy decisions and the promotion of integrated approaches to solid waste management.

Indicators

Access to an improved water source: The percentage of the population with reasonable access to an adequate amount of water from an improved source, such as a household connection, public standpipe, borehole, protected well or spring, and rainwater collection. Reasonable access is defined as the availability of at least 20 litres a person a day from a source within one kilometre of the dwelling. Given that adequate data on safe drinking water are limited because of the complexity of defining and measuring it the indicator was developed by the WHO/UNICEF Joint Monitoring Program (JMP) as a proxy indicator measuring access to safe water and is equivalent to SDG Indicator 6.1.1. (United Nations 2015).

Improved sanitation facilities: The percentage of the population using safely managed sanitation services, including a hand-washing facility with soap and water. It refers to a facility at the household level which is not shared with other households and where excreta is safely disposed in situ or treated off-site. These data were developed by the WHO-UNICEF Joint Monitoring Program (JMP) to facilitate global analyses of sanitation standards by helping to account for differences in national interpretations of safe sanitation and variations in reporting methods. The indicator is equivalent to SDG Indicator 6.2.1

Collection Coverage: The amount of Municipal Solid Waste (MSW) collected as a proportion of total MSW generated. The indicator gives an indication of the infrastructure capacity associated with collection of waste from point of production (residential, industrial commercial, institutional) to the point of treatment or disposal. It mirrors SDG Indicator 11.6.1.

Unsound Disposal: The percentage of total Municipal Solid Waste (MSW) generated that is burnt or disposed of in uncontrolled dumpsites. This indicator gives an indication of the lack of adequate infrastructure relating to disposal of waste.

Recycling Rate: The amount of Municipal Solid Waste (MSW) recycled as a proportion of total MSW generated. Recycling rates give an indication of capacity around recovery of resources. This indicator relates to SDG Indicator 12.5.1 'National recycling rate, tons of material recycled' although is measured here as a proportion rather than a total amount.

Water

Water underpins all life on Earth. Freshwater ecosystems support a wide diversity of life and provide critical goods and services that support human populations and livelihoods. The world's tropical regions account for 54% of the Earth's renewable water resources (State of the Tropics 2014). However, in many regions, freshwater resources are insufficient to support growing populations and are often overexploited or contaminated. Water quality can be affected by a range of factors, including pollution from domestic and industrial sources, poor sanitation and hygiene, inadequate infrastructure and contamination of groundwater. In many developing nations rapid population growth and urbanisation combined with budget constraints have often placed a strain on water infrastructure. Combined with climatic impacts, including the impacts of droughts, these factors contribute to significant water scarcity in many parts of the Tropics with almost half of the region's population regarded as vulnerable to water stress (State of the Tropics 2014).

Access to adequate safe water is an important determinant of health and wellbeing (WHO 2017). Water based diseases transmitted through contaminated water are responsible for significant outbreaks of cholera, typhoid, viral hepatitis A, dysentery, and diarrheal diseases which disproportionately impact poor and vulnerable populations. Such diseases are a major reason for the high rates of under-five mortality and morbidity in the Tropics (State of the Tropics 2014). A large proportion of the global disease burden could be prevented by increasing access to safe drinking water and improving sanitation and hygiene (WHO 2017). Annually, safer water could prevent an estimated 1.4 million child deaths from diarrhoea and an estimated 860,000 child deaths from malnutrition across the globe. Given that contaminated or polluted water is a major cause of illness and death, and that poor water infrastructure also contributes to the spread of diseases such as malaria, poor water infrastructure is a significant factor contributing to human poverty, poor education and health outcomes, and limited economic development opportunities. Water is also critical to the health and vitality of natural ecosystems, and the ecosystem services they provide to society (UNDP 2006), which underpin human health and wellbeing.

What is water infrastructure?

Infrastructure relevant to the provision of safe clean water, management of wastewater and the protection of water sources includes a broad range of facilities ranging from dams, pump stations, pipelines, channels and household level facilities, to sewage and wastewater treatment and desalination plants. The Sustainable Development Goal relating to water expands on the Millennium Development Goal to now focus on the entire water cycle, including the management of water, wastewater and ecosystem resources. This more holistic, integrated perspective means that all aspects of infrastructure relating to water use and management need to be considered to achieve the goal (WHO 2017). In this report, we focus on a narrower subset of the targets relating specifically to basic development needs in the provision of safe clean water. To provide some context for the discussion that follows we take stock here first of the renewable water resources available across the Tropics.

Availability and use of renewable water resources

A critical aspect of planning and development of sustainable water infrastructure is understanding the dynamics of renewable water resource availability. Freshwater makes up only 2.5% of the Earth's total water resources most of which (69%) is locked up in polar ice sheets and permanent snow cover. A further 30% of freshwater is found in underground aquifers and only 0.3% is available as surface water. Unlike many other natural resources water is a highly dynamic resource. Significant spatial and temporal variation in precipitation, the movement of water across geo-political boundaries, and its physical ability to change state (between solid, liquid and gas) makes it an inherently difficult resource to catalogue and monitor. Obtaining reliable, quantifiable water availability data at national scales is therefore difficult.

In practice, only a small proportion of renewable water is available for human use. This is the 'exploitable' renewable water resource of which it is estimated there is 9 trillion cubic metres globally (or 17% of the total freshwater available) (WMO 1997, Molden et al. 2001). The unexploited proportion primarily consists of water occurring in flood events or is accounted for as minimum long-term river flows. Furthermore, of the exploitable amount available for use, in many regions, water is often polluted or contaminated. This further compromises its utility, particularly for domestic consumption, and increases the potential for water scarcity and the cost of supplying clean water. As a result of its variable availability and unequal distribution water can be difficult to share equitably among and within nations. Effective and equitable management and governance of water resources is critical given the significant implications it has for people's access to safe drinking water, its availability for food production and industry, and the need to consider environmental flows and the ecosystem services water provides.

Water scarcity in terms of human use is defined as access to less than 2000 cubic metres of water available per person per year (FAO 2000). In the 20th century water use increased at more than twice the population growth rate and, in some areas, reliable access to water is now limited or non-existent (FAO 2012). It is estimated that in developing countries in Asia, Africa and Latin America, water use for residential needs is just 50-100 litres per person per day (FAO 2016). In regions with insufficient water resources, the amount may be as low as 20-60 litres per day. In general, daily water consumption rates by people in developed countries is on average around 10 times more than in developing countries (FAO 2012).

The combination of population growth, increasing economic affluence, rapid urbanisation and the impacts of pollution are placing increased pressure on water resources (FAO 2012). In 1962, 25 nations worldwide suffered water scarcity (accounting for less than 3% of the global population). By 2010 the number had more than doubled to 54 nations (39% of the global population). In the Tropics, although the region accounts for 54% of the world's total renewable water resources, at least half of all nations in three of the eight tropical regions experienced water scarcity in 2010 (State of the Tropics 2014). Scarcity was highest in South Asia where more than 90% of the population is considered vulnerable (Figure 3.1). Over half of the population in the tropical regions of Africa are also significantly affected.

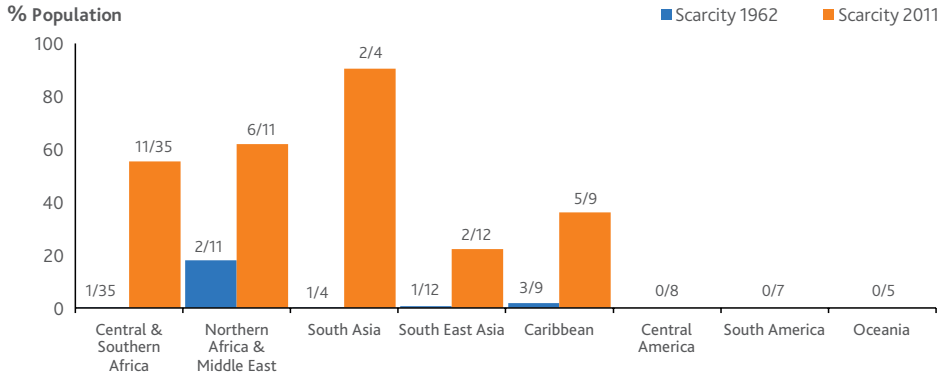

Figure 3.1 **Proportion of populations in the Tropics experiencing water scarcity in 1962 compared to 2011 including number of nations within each tropical region experiencing scarcity indicated above columns (State of the Tropics 2014).**

By far the biggest user of renewable water resources is the agricultural sector accounting for 81% of use in the Tropics and 64% in the rest of the world (Figure 3.2). In the rest of the world use of water for industrial purposes ranks second, while in the Tropics municipal withdrawals are greater than for industry. In the Tropics, South Asia and Northern Africa & Middle East allocate the greatest proportion of their used water to agriculture (both at 91%). South Asia also uses the greatest proportion of its total renewable water resources at 28%. South America and Oceania have the lowest impact on water resources, extracting less than 1% of their total renewable water annually. The Tropics uses around 4% of its renewable water compared with 11% for the rest of the world. However, the unequal distribution of water resources among nations and regions still leaves much of the Tropics suffering chronic water stress.

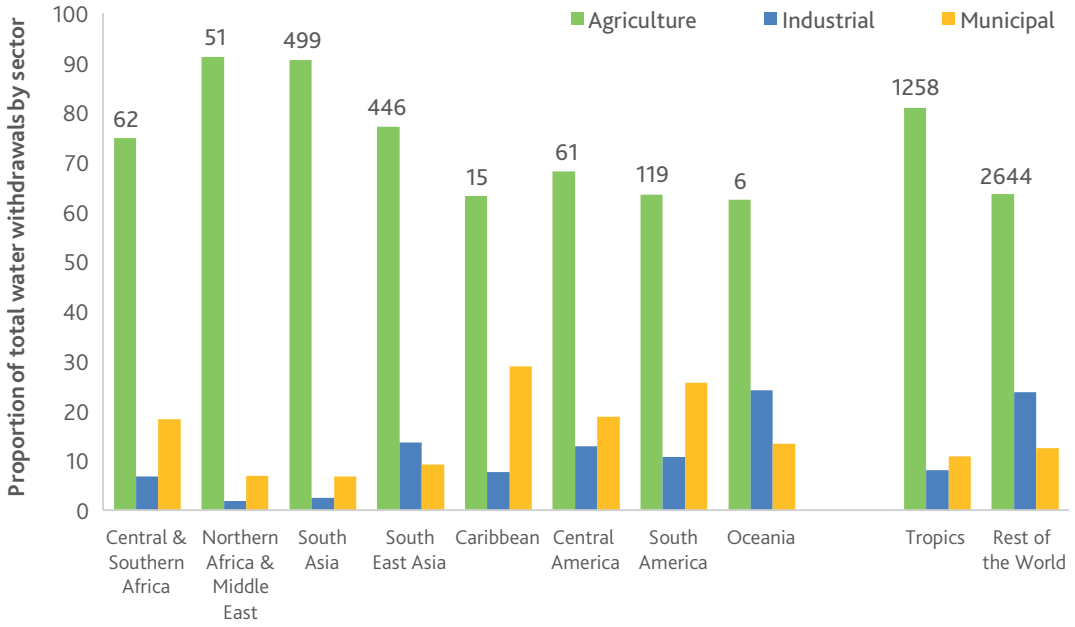

Figure 3.2 **Proportion of water withdrawals by major sector including total withdrawals in billion cubic metres/year (indicated above each region). (Data source: FAO 2016)**

Trends

Access to an improved water source through provision of infrastructure has steadily increased in the Tropics in line with global improvements (Figure 3.3). In 2015, approximately 6.6 billion people, or 91% of the global population had access to a form of improved water infrastructure. Outside of the Tropics access increased from 82% in 1990 to 95% in 2015, while the comparable change in the Tropics ranged from 66% to 84%. Starting from a lower base progress has therefore been faster in the Tropics in recent decades, but the region remains behind the rest of the world.

Although over two billion additional people gained access to drinking water from an improved source between 1990 and 2015, there are still almost 800 million people without access to this basic requirement. Almost all of these people live in developing nations, and most of them are in rural areas (UN 2012).

Despite overall improvements there are notable differences between regions within the Tropics. While more than 90% of the population of the tropical regions of Asia and the Americas had access to improved water infrastructure in 2015, less than two out of three people in Northern Africa & the Middle East (58%), Central & Southern Africa (66%) and Oceania (64%) had such access.

In terms of rates of change in access over time, South Asia and Central and Southern Africa improved most between 1990 to 2015 with an increase in improved water access of 23 percentage points (from 70% to 93% and 44% to 66%, respectively). Central and Southern Africa, while starting from a much lower base had the highest rate of change, demonstrating that development efforts in the region have made good progress.

Improvements in Northern Africa & the Middle East have been more modest, however, and are likely due to several factors including political instability, high population growth in urban and slum areas and the low priority given to improving water services in budget allocations. Additionally, supplying water in this region is expensive due in part to the difficulty of regulating prices charged by private small-scale providers of water (UNEP 2010).

Based on the proportion of people with access to clean water, other regions of the Tropics have made no progress or have even gone backwards. The proportion of the population with access in Oceania increased by only one percentage point since 1990, while the Caribbean declined from 84% coverage in 1990 to 83% in 2015. The lack of progress in these regions overall, however, is explained by the disproportionate impact of infrastructure development and provision in just two nations: Papua New Guinea (PNG) in Oceania (the most populated nation in the region) and Haiti, the second most populated nation in the Caribbean. In Papua New Guinea, most people continue to live in rural, remote and often inaccessible areas where developing and maintaining public infrastructure is costly and logistically challenging. A general lack of access to clean water and sanitation may be among the key reasons behind the country's high infant and child morbidity and mortality rates (State of the Tropics 2014). If PNG is removed from the analysis, however, coverage in Oceania increases to 94%. Similarly, for a variety of historical and socio-political reasons Haiti is disproportionately underdeveloped and also experienced significant damage to water infrastructure in the 2010 earthquake. Removing it from the cohort of nations in the Caribbean increases the region's overall access to an improved water source to 95%.

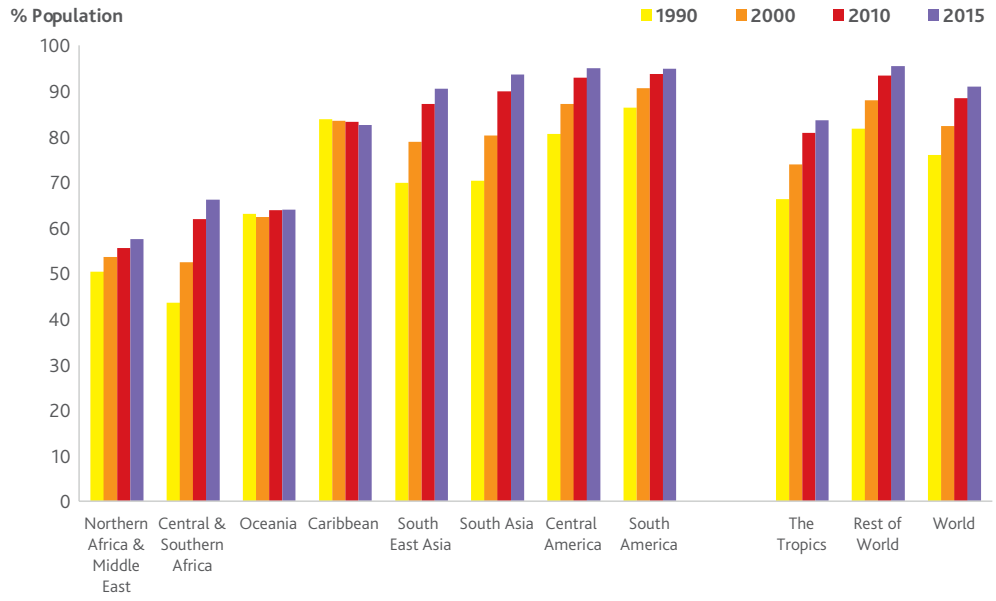

Figure 3.3 Proportion of population with access to an improved water source by region from 1990 to 2015. (Data source: WHO & UNICEF 2016)

Differences between urban and rural areas

The water related infrastructure deficit is disproportionately experienced in rural areas. In the Tropics, 93% of urban areas have access to an improved water source compared to only 75% in rural areas (Figure 3.4). In the rest of the world the gap is considerably smaller at 98% coverage in urban and 90% in rural areas. Nonetheless, although still significant, the gap between rural and urban areas in the Tropics reduced from 34% in 1990 to 18% in 2014.

Differences between regions in the Tropics are also pronounced. Coverage in rural areas in regions such as South Asia, South-East Asia and Central America is relatively high (above 85%) and the difference between rural and urban areas is relatively small. In contrast, rural areas of Northern Africa and the Middle East and Oceania have the lowest access to improved water sources at 39% and 47% respectively. They also have the greatest disparities between rural and urban areas with differences of 39 percentage points in Northern Africa and the Middle East and 49 percentage points in Oceania.

The rate of change in access to improved water sources between tropical and non-tropical rural regions has been relatively consistent with the gap between the two increasing slightly from 12 percentage points in 1990 to 15 percentage points in 2014 (Figure 3.5). There are notable differences, however, in the rate of change in access between regions in the Tropics (Table 3.1). While rural areas of South Asia, South-East Asia, Central America and Central and Southern Africa have experienced significant improvements since 1990, Northern Africa and the Middle East and Oceania have made limited progress in terms of the proportion of population with access. Political instability and conflict is a factor in Northern Africa and the Middle east while challenging geographical conditions and associated logistical challenges and costs has affected improvement in Oceania.

Rural areas have lower population densities which are often widely dispersed, and economic activity tends to be lower compared with urban areas. This can make the delivery of safe drinking water more expensive on a per capita basis, and contributes to relatively low access rates in rural areas. The fragmented nature of political representation for people living in rural areas (even where the majority of the population of a country may live in rural areas) can also mean that securing financial commitments to provide safe drinking water is difficult. The distribution of international aid also appears to be a factor, with the proportion of water and sanitation aid going to rural areas globally falling from 27% in 2003 to 16% in 2008 (WHO 2011).

Although urban areas in the Tropics fare much better in terms of providing access to water infrastructure than rural areas, the rapid rate of urbanisation and migration of people from rural to urban areas frequently means infrastructure development in urban areas is not keeping pace. Furthermore, in urban areas the major issue has not been changes in access rates, but changes in the absolute number of people without access. For example, the urban population in the Tropics without access to safe drinking water has increased from 107 million to 137 million due to large numbers of people living in informal settlements or slums. Tropical cities are growing much faster than background population growth and this rapid rate of change threatens in many cases already stressed water and sanitation systems (Barrios et al. 2006)

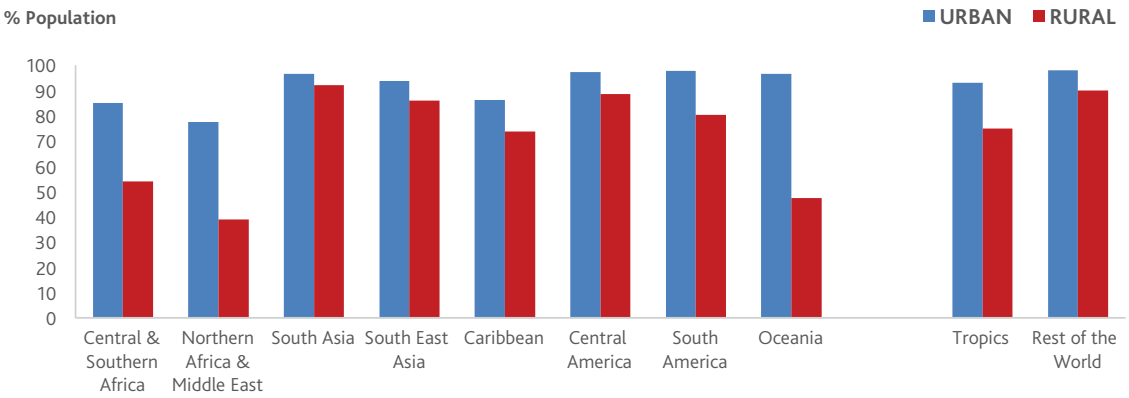

Figure 3.4 Percentage of population with access to an improved water source in urban and rural areas in regions of the tropics in 2014 (Data source: WHO & UNICEF 2016)

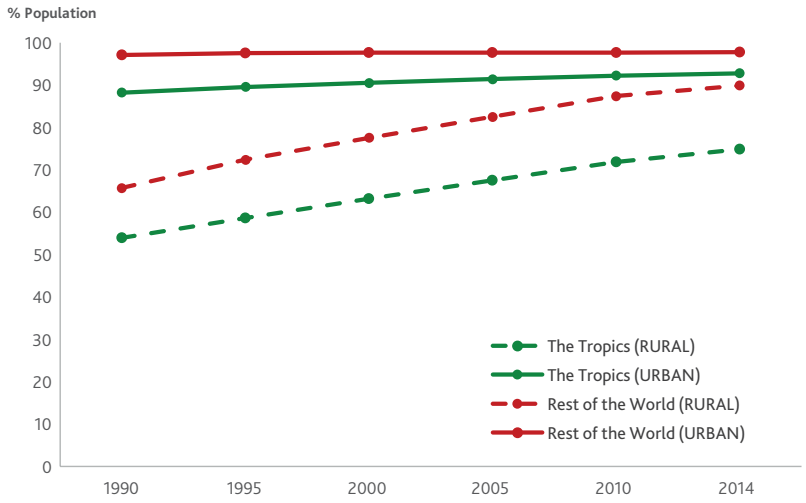

Figure 3.5 Change in proportion of the tropical and non-tropical population with access to an improved water source in urban and rural areas (Data source: WHO & UNICEF 2016)

Table 3.1 Change in proportion of regional populations in the Tropics with access to an improved water source in urban and rural areas between 1990 and 2014.

	1990		1995		2000		2005		2010		2014*		PPT Difference 1990 to 2014	
Region	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Central & Southern Africa	80	30	82	35	83	40	84	45	85	50	85	54	5	24
Northern Africa & Middle East	71	40	74	44	74	44	76	45	76	45	78	39	7	-1
South Asia	89	64	90	70	92	76	94	82	95	88	97	92	8	28
South East Asia	88	61	89	66	91	72	92	77	93	82	94	86	6	25
Caribbean	94	54	94	70	92	70	91	71	88	73	86	74	-8	19
Central America	92	61	93	67	94	73	95	78	97	84	97	89	6	28
South America	95	65	95	68	96	71	97	74	97	78	98	80	3	16
Oceania	91	40	91	40	96	45	96	46	97	47	97	47	5	7

Gender disparities

Inadequate access to improved water infrastructure has a disproportionate impact on women and girls. In almost three-quarters of households without on-premises access to water, women and girls have the primary responsibility for collecting water (WHO 2011). It is estimated that girls and women in developing nations spend 40 billion hours every year hauling water, spending as much as eight hours a day, and carrying up to 40 litres of water.

The issue is most pronounced in rural areas of sub-Saharan Africa, where water collection times of more than 30 minutes per trip are common (WHO & UNICEF 2011). If the time needed to collect water is considered in assessing whether a source is improved, access is significantly lower than is currently reported. In sub-Saharan Africa for example, if 30 minutes is used as the cut-off, coverage drops by eight percentage points (WHO & UNICEF 2011). Research also indicates that if the round trip to collect water is more than 30 minutes, households tend to collect less water, increasing the risk that minimum daily requirements for drinking and good hygiene practices will not be met further increasing susceptibility to waterborne diseases (WHO & UNICEF 2011). In addition to health issues, other consequences of this burden can be significant including reducing involvement in education and opportunities to engage in productive work, income generation, and other social and political activities.

Other types of infrastructure

Although not considered in detail in this report, desalination plants and recycled water supply systems are another source of water production infrastructure that are increasingly used to meet supply shortfalls particularly for the municipal sector. Over 150 nations use desalination to meet some of their freshwater demand, and in 2008 there were almost 14,000 facilities worldwide with capacity to supply over 52 million cubic metres of fresh water per day (Henthorne 2009, Fichtner 2011). Given chronic water stress is an issue in at least 16 of the 22 Middle East and Northern Africa nations, these nations have become leaders in developing desalinization technologies (State of the Tropics 2014).

Sanitation and Hygiene

Providing access to improved sanitation facilities has been a primary focus of international development initiatives since the 1970s, although progress towards universal coverage has been slow. A lack of infrastructure and poor maintenance of existing facilities are the root causes of the sanitation problem. Logistical constraints due to geography, technological and technical limitations, inappropriate interventions in the past, and a lack of commercial involvement and funding shortages has meant that many governments and communities have been unable to support the development and maintenance of appropriate sanitation infrastructure (UNDP 2006).

Limited access to adequate sanitation and hygiene facilities has numerous adverse social, economic and environmental impacts. Poor sanitation can lead to polluted water and contaminated living conditions which can spread communicable diseases leading to high rates of morbidity and mortality (State of the Tropics 2014). Poor sanitation can also decrease productivity, economic activity and lead to widened gender inequalities . The impact of poor sanitation and hygiene on people's livelihoods was recently highlighted by the theme of the UN's 2016 World Toilet Day. Some estimates suggest that in several countries a lack of adequate sanitation infrastructure contributes up to a 7% loss in GDP due to lost productivity and other economic, environmental and social consequences of this critical infrastructure deficit (Hutton 2011).

The provision of improved sanitation facilities is the focus of SDG 6 of the 2030 Agenda for Sustainable Development which calls for achieving access to adequate and equitable sanitation and hygiene for all, ending open defecation, and paying special attention to the needs of women and girls and those in vulnerable situations.

What is sanitation infrastructure?

Sanitation infrastructure encompasses facilities that promote hygiene through the separation of hazardous wastes, especially faeces, from human contact through disposal and treatment. At the household level it includes basic facilities such as pit latrines, toilets and septic tanks. Treatment may be decentralised, also referred to as on-site sanitation, and include a system whereby the treatment of excreta or sewage takes place where it is generated (e.g. pit latrines, septic tanks, etc), or centralised and include surface run-off management infrastructure, sewerage systems and sewage treatment plants.

In this case, we consider improved sanitation infrastructure which refers to the management of human excreta at the household level and is based on the Joint Monitoring Program (JMP) for Water Supply and Sanitation definition which may include a flush toilet, connection to a piped sewer system, connection to a septic system, a pit latrine, or composting toilet.

Trends

Progress towards realising universal access to improved sanitation infrastructure has been relatively modest. Between 1990 and 2015 the proportion of the world's population with access to improved sanitation facilities increased from 54% to 67% (Figure 3.6). In absolute numbers this equates to almost 2.5 billion people, or one in three worldwide, that still do not have adequate access. Most of this infrastructure deficit is in the Tropics where just over half of the region's population (1.6 billion people) had adequate access in 2015. By comparison, 78% of the population in the rest of the world had access in 2015.

The degree of change in access to improved sanitation facilities varies markedly between regions in the Tropics. The greatest improvement between 1990 and 2015 was in South East Asia which increased from 48% coverage to 73% – a change of 25 percentage points equating to an additional 314 million people with access. A similar increase (23 percentage points) was observed for South Asia albeit from the lowest base of all tropical regions in 1990 at 20%. Nonetheless, this equates to 240 million people now having access to improved facilities. Most other regions in the Tropics have also made slow progress, with coverage in Oceania actually declining. The proportion of people with access here went from 50% in 1990 to 48% in 2015. Most of this change was driven by Papua New Guinea. Although an additional 450,000 people gained access over this time in PNG, the relative proportion of the population with access dropped from an already low 20% in 1990 to 19% in 2015, highlighting that sanitation infrastructure development here has not kept pace with the country's rapid population growth (ADB 2012). The proportion of people with access to improved sanitation also declined in two other nations in Oceania (Tonga and Samoa), while coverage in the Solomon Islands, while improving, remains low at less than 30%.

Progress in the Caribbean has also been slow primarily as a result of the impact of natural disasters, civil unrest and political instability in Haiti. Central & Southern Africa and Northern Africa & the Middle East had the lowest proportions for improved sanitation coverage in the Tropics at less than 35%. Civil unrest, poverty and rapid unplanned urban growth in many nations of these regions have affected the capacity to deliver sanitation infrastructure and solutions (SIWI 2005). In contrast to other parts of the Tropics, Central and South America both exhibited notable improvements in access. In 2015, both regions had higher coverages (82%) than global estimates.

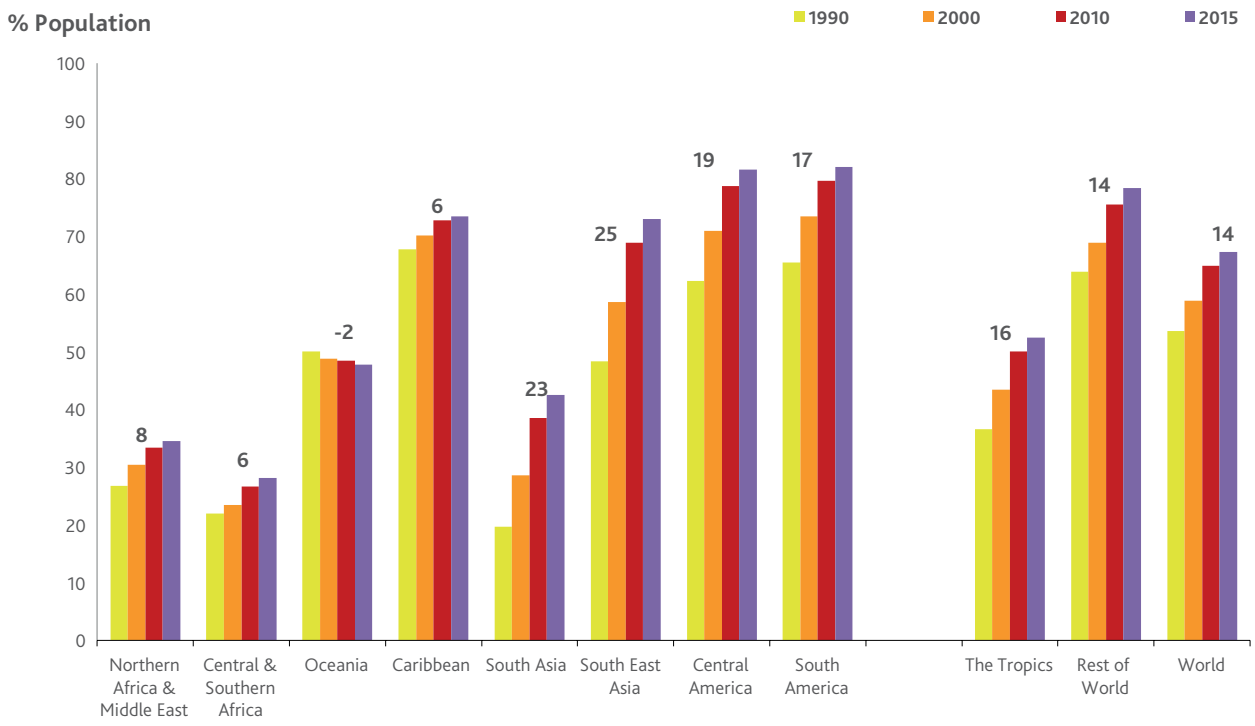

Figure 3.6 Proportion of population with access to improved sanitation infrastructure by region from 1990 to 2015. Numbers above bar clusters denote % change between 1990 and 2015 (WHO & UNICEF 2016)

Investment and funding barriers

The means of improving sanitation are seemingly straightforward, but efforts to improve global access are complex and involve a range of financial, technical, political and cultural issues. Investments in sanitation infrastructure typically involve a long project cycle and high capital and operating costs. Poor economic and budget conditions in many nations with low coverage means that improving sanitation is often a lower order or neglected infrastructure issue. Often those that are most in need of improved sanitation are the least empowered to improve their circumstances or to afford such services. High costs coupled with funding shortfalls mean that many developing nations rely on international aid to improve sanitation infrastructure.

Apart from inadequate investment and a lack of political will, other common barriers to increased access include a focus on conventional interventions without community involvement or necessary considerations of local cultural sensitivities. The challenges of quantifying the broad range of society-wide benefits that improved sanitation delivers also adds to the problem, while a health system focus on treating rather than preventing diseases has also been identified as a factor that can contribute to a lack of sanitation coverage (Water Aid 2011).

Governments and international bodies typically combine water and sanitation into the same sector for development and administrative purposes, despite each having unique issues. As a development issue, water has historically received greater international attention and resourcing than sanitation, and this has led to sanitation being viewed as a less important add-on to water supply programs (Harvey 2008). In the decade to 2000, public investment in sanitation globally was just one-quarter that of water (World Bank 2008). These funding anomalies are widening, and in 2010 sanitation represented one-fifth of the total water, sanitation and hygiene sector expenditure in 2010 (WHO 2012b). Efforts to improve sanitation coverage have not been helped by the proportional decline in international aid provided for water and sanitation compared with 20 years ago (Graham 2011).

Cultural considerations

A lack of consideration for community needs, cultural sensitivities and priorities in decisions regarding location and type of sanitation facilities has often resulted in weak support from local populations for sanitation interventions. This has led to the neglect or abandonment of sanitation facilities or promoted alternative uses including for storage and animal shelters. In India, for example, a recent study showed that about 50% of toilets built by a large government program were not used for their intended purpose (Duncan et al 2010). Furthermore, in some areas of South Asia and Africa, the practice of open defecation is ritualised and bound in tradition. In certain circumstances it is believed that these cultural values and beliefs have led to a resistance to the use of toilets (Water Aid 2009).

Aside from investment in infrastructure, a key factor in improving sanitation outcomes is providing education and training in good hygiene practices and improving awareness of the benefits of good sanitation practices, especially in communities that have not previously had sanitation. Past shortfalls in infrastructure provision has led to a major shift in policy orientation towards demand-led approaches to improving sanitation. These are aimed at motivating people to improve their own sanitation and accelerate sanitation coverage in both rural and urban settings. One of these approaches is Community-Led Total Sanitation (CLTS) which was first developed in Bangladesh (see Box 3.2).

The Community-Led Total Sanitation (CLTS) initiative — BOX 3.2

Successful efforts to improve sanitation facilities in developing nations have had a long and checkered history. In many places providing toilets has not necessarily meant that people will use them or improve their sanitation and hygiene practices. Recognising this issue the Community-Led Total Sanitation (CLTS) approach is a success story first introduced by non-governmental organisations to rural communities in Bangladesh in 2000. The CLTS is a communication-based approach that aims to change behavior by raising awareness of the link between open defecation and disease. By involving the entire community emphasis is placed on highlighting the collective benefits of eliminating open defecation rather than focusing on individual behavior or the construction of toilets without any broader education efforts.

The considerable early success of CLTS in improving sanitation outcomes encouraged its support by government leading to its broader implementation. Sanitation coverage in Bangladesh has subsequently increased from 34% of the population with access in 1990 to 61% by 2015, with open defecation rates falling from 32% to less than 5%. The success of the program has since led to its adoption in an increasing number of other tropical nations in Asia, Africa and Latin America (Duncan et al. 2010).

Gender disparities

Poor access to adequate sanitation and hygiene facilities disproportionately impacts women and girls because they are often faced with additional challenges relating to menstrual hygiene, sexual harassment and personal safety. Without access to a toilet women are more likely to restrict toilet visits increasing risk of health problems such as urinary tract infections, constipation and mental health issues. Relying on the cover of night to go to the toilet in fields or by the roadside also increases their exposure to potential physical attack or sexual assault. In many countries the lack of toilet facilities can impact girls' attendance and performance at school, and limit their opportunities for participating in social activities or work (Jasper et al. 2012). The direct involvement of women in planning and management of sanitation and hygiene infrastructure is critical in order to ensure that sanitation infrastructure developments are effective and inclusive.

Sewage disposal pathways

For developed nations, access to onsite flush toilet facilities and the removal of waste via a sewer or septic tank at the push of a button is taken for granted. Yet for about half of all people that live in the Tropics, such facilities are unavailable, and the separation of water and excrement is a formidable public health issue. In urban slums and rural communities the absence of quality sanitation facilities frequently means human waste is disposed in fields, on streets and in drains, creating an immediate local hazard and favourable conditions for spreading diseases. In some regions, human excreta contaminates surface and ground water or is discharged untreated into rivers and water systems, causing serious pollution and endangering the health of downstream users, plant and animal life and aquatic resources that people depend on (UN Water 2008). The anticipated health benefits of improved water supply have been severely limited by poor progress in the management of human excreta, one of the primary pathogenic sources of water contamination (UN Water 2008). Diseases associated with poor sanitation account for about 10% of the global burden of disease, with diarrhoeal diseases – generally due to faecal-oral transmission of viral and bacterial pathogens– the most prevalent, causing up to 2.5 million deaths annually, mostly among children in developing nations (Mara et al. 2010). In 2008, diarrhoea was the leading cause of death among children aged under five years in sub-Saharan Africa (accounting for 19% of all deaths in this age group). It is estimated that improved sanitation could reduce rates of diarrhoeal diseases by up to 37% (Mara et al. 2010), with the provision of high-quality piped water and sewer connections resulting in greater reductions in diarrhoea compared with other interventions (Wolf et al. 2014).

The practice of open defecation – the last recourse for those without any form of sanitation– poses one of the more serious pollutant threats to ground water resources and agricultural produce. Encouragingly, the proportion of the world's population practising open defecation declined from 24% in 1990 to 15% in 2010, however, more than one billion people still participate in this practice, with 90% of these living in rural areas, and around two thirds of them living in the Tropics. In the Tropics rates of open defecation are highest in South Asia (46%), followed by Northern Africa & the Middle East (42%) and Central & Southern Africa (24%), with the incidence reportedly greatest in rural areas. In other tropical regions the problem is less acute, with rates ranging from 3% in Central America to 12% in South East Asia.

Although the scale of sanitation needs in rural areas is large, public health risks in urban slums where inhabitants live in cramped and squalid living conditions are considered more acute. The illegal status of many of these settlements means they are not recognised by the authorities responsible for providing sanitation and are excluded from town planning. Even in slum areas where the use of improved sanitation facilities such as pit latrines is common, the risk of faecal oral disease remains high. At any given time it is estimated that close to one-half of the urban populations of Africa, Asia and Latin America have a disease associated with poor quality water, sanitation and hygiene facilities (Duncan et al. 2010).

Solid Waste Management

Solid waste is a by-product of human settlements that has increased significantly since industrialisation. Technological advances and economic systems that promote consumerism alongside growing human populations, affluence and urbanisation result in ever increasing waste generation rates. In 2012, an estimated 1.3 billion tonnes of solid waste was generated, equating to approximately 1.2kg per person per day. By 2025, the World Bank estimates that 4.3 billion urban residents will be generating an estimated 2.2 billion tonnes of waste per year (World Bank 2012).

Despite its significant impact on human and environmental systems, solid waste management has often had a lower profile than other basic human development needs. Inadequate management of waste has significant social, economic and environmental impacts, including posing a threat to human health and the environment, as well as being a contributor to greenhouse gas emissions. The economic costs of dealing with the impacts of inadequate waste management are significant and much higher than the costs of implementing sustainable waste management practices from the outset. Solid waste management is an essential utility service and yet, approximately half of the waste currently produced around the world is not collected, treated or disposed of safely (World Bank 2012).

Tackling the issue indirectly or directly addresses more than half of the sustainable development goals within the 2030 Agenda (UNEP 2015), and is directly related to promoting responsible consumption and production practices (Goal 12).

Municipal Solid Waste generation

Waste comes in many different forms including municipal solid waste (MSW), commercial and industrial waste, construction and demolition waste, and agricultural and mining waste. How these are defined differs widely between countries adding to the complexities associated with identifying and quantifying waste generation and waste management outcomes (UNEP 2015). Here we focus on municipal solid waste (MSW) – one of the most significant by-products of an urban lifestyle. MSW includes waste from households, businesses and institutions, small scale construction and demolition waste, waste from hospitals and smaller industries that is not classified as hazardous, and wastes from streets and public areas (World Bank 2012; UNEP 2015). It does not include agricultural or mining waste, or waste from larger industries.

MSW generation rates vary widely within and between countries and regions (Figure 3.7). Based on latest available data, generation rates per capita are lower in the Tropics (282 kg/year) than in the rest of the world (394 kg/year). The highest rates are in the island nations of the Caribbean (400kg/year) being twice the regional average of South Asia (197 kg/year). Generation rates were also comparatively lower in Central and Southern Africa (215 kg/year) and Northern Africa and the Middle East (222 kg/year).

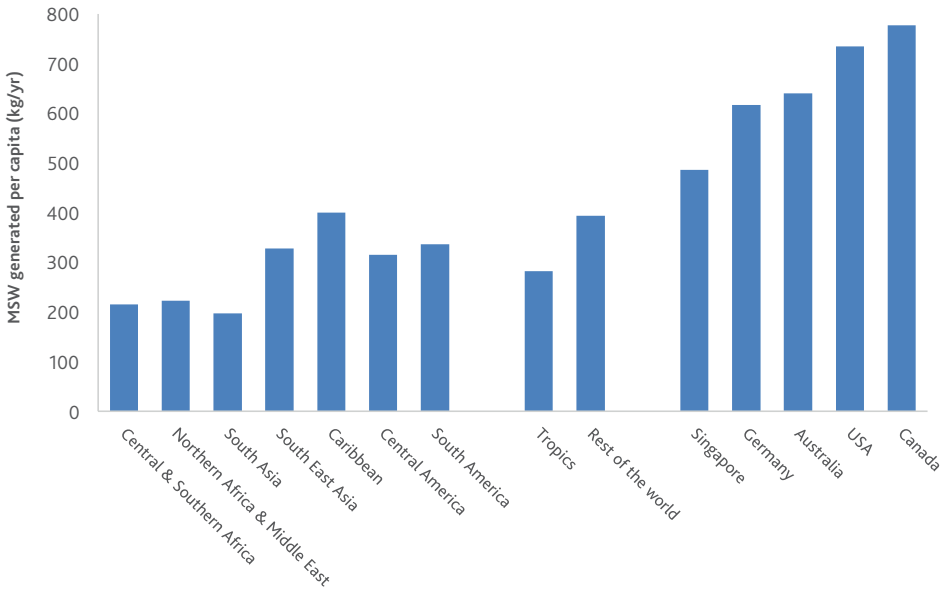

Figure 3.7 **Municipal waste generation per capita by region, including selected OECD high income nations (Oceania was omitted due to poor data coverage).**

Waste generation rates depend on several factors including socio-cultural influences and climatic factors, but MSW generation rates are most closely correlated with national income. In 2010, High Income Countries (HIC) generated an average of eight times more municipal solid waste by total volume than did Low Income Countries (LIC), with the per capita rate 3.5 times greater in the richer countries (Figure 3.8). In high-income countries, MSW generation rates appear to be stabilising, or even decreasing, which may suggest that the link between growing waste generation and economic growth is beginning to weaken (UNEP 2015). However, projected waste generation rates in low to mid income countries are predicted to soar as their populations rise, economies grow and they become more urbanised (Figure 3.8).

Open dumpsite, Lima, Peru. Alex Proimos.

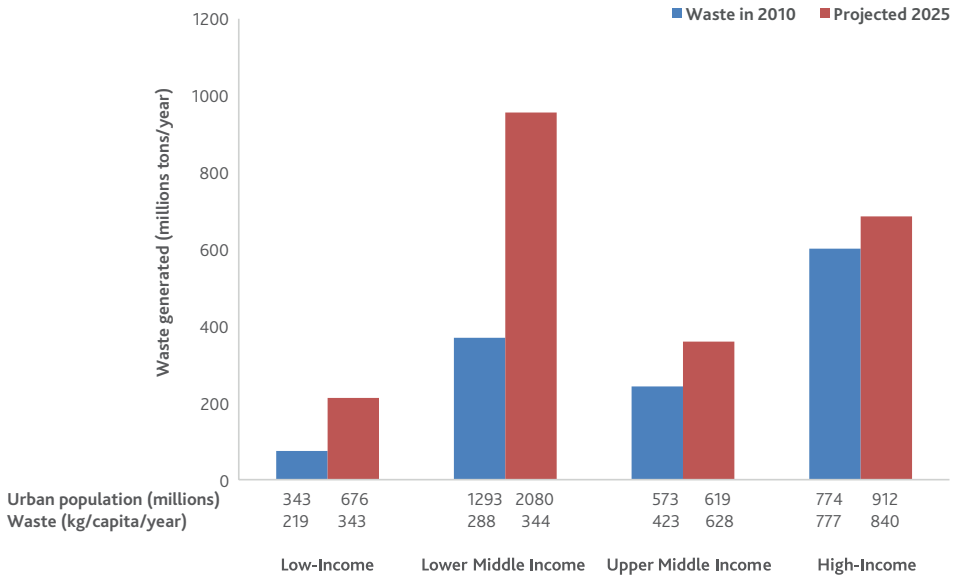

Figure 3.8 Urban waste generation by income level in 2010 and projected forward for 2025 (from World Bank 2012)

Waste composition differs between regions and the income level of countries (Figure 3.9). In general, lower income countries have significantly larger proportions of organic matter as part of their waste composition than do high income countries. The proportion of paper in waste is highest in rich countries (31%) declining with income levels to be around 5% in low income countries. Other components of solid waste such as plastic, metal and glass are generally similar with less apparent relationship to income level. Household hazardous waste is estimated to constitute less than 1% of all municipal solid waste across all income levels, although even at low levels it makes options for waste management more complicated (UNEP 2015).

The composition of waste influences how it is collected and disposed of. Physical characteristics such as moisture and density affect waste management and the types of infrastructure and technologies needed for its collection and treatment. In most of the Tropics, the higher levels of organic matter mean waste is wetter and denser, so there is less need for compaction during collection and the MSW may not burn without the use of additional fuel. While this type of waste presents certain challenges it also offers opportunities, for example, in composting or generating biofuels and fertilizers (Demirbas 2008).

Waste management infrastructure

Waste management practices vary between countries, within countries (particularly between rural and urban areas but also within cities), and between sectors (e.g. residential, agricultural and industrial). Infrastructure relating to waste management occurs across a waste logistics chain. That is, from its generation and collection through to its disposal or recovery, and includes the transport networks on which they depend. As such waste management infrastructure may range from collection facilities such as residential and community bins, waste collection vehicles and transfer stations to disposal sites such as sanitary landfills, resource recovery facilities or uncontrolled dumps.

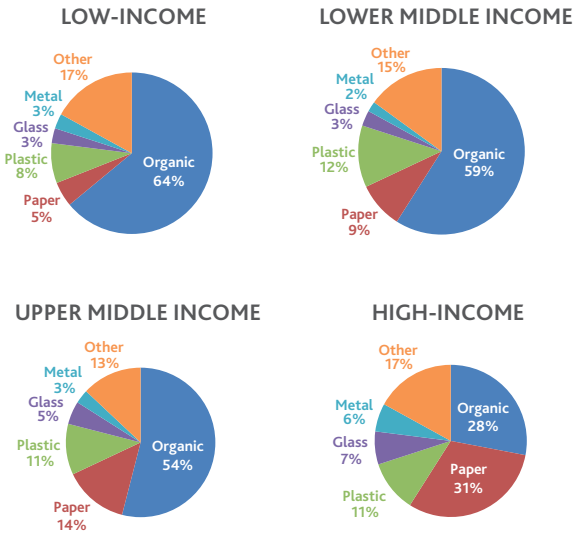

Figure 3.9 Waste composition by income level of country (from World Bank 2012).

Data quality and availability

Collating good quality data and developing appropriate indicators for waste management is challenging for several reasons. A lack of standard definitions of what constitutes waste alongside unreliable estimates and significant knowledge gaps due to a lack of measurement limit effective comparisons between cities and countries. There is also very limited information on the degree of recycling that occurs in the informal

waste management sector or the extent to which uncontrolled or illegal waste dumping or burning occurs.

Nevertheless, although acknowledging that issues relating to poor data quality requires a degree of caution in interpretation, the World Bank (2012), in a global analysis of solid waste management suggest there is sufficient information on solid waste management to estimate global trends. Here we draw on the same data, including information from the Waste Atlas (D-Waste & ISWA 2016), to assess the state of waste management infrastructure in different regions of the Tropics.

Trends

Although the relative contribution of the Tropics to the global municipal solid waste volume is notably lower on a per capita basis, provision of waste management infrastructure lags significantly behind the rest of the world. As a proportion of total MSW generated approximately 64% is collected in the Tropics compared with 87% outside (Figure 3.10). There is again significant regional variation in infrastructure and capacity around waste management in the Tropics. Collection coverage in South America at 89% exceeds estimates for the rest of the world, while Central America and the Caribbean also have coverage over 80%. Collection coverage in Central and Southern Africa, South Asia and Northern Africa and the Middle-East are all below 50% with particularly low rates in the latter. Oceania has very poor data coverage (only four nations report information) and those include Australia and Hawaii hence the estimate reported (76%) is likely to be significantly overestimated. Many of the nations in the region are also Small Island Developing States that have particular challenges relating to waste management given their size, logistical challenges and potential for untreated waste to contaminate limited freshwater resources (SPREP 2010; Agamuthu & Herat 2014).

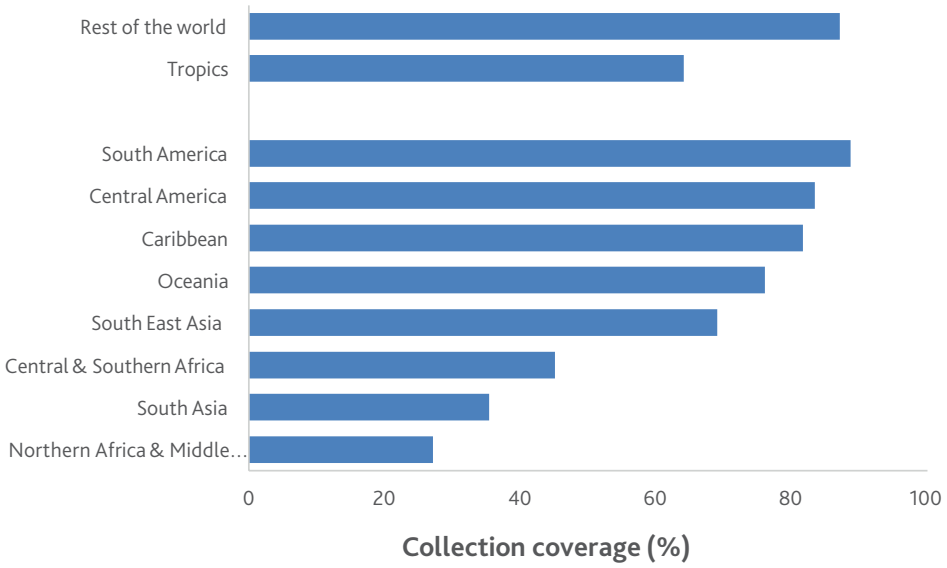

Figure 3.10 **Municipal solid waste collection coverage by region in the Tropics (D-WASTE & ISWA. 2016)**

Data availability relating to the amount of municipal solid waste that is recycled is generally poor. Nonetheless, some general global and broad regional trends are evident (Figure 3.11). Overall, nations of the Tropics recycle some 6.7% of the total MSW generated compared with 11.1% in the rest of the world. This compares with individual jurisdictions such as Singapore (59%) and Germany (47%) that have among the highest recycling rates in the world.

Importantly, data relating to recycling do not include the informal sector which is not only an important income generating activity, it makes up a very large component of the overall waste management picture in the Tropics. An estimated 15-20 million people make a living in small scale recycling initiatives throughout Asia, Africa and Latin America, accounting for around 20% of all waste management . It is suggested that even relatively small economic investments aimed at integrating informal recycling workers into formal efforts can have significant benefits through providing livelihood options, improving working conditions, reducing child labour, increasing opportunities for education and improving environmental impacts. The overall costs of waste management are also reduced because there is less waste (World Bank 2012).

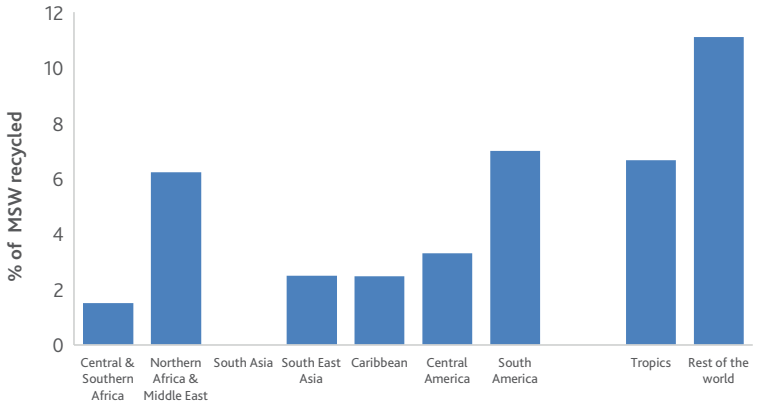

Figure 3.11 Amount of MSW recycled as a proportion of total generated by region. Regions in the tropics with less than three countries with adequate data are omitted. (D-WASTE & ISWA. 2016)

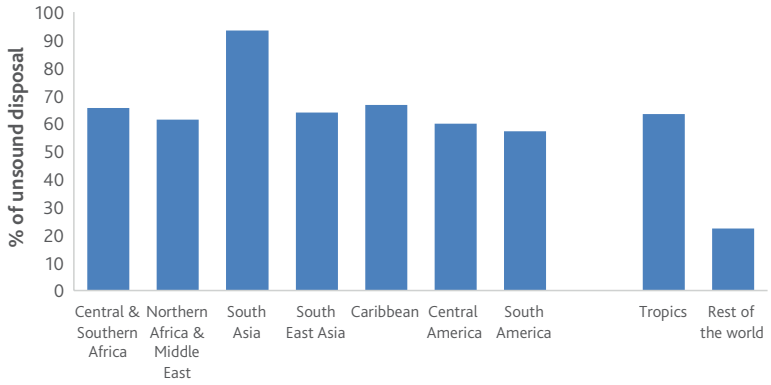

Figure 3.12 The proportion of total MSW generated that is disposed or burnt in uncontrolled dumpsites by region in the Tropics. (D-WASTE & ISWA. 2016)

The proportion of MSW generated that is burnt or disposed of in uncontrolled dumpsites gives an indication of the lack of infrastructure capacity to sustainably dispose of waste. The Tropics overall has a rate of unsound disposal almost three times higher than in the rest of the world with most regions disposing approximately 60% of their municipal solid waste in this way (Figure 3.12). South Asia especially stands out with over 90% of its MSW not disposed of appropriately.

Health and environmental impacts

Poor waste management practices impact many aspects of society, the economy and the environment. Residents in developing countries, especially the urban poor, are more severely impacted by poorly managed waste. In the seven months to June 2016, for example, the International Solid Waste Association recorded more than 750 deaths related directly to poor waste management in dumpsites around the world (ISWA 2016). In some cases, such poorly managed dumps result in catastrophic events such as the 2005 landslide at a dumpsite in Bandung, Indonesia following heavy rains that killed 143 people (Lavigne et al. 2014).

In low and middle-income countries, waste is often disposed in unregulated dumps or openly burned leading to poor air quality, contaminated water, and the promotion of disease vectors. Poorly managed landfill sites are also significant for greenhouse gas emissions while open burning of waste releases smoke, particulates, and gaseous contaminants into the atmosphere that may carry long distances from their origin. The potential for the spread of infection is also significant for residents close to waste sites and for waste workers, particularly those in the informal sector.

Economic costs and the transition to sustainable waste management

Solid waste management is generally the responsibility of municipal governments and is one of the most important services they provide. Managing waste effectively is at the heart of developing sustainable cities and communities and is often closely aligned to effective governance, but it remains a challenge for many developing countries. Waste management is expensive, often comprising up to 50% of municipal budgets (UNEP 2015), and in many tropical countries is the largest single expense for cities (World Bank 2012).

The degree of sophistication and sustainability of waste management logistics chains vary within and between countries and have changed over time. High-income countries have moved from a baseline of uncontrolled dumping and burning of waste, through more environmentally sound and sustainable practices, and are now moving towards waste prevention and the circular economy (UNEP 2015).

Despite producing less waste per capita than wealthier nations, many developing countries do not have the basics in place for effective or affordable waste management systems. In the lowest income countries collection costs make up more than 90% of total waste management costs and almost all collected waste is subsequently burnt or disposed in open dumps and landfills (UNEP 2015). Many of these countries can barely afford to meet collection costs for half of their population let alone reach universal coverage or dispose and treat waste appropriately. Due to the disproportionate costs involved, many low income countries find even the first steps in transitioning to more sustainable waste management infrastructure and practices challenging (Table 3.2). Better technologies generally become more affordable as income levels rise.

Despite the high upfront financial cost of good waste management, the costs of dealing with poor waste practices are much higher in the longer term (UNEP 2015). As well as the extensive health and environmental benefits of effective waste management there are many direct economic opportunities. The waste management sector is a large employer in many jurisdictions and a major industry in itself. Environmentally sound waste management, the recycling of dry waste and organic materials and energy recovery from waste all represent 'new' green industrial sectors with the potential for contributing between 9 and 25 million new jobs worldwide (McKinsey & Company 2011). Recent estimates to business based on moves towards a circular economy and the adoption of better resource efficiency and waste prevention suggest benefits in excess of USD $1 trillion per annum worldwide. In this case, not only does waste prevention avoid waste management costs, but it saves on broader costs relating to raw materials, energy and labour costs associated with wasted products (McKinsey & Company 2011; UNEP 2015).

In addition to generating different types of waste, tropical nations face particular climatic issues relating to waste management including high rainfall, humidity, heat and extreme weather events. High rainfall in particular can contribute to movement of waste and leaching of harmful chemicals onto land and into ground and surface water sources, which can be an especially acute issue in Small Island Developing States and other regions where water scarcity is a problem (Agamuthu & Herat 2014). Since most of the waste that is generated in tropical developing nations ends up in dumpsites and landfills, addressing best practice options for waste storage with these conditions in mind and in view of limited economic resources and technical capacity in these countries merits more attention (ISWA 2013). Most of the operational guidelines for developing and managing landfills have been prepared for and by developed countries which may not be applicable to tropical nations. Recent initiatives such as those developed by the International Solid Waste Association demonstrate the need and potential for more focus on developing context relevant infrastructure and practices that address uniquely tropical waste management challenges and opportunities (ISWA 2013).

Table 3.2 Estimated Solid Waste Management costs by disposal method (from UNEP 2015).

	LIC	LMIC	UMIC	HIC
Income (GNI/capita)	<$876	$876 – 3,465	$3466 – 10725	>$10726
Waste Generation (tonnes/capita/year)	0.22	0.29	0.42	0.78
Collection Efficiency (percent collected)	43%	68%	85%	98%
Cost of collection and disposal (US$/tonne)				
Collection	20-50	30-75	40-90	85-250
Sanitary Landfill	10-30	15-40	25-65	40-100
Open Dumping	2-8	3-10	NA	NA
Composting	5-30	10-40	20-75	35-90
Waste-to-Energy Incineration	NA	40-100	60-150	70-200
Anaerobic Digestion	NA	20-80	50-100	65-150

Table 3.3 Estimated Solid Waste Management Costs 2010 and 2025 Data Source

Country Income Level	2010 Cost	2025 Cost
LIC	$1.5 billion	$7.7 billion
LMIC	$20.1 billion	$84.1 billion
UMIC	$24.5 billion	$63.5 billion
HIC	$159.3 billion	$220.2 billion
Total Global Costs	**$205.4 billion**	**$375 billion**

Looking Forward

Sustainable development in the Tropics depends on addressing significant infrastructure deficits in the provision of water, sanitation and waste management services which are among the most basic of human needs. While progress has been made in recent decades it is variable both between these sectors and between different regions across the Tropics. The latest UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) assessment suggests most countries are not spending enough to meet water and sanitation goals by 2030 and that radical increases in investment will be required in the next few years (UN-Water 2017).

In addition to investment, however, is the need to improve governance and human and institutional capacity in order to develop, operate and maintain effective and resilient infrastructure. Nations that have established clear institutional responsibility and specific budget guidelines for water, sanitation and waste management have generally had much better long term outcomes. Top-down centralised supply led infrastructure solutions have historically dominated the sanitation and water landscape with variable effectiveness. Decentralised demand led strategies such as the Community-Led Total Sanitation alongside local innovations have met with considerable success in a number of tropical nations. However, in order for these bottom-up approaches to have a greater impact, future programs need to be implemented on a much larger scale than has occurred to date.

Critically, efforts will require collaborative action across developing nation and donor governments, civil society, multilateral agencies and the private sector in order to consider multi-disciplinary perspectives that incorporate different aspects of planning, engineering, local environmental, cultural and public health issues, while considering factors such as technical capacity, social acceptability, economic sustainability, institutional viability, and political will. Particular emphasis on the role of users and communities as collaborators in infrastructure planning and project implementation is needed.

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4

PUBLIC-PRIVATE-PEOPLE PARTNERSHIP FOR PUBLIC SPACES IN SEBERANG PERAI, PENANG, MALAYSIA

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An image often associated with the tropics is one of lush, green jungle, filled with biodiversity and wildlife. However, the tropics are also home to fast-growing cities and urbanizing populations. Greenery and green spaces in these urban centres do not occur spontaneously. Preserving green spaces and providing public access in the face of limited budgets and competing demands is a challenge for many fast-growing cities in the developing countries of the tropics.

Meeting this challenge is well worth it. From an infrastructure perspective, green spaces attenuate stormwater flows, mitigate air pollution, and reduce urban heat island effects ,(Villarreal et al., 2004, Oliveira et al., 2011, Nowak et al., 2006). These spaces also promote healthier living by enabling physical activity, facilitating community interactions, and fostering a sense of place and neighbourhood (Cohen et al., 2007, Harper et al., 2012, Hur et al., 2010). Merely viewing greenery relieves stress, improves mental health, and even reduces recovery times for patients (Beyer et al., 2014, Ulrich, 1984). Many of these benefits are linked to the quantity and quality of, as well as public access to these greenery and green spaces (Larson et al., 2016).

While the benefits of greening cities are plentiful, finding the resources to do so is a challenge for any city council, which has to balance a variety of competing needs. This is especially true for tropical cities, which are located in countries that have on average a third of per-capita GDP compared with the rest of the world (State of the Tropics, 2014 (State of the Tropics, 2014)). Consequently, spending on green infrastructure is crowded out. In the South-East Asian region, "almost all cities… have inadequate and poor quality greenspace," (Said and Mansor, 2011). As the ability to carry out top-down investment is limited in many tropical cities, policies that encourage private investments and initiatives, as well as community ownership of these green spaces are necessary (Brown and Ferreira, 2013).

In Malaysia, the municipal council for Seberang Perai, known as Majlis Perbandaran Seberang Perai (MPSP), has taken this challenge seriously. This province, which comprises the mainland portion of the Penang state, has a population of 897,600 within an area of 738km^2. The province is economically and socially diverse and integrated, as reflected in its numerous mixed-income neighbourhoods. Public spaces are especially important in this context in encouraging community interaction and place-making across socio-economic, ethnic, and religious boundaries.
MPSP has placed a high emphasis on public spaces in its budget, in response to constituent feedback in participatory budgeting programmes. The council allocated RM 3.3 million between 2012 and 2016 for its 1,776 open spaces and five parks. While this is a significant sum for MPSP's limited resources, it is insufficient to

Image: Perai River. Marufish.

rejuvenate many of the existing open spaces that were found to be unattractive and under-utilized.

In response to this need, MPSP launched the 4P's concept of development, which stands for Public, Private, People, & Partnership. The objective of this 4P's project is to solidify social integration, social development and improve environmental protection to deliver a "Cleaner, Greener, Safer and Healthier Penang & Seberang Perai." In the programme, MPSP (Public) opened up sponsorship opportunities to corporate bodies (Private) while utilizing its ties to the community (People) to create effective partnerships. This has resulted in many successful collaborations with private companies, non-profit organizations and individuals partnering the council in upgrading and maintaining its public spaces. Since 2012, MPSP has completed twenty-four 4P's projects with an additional nine projects in progress. This represents a value of RM 6.4 million from MPSP's partners, almost double MPSP's allocation. This has enabled rejuvenation of parks such Taman Tunku, located in the township of Seberang Jaya.

Taman Tunku, named after Malaysia's first Prime Minister, Tunku Abdul Rahman has an area of 11.73 acres. It is located by the Perai River in the middle of a fast growing town, and is strategically situated next to key public facilities in Seberang Jaya, including the Seberang Jaya Mosque, swimming pool, sport centre, and food court. In addition to serving as a recreational park for the community Seberang Jaya it also serves as a retention area for storm water management – an important ecosystem service in tropical Malaysia. Prior to the 4P's project for this park, Taman Tunku had not been well-maintained. Consequently, the park appeared overgrown, dilapidated, and uninviting, and was thus under-utilized.

In response to the 4P's initiative by MPSP, the Surveyors, Planners, Engineers, Architects and Developers (SPEAD) in Seberang Perai became sponsors for the upgrading work of Taman Tunku. MPSP and SPEAD jointly developed the concept "The Natural Bonding between Human and Environment" and its implementation. SPEAD provided architectural and engineering planning and invested RM 470,000 into constructing jogging and cycling paths and a mini-plaza, providing additional amenities, and repairing existing facilities including the children's playground, gazebo, and Zen garden. MPSP planted 240 new shade trees in the park, engaged the community through the planning and upgrading process, and facilitated activities in the park that revitalized community use and ownership of this public space. Upgrading works began on March 17th, 2012 and were completed on June 31st, 2012.

Image: Malaysia. Linus Mak.




A significant increase of the numbers of visitors was observed following project completion. Many programmes have been held by MPSP in Taman Tunku, including aerobic programmes, cycling, jogging, Tai chi, family day, etc. This has promoted social interactions, relationships and ties in the community. These activities and the collaborative work on the park has created a sense of ownership and partnership of Taman Tunku among the SPEAD members, the local community, and MPSP. The benefits are seen in publicity and community relationships for SPEAD, a better quality of life for the community, and improved trust in governance and reduced cases of park vandalism for MPSP. The successful revitalization of the park has drawn additional sponsors, including Sony and Panasonic, for further upgrading and a river conservation programme.

Generating sustained interest from the private sector for upgrading and revitalizing public spaces is not a simple task. MPSP's success in its 4P's programme cannot be duplicated merely by allowing logos to be placed on sponsored items and facilities. The "People" portion of MPSP's public-private-people-partnership is central to its vision, not merely for this project, but for its entire orientation. This has earned MPSP the goodwill and trust of the communities it services. Thus, by supporting MPSP initiatives, sponsors tap into the positive image of MPSP and are assured that the projects are desired by and will benefit the target communities. Additionally, while infrastructure upgrading is necessary to revitalizing these public spaces, it is insufficient. The MPSP slogan, a "City without Activities is a City without Souls," recognizes the importance of communal activities in place-making. By facilitating this, MPSP ensures public buy-in and maximizes the value of the investment it and its partners make. The creative partnerships, good governance, and holistic thinking MPSP has displayed are key ingredients that have made the 4P's plan successful, and that other cities will need to emulate to draw private and community partnership in securing public green spaces.

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SUSTAINABLE URBAN AND INDUSTRIAL COASTAL DEVELOPMENT IN THE GREAT BARRIER REEF WORLD HERITAGE AREA

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Key Messages

- The Great Barrier Reef is among the most biodiverse tropical places on the planet
- Coastal development and industrial expansion continues adjacent to this sensitive ecosystem, and now extends to 10% equivalent along the coastline.
- Development and expansion has fragmented and removed entirely important coastal wetland habitat features (i.e. freshwater wetlands, mangroves, seagrass), which is important habitat for marine animals
- Trials incorporating green engineering thinking is showing that traditional hard engineering solutions could be more eco-friendly
- Implementation of more eco-friendly design in coastal construction is possible and is necessary as coastal city's expand in the coming decades.

Coastal development in the tropics

Expansion of tropical urban and industrial centres continues to threaten the ecological and cultural values that coastal wetlands and rivers provide. In many places, the modern day seascape exists as a multiuse environment, used for shipping goods and services, wastewater disposal, urban development, road corridors, agricultural/aquaculture enterprises and recreation. A recent report prepared by the World Bank outlined that urbanisation is a key process in ending extreme poverty. Although the growth of urban areas provides new opportunities for more people to prosper, poorly planned urban expansion could exacerbate inequality in access to services, employment and compromise the natural environment.

The construction of coastal engineering infrastructure such as seawalls and breakwaters are generally created for the protection of expensive shoreline assets (e.g. bridges, residential property and port development) from the impacts of ocean driven erosion, exacerbated by sea level rise and other climatic factors such as extreme weather. Coastal managers are continually challenged with balancing conservation and protection while also approving further coastal development. While ecological research has centred on examining how well individual engineered habitats mimic natural habitats (Browne and Chapman, 2014, Chapman and Underwood, 2011, Chapman, 2003), data quantifying how much engineering exists in coastal seascape areas, what has been lost following this expansion, and determination of opportunities to repair and restore estuaries following post development, is not available (Waltham and Sheaves, 2015b).

Effective management of new and existing marine artificial structures continues to challenge industry and government organisations (Dafforn et al., 2015). Research and development that integrates ecological philosophies as part of the engineering design is emerging with positive outcomes (even providing net ecosystem benefits). Examples of eco-friendly or 'green' engineering in urbanised marine environments are emerging

Figure CS5.1 Sensitive receptor marine habitats, soft coral and seagrass, along the GBR coastline.

(e.g., Seattle, Singapore), but the same level of research and development in Australia is limited. The need to balance coastal development with environmental outcomes led to the preparation of two planning documents (1/ Fisheries Guidelines for Fish-Friendly Structures 2006 – Queensland Government; and 2/ Environmental Friendly Seawalls 2012 – New South Wales Government). Both documents provide a starting point towards sustainable development, though local specific data are needed to realise the full potential of sustainable development.

Background to the project

The tension between coastal development and conservation is particularly important on the tropical east coast of Australia where plans to extend development (mining, agriculture and port infrastructure) (Stone et al., 2016) lie adjacent to the World Heritage listed Great Barrier Reef (GBR). The GBR is a tropical marine ecosystem of globally significant biodiversity with extensive environmental, cultural, social and economic value (Great Barrier Reef Marine Park Authority, 2014).

Recognised as a World Heritage Area and National Marine Park, the GBR has a series of inscribed international agreements, and national and state legislation/policies in place for its protection and management (McCook et al., 2010). The GBR lagoon has important tangible linkages with adjacent coasts and estuaries, which are connected as part of a larger nursery and feeding complex that supports the life histories of marine and freshwater species (Sheaves et al., 2012). Many economically important fisheries (up to 62% of the commercial and 76% of recreational catch have a critical estuary lifecycle phase (Sheaves, 2001), relying directly on the connectivity between the reef and the shallow tidal and freshwater wetland features often lost to development (Great Barrier Reef Marine Park Authority, 2014, Lanyon, 1986). Many functional characteristics of this habitat complex are under threat due to on-going agricultural runoff contributing to poor water quality (Brodie et al., 2013), loss of natural freshwater wetlands as nursery habitat (Pearson et al., 2013), expansion of adjacent urban areas, and port expansions following increasing mining activities (Waltham and Sheaves, 2015a). The impact of rising sea surface temperatures are also already affecting the ecosystem health of the GBR with widespread heat induced coral bleaching occurring in 2016 and 2017 (Hughes et al., 2017).

The declining health and resilience of GBR ecosystems in response to continuing landscape and climate change, has attracted local and global media attention (Brodie and Pearson, 2016). These concerns that the GBR was "in danger" led to a request by UNESCO (June 2011) for Australian government agencies to conduct a strategic assessment of the Great Barrier Reef World Heritage Area (GBRWHA). Central to this assessment was addressing exactly how future coastal development could continue while still satisfying conservation and protection obligations/responsibilities under the world heritage agreement. The assessments highlighted weaknesses in knowledge and uncertainty in the design and implementation of coastal infrastructure projects. This has led to repeated problems with the implementation and operation of coastal development alongside impacts on coastal wetland habitats (Sheaves et al., 2015). Often there is no failure of governance or compliance, rather problems stem from incomplete knowledge and understanding of key values, which impacts effective decision making.

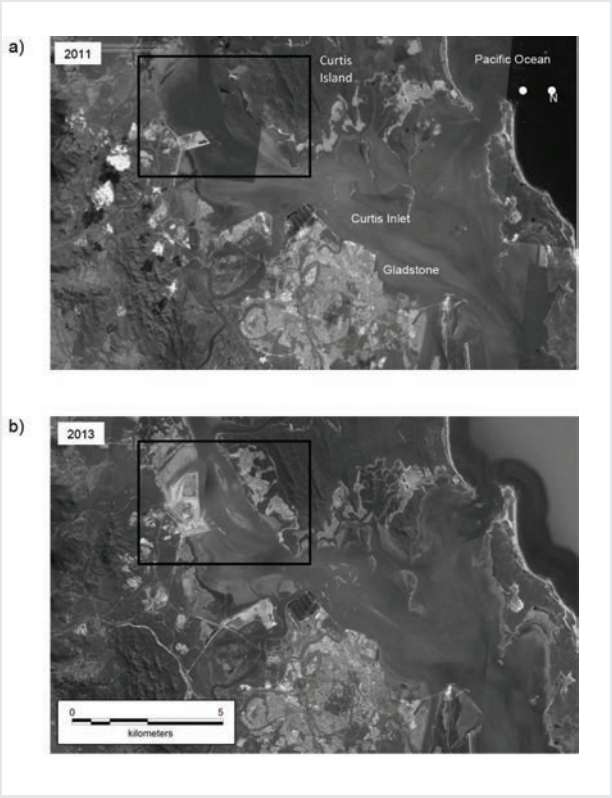

Figure CS5.2 Google earth image showing expansion of port development and associated infrastructure in Curtis Inlet, Gladstone: a) 2011; and b) 2013. Development has added extensive engineered structures along Curtis Island, and also western region of Inlet (see insert box).

Extent of coastal development

Mapping coastal engineeirng in the Great Barrier Reef

There are tools available to address this important data gap . A recent study used the freely available Google Earth imagery as a basis to identify the location of each engineering structure on the GBR coastline. This method measured the footprint dimensions of the infrastructrure (length, width and surfact area) related to the surface area of adjacent coastline, estuary or wetland; thus understanding the full extent of natural ecosystems replaced

with development. The results found approximately 10% of the GBR coastline has been modified with seawalls, jetties, pontoons and heavy industry facilities (Waltham and Sheaves, 2015a). The result now is a seascape that includes natural wetland areas, interspersed among coastal development and land use change.

Innovative solution – Greening engineering trial Townsville seawall

Figure CS5.3 Green engineering trial along seawall Townsville

There are also options for reducing the impact these hard structures have on the natural environment, and thus limit their impact on the adjacent reef. The concept of ecological sustainable development has emerged over the past four decades to assist managers challenged with balancing requests for development approval against the need to achieve ecosystem conservation and protection. In 2003, Anastas and Zimmerman provided 12 principals fundamental in ecological sustainable development – termed "green engineering". This concept centred on combining environmental science with engineering design principals. While green engineering has been embraced in terrestrial landscapes (roof top gardens, green walls), access to scientific data in coastal settings is less available. In the few marine examples available, research focused on how structures could mimic adjacent natural habitats, thus enhancing the ecosystem of the new structure. Basically, this research attached additional structure or re-engineered rock and concrete seawalls to include water retaining features, shading and crevices along otherwise featureless or smooth engineering surfaces. The results are encouraging, revealing that these small, inexpensive, design changes provide additional microhabitat complex for the colonization of marine organisms.

A green engineering trial been completed along a seawall in Townsville, on Australia's tropical east coast (Waltham in press). In this trial, flower pots were added to an existing seawall, at mid tide so that they would retain seawater at low tide, creating an artificial rock pool (see figure). Seawalls are exposed at low tide to direct sunlight, which minimises habitat opportunities to marine life that are sensitive to temperature and exposure. The flower pots retain water at low tide so they supported a range of different marine life. Over the course of the two year study, sponges, barnacles, oysters, snails, and algae all colonised the artificial rock pools, indicating that a few small engineering changes to hard infrastructure in tropical estuaries can have a positive impact on local ecosystems.

Applicability to the tropics

The tropics is set to experience unprecedented population increase and urban expansion. Somewhat paradoxical to this, the tropics has the highest biodiversity on the planet. This means that managers face the challenge of approving more development and expansion, while at the same time responsible for protecting the leftover natural coastal habitats. The social acceptability of eco-friendly engineering is becoming more pertinent as more emerging green and smart city initiatives are realised through changes to strategic planning and policies (e.g. GREEEN Cities for sustainable living – Asia Development Bank 2016; East Asia's Changing Urban Landscape – World Bank (2015). In the case study here, adding water retaining features to an existing seawalls provided habitat features and improved biodiversity, on otherwise a featureless rock seawall. Similar data is emerging from trials in Singapore, Spain, Turkey, Washington State (USA), and Sydney (Australia).

Future outlook and conclusions

This case study delivers several lessons that can be applied to other parts of the Tropics. These include:

- Using freely available spatial mapping tools can easily and consistently generate data on the type and distribution of coastal engineering structures. Such mapping methodology could be easily adopted to other tropical regions, building a more encompassing data set for comparison and planning;
- Addition of water retaining features, installed to an existing seawall, provided important microhabitat opportunities for marine species that were not found on the adjacent exposed seawall;
- Trials elsewhere using green engineering technology continue to demonstrate that balancing coastal development and protection with biodiversity and conservation outcomes might be more achievable than previously believed.
- More research is necessary on other coastal features, including port development and offshore oil platforms, residential canal estates, marinas, pontoons, jetties and bridge pillions. In all these coastal features, the benefits of greening engineering could be fully realised, and providing data necessary that informs coastal policy and planning in other tropical sprawling centres.

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4

TRANSPORT

SUMMARY

- Access to transportation is essential for human development and wellbeing in the Tropics, however implementation of transport infrastructure requires a fully integrated environmental and social cost benefits approach.
- Airfreight originating in tropical countries and territories remains a small proportion of the global total, and is largely dominated by South East Asia.
- Air passenger traffic in the Tropics has grown at just under 7% per annum between 1981 and 2015 compared to the rest of the world which grew at just under 5% per annum. Between 2010 and 2015, air-traffic passenger numbers from the Tropics grew by almost 9% per annum, driven by strong growth in Central America, South America, South Asia and South East Asia.
- It is estimated that between 2000 and 2010, the global roadway network length increased by 12 million kilometres. China and India accounted for more than 50% of paved road additions during that period. Some estimates predict the addition of further 25 million kilometres of new roads are anticipated by 2050.
- Private investment in roads represents the largest investment in transport projects across the Tropics on the whole, although the majority of investment in both Central and Southern African and Northern Africa and the Middle East was in new seaport infrastructure.
- Improvements in technology mean that the future of sustainable transport may include other means for people to access the goods and services it provides.
- Well planned cities and communities can offer people the ability to access what they need without long trips in fossil fueled powered vehicles, instead using more physically active forms of transport (e.g. bicycling or walking) comfortably and safely.

4

Sustainable transport plays an integral role in food security, health, energy and human settlements. Road and rail provide access to schools and services and allow goods to be carried to markets. Sea and airports are gateways to the rest of the world. The United Nations defines sustainable transport as "the provision of services and infrastructure for the mobility of people and goods – advancing economic and social development to benefit today's, and future generations – in a manner that is safe, affordable, accessible, efficient and resilient, while minimising carbon and other emissions and environmental impacts" (United Nations, 2016)

From a sustainability perspective, the transport sector is responsible for one quarter of energy related greenhouse gas emissions worldwide and new transport corridors can have wide reaching environmental impacts. Greenhouse gas emissions from the transport sector have more than doubled since 1970 and have increased at a faster rate than any other end use sector (Sims et al., 2014b). It is the largest end user of energy in developed countries and the fastest growing one in most developing countries.

Transport is a cross cutting issue in global sustainable development (Box 4.1) and has particularly relevance in the Tropics where there is a high number of land locked nations and small island developing states. Physical, social and political isolation are significant contributing factors to extreme poverty and inequality. Access to sustainable, reliable transport is essential for social and economic development.

Transport infrastructure development is expensive but when built well and with appropriate management and maintenance provides significant long term economic and social benefits. Globally it is estimated that $1.3 trillion per annum will needed to be invested in transport infrastructure to achieve the 2030 Agenda (Woetzel et al., 2016). The Asian Development Bank estimates that South East Asian nations alone will need to invest $227 billion per annum between 2017 and 2030 to meet transport infrastructure needs (ADB, 2017). However, regardless of cost, how tropical countries develop and maintain their transport infrastructure is a central aspect of sustainable development in the Tropics and globally.

International goals and agreements | **BOX 4.1**

Sustainable transport is an integral part of the sustainable development agenda. Of the 2030 Agenda's 17 goals and 169 targets, five goals and their associated targets are directly related to the transport sector:

SDG #3 ***Good health and wellbeing; Ensure healthy lives and promote well-being for all at all ages.***

- By 2020, halve the number of global deaths and injuries from road traffic accidents. Road quality and effective governance after the construction of new road infrastructure is essential

Goal #7 ***Affordable and clean energy – Ensure access to affordable, reliable, sustainable and modern energy for all.***

- By 2030, double the global rate of improvement in energy efficiency. The transport industry is a major user of fossil fuels and improvement

SDG #9 ***Industry, innovation and infrastructure – Build resilience infrastructure, promote inclusive industrialization and foster innovation***

- Develop quality, reliable, sustainable, and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.

SDG #11 ***Sustainable Cities and Communities – Make cities and human settlements inclusive, safe resilient and sustainable.***

- By 2030, provide access to safe, affordable, accessible, and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities, and older persons.

SDG #12 ***Responsible Consumption and Production – Ensure sustainable consumption and production patterns.***

- Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities.

Transport is also a critical enabler of achievement in other sectors' targets, such as agricultural productivity (SDG 2); air pollution (SDG 3); access to safe drinking water (SDG 6); sustainable cities (SDG 11); reduction of food loss (SDG 12); and climate change adaptation and mitigation (SDG 13).

Indicators

Air transport, freight (million tonnes/km) and passengers carried

Airports are among the most important infrastructural elements of modern cities and countries. The air transport industry places a vital role in connecting nations and contributing to trade and economic growth, especially in industries that rely on rapid transit times such as tourism, logistics and high tech manufacturing. Freight and passengers carried in the Tropics are indicators of not only growth and development of this industry but capability of nations and cities to manage and profit from trade and tourism. Air transport of both cargo and people plays a particularly important role in small-island developing states and land locked countries in the Tropics where boat services are non-existent, infrequent, or the on ground infrastructure for transport is poor.

Road Density (km/km^2)

Roads provide substantial social and economic benefits, increasing access to markets, education, healthcare and other services. They are considered an important infrastructure investment with a high rate of return for government and private investors. However, new roads, particularly in wilderness areas can dramatically increase land colonization, habitat disruption and overexploitation of wildlife and natural resources.

Port capacity – Container port traffic (TEU: 20 foot equivalent units).

International trade is highly dependent on shipping. The vast majority of trade by volume, particularly in developing countries is transported by sea. Access to ports has long been a measure of how a nation can access global markets. Alongside trade liberalisation policies, new technologies associated with long haul ocean going vessels and the rise of the shipping container has driven growth in international shipping globally.

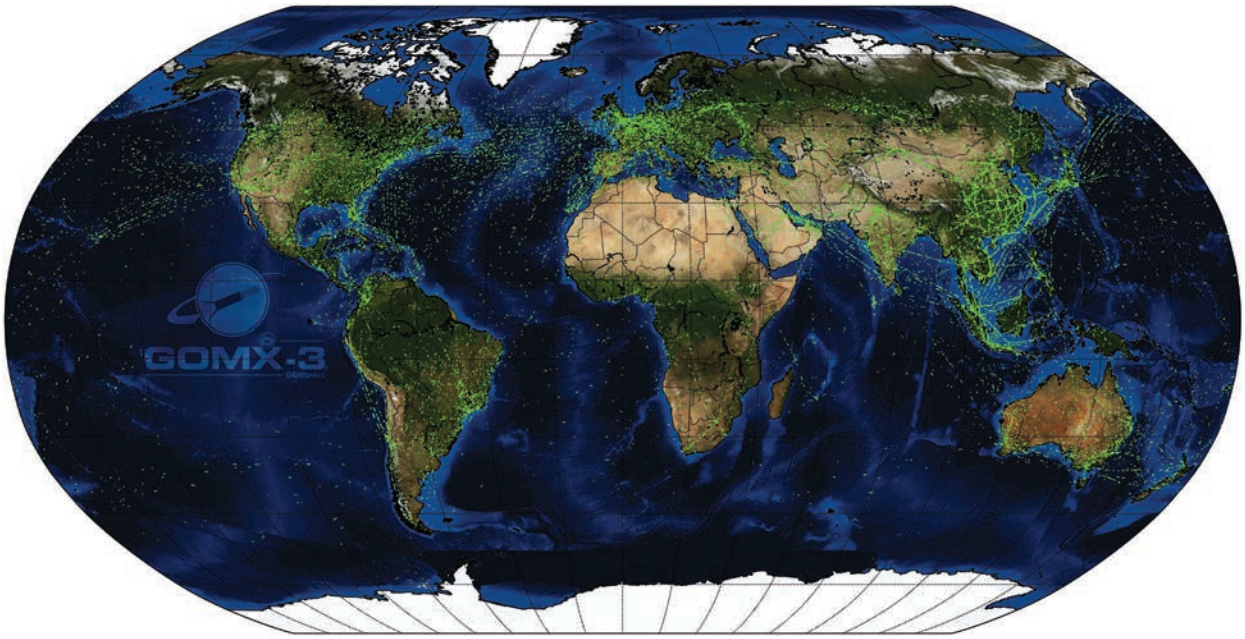

Figure 4.1 Detections of aircraft in flight made by ESA CubeSat GomX-3 during the six months to October 2015. (Image credit: European Space Agency (ESA/GomSpace, 2016))

Trends

Air freight (million tonnes/km) and passengers carried (total)

Air transport provides rapid and intercontinental connections making it an essential economic and social conduit throughout the world (World Bank, 2012). In 2015, estimates suggest some 3.4 billion passengers traveled by air, almost half the world's population, and twice the number travelling at the turn of the century (World Bank, 2016b). Similarly, airfreight increased globally from just under 30 billion tonnes per kilometre in the early 1980s to almost 200 billion tonnes per kilometre by 2015. Figure 4.1 shows aircraft detections by satellite during the six months to October 2015. It clearly demonstrates the most important and common flight routes, particularly within regions rather than between. Flight paths are concentrated over North America, Europe and Eastern Asia, however there are also hubs of activity in South America and South East Asia.

Air freight

Globally, growth in airfreight has been weak since 2010, likely to be the result of slower global growth following the Global Financial Crisis and slow growth in trade, particularly those commodities commonly carried by air (Crabtree et al., 2014). Air cargo typically includes commodities that are time sensitive such as express mail, perishable food items and live animals. According to Crabtree et al (2015), weakness in consumer demand and business investment in Europe, North America and Japan accounts for much of the slowdown, with growth in China, India and Brazil also slowing. Despite this slow down, airfreight is expected to grow over the next few decades, particularly as technology related to fuel efficiency, continues to improve (Crabtree et al., 2014).

Airfreight originating in tropical countries and territories remains a small fraction the global total and is dominated by South East Asia (Figure 4.2 & Figure 4.3). Hong Kong's Chep Lak Airport is now the largest cargo airport in the world, exceeding Memphis, USA in 2010.

Air passengers

The number of people travelling by air, however, has continued to rise, with the global economic downtown in 2008 having a small impact (Figure 4.4). Air passenger traffic in the Tropics has grown at just under 7% per annum between 1981 and 2015 while the Rest of the World grew at just under 5% per annum. The regions of highest growth in the Tropics were South Asia and South East Asia (8.3% and 9.3% respectively) (Figure 4.5). Between 2010 and 2015, air-traffic passenger numbers grew by almost 9% per annum, driven by strong growth in Central America, South America, South Asia and South East Asia. In 2015, South East Asia accounted for 57% of all passenger travel in the Tropics and 13% of global passenger traffic.

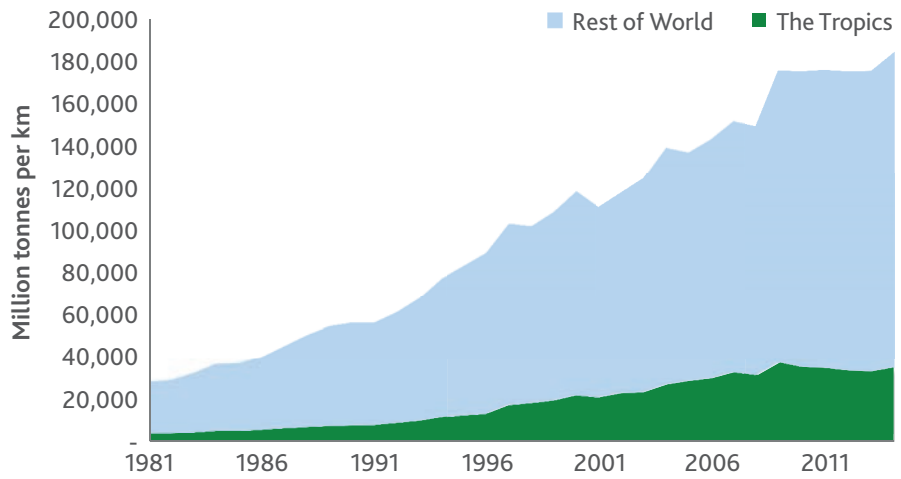

Figure 4.2 Tropics and Rest of the world share in airfreight (million tonnes per km) (World Bank, 2016b, BITRE, 2016, FAA, 2016, IBGE, 2010, GACA, 2015, INEGI, 2015, AAI, 2016, BBS, 2014, CAAC, 2014).

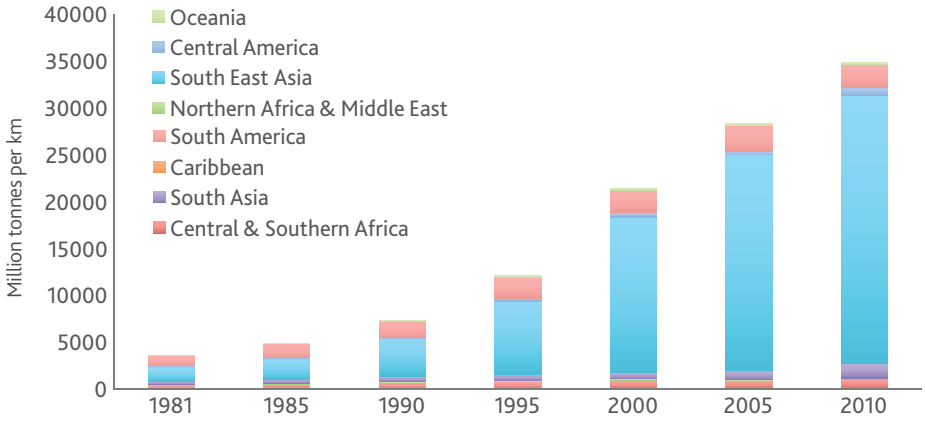

Figure 4.3 Tropical share in air freight by region (million tonnes per km). (IBGE 2010, BBS 2014, CAAC 2014, GACA 2015, INEGI 2015, AAI 2016, BITRE 2016, FAA 2016, World Bank 2016)


Image: Suvanrnabhumi Airport. Mark Ziembicki

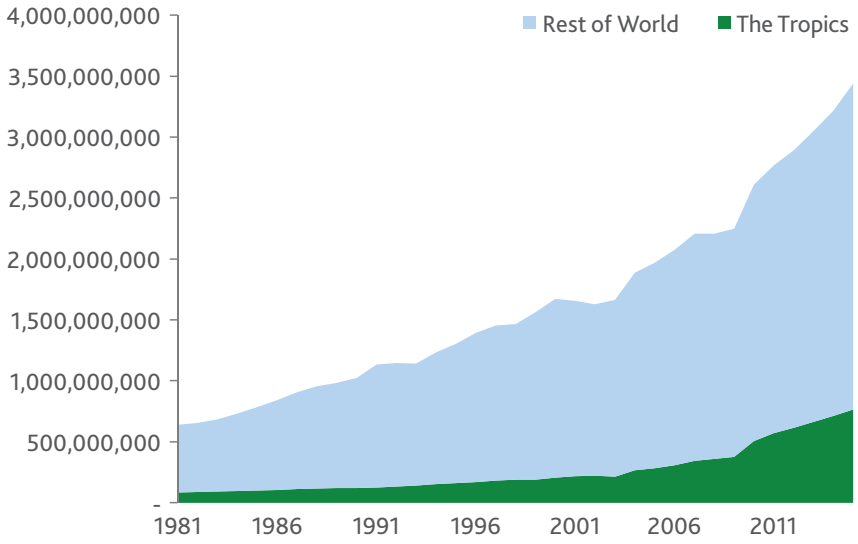

Figure 4.4 Total number of air traffic passengers (based on port of origin) in the Tropics and the Rest of the World (IBGE 2010, BBS 2014, CAAC 2014, GACA 2015, INEGI 2015, AAI 2016,

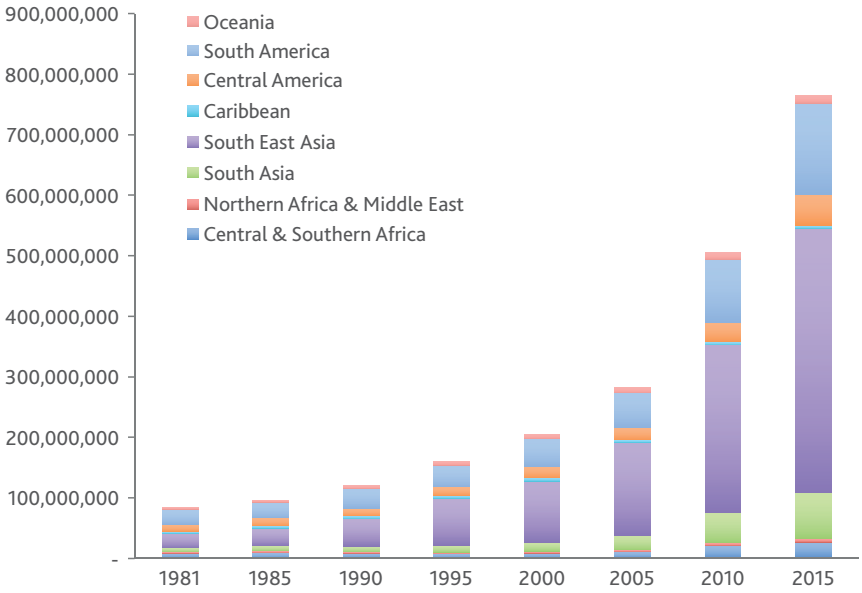

Figure 4.5 Total number of air traffic passengers (based on port of origin) per annum by tropical region over time. Calculations based on data from: IBGE 2010, BBS 2014, CAAC 2014, GACA 2015, INEGI 2015, AAI 2016, BITRE 2016, FAA 2016, World Bank 2016)

Road density

It is estimated that between 2000 and 2010, the global roadway network length increased by 12 million kilometres (Dulac, 2013). China and India accounted for more than 50% of paved road additions during that period. Some estimates suggest that a further 25 million km of new roads are anticipated by 2050 (Laurance et al., 2014)

The quality and availability of data on road density varies between nations. In the Tropics, many roads remain unmapped (Laurance et al., 2011, Laurance et al., 2014). The best available data are obtained from the Socio-Economic Data and Applications Center (SEDAC, 2016) which collates data from multiple sources. Unfortunately time series data are not available, however relative road density can be calculated from aggregate sources to gain an estimate of latest available density (SEDAC, 2016). These data tend to refer to major roads only and do not take into account multiple lane roads.

Road density has been increasing globally with many nations seeing roads as important nation building infrastructure. For example, in Mexico, 66% of all investment in transport infrastructure that has a private component was spent on road

development in the past decade (World Bank, 2016a). Road density varies dramatically across the world with high densities in Europe and North America (Figure 4.6). There is variation between tropical regions as well. High road densities in Central America and the Caribbean are reflective of high population density and large per capita use of private vehicles (Sims et al., 2014a).

Road densities remain highly variable in tropical Africa with landlocked, small nations having much greater densities of roads than those nations with larger land areas, desert areas or long coastlines. It is important to note that the data used here only capture major roads and highways and do not reflect the quality of those roads.

Driven by tropical Australia, which has a low population and large land area, Oceania has the lowest road density in the Tropics. However, even when Australia is removed from the analysis, road densities in Oceania remain low at 0.03 km of road per square kilometre.

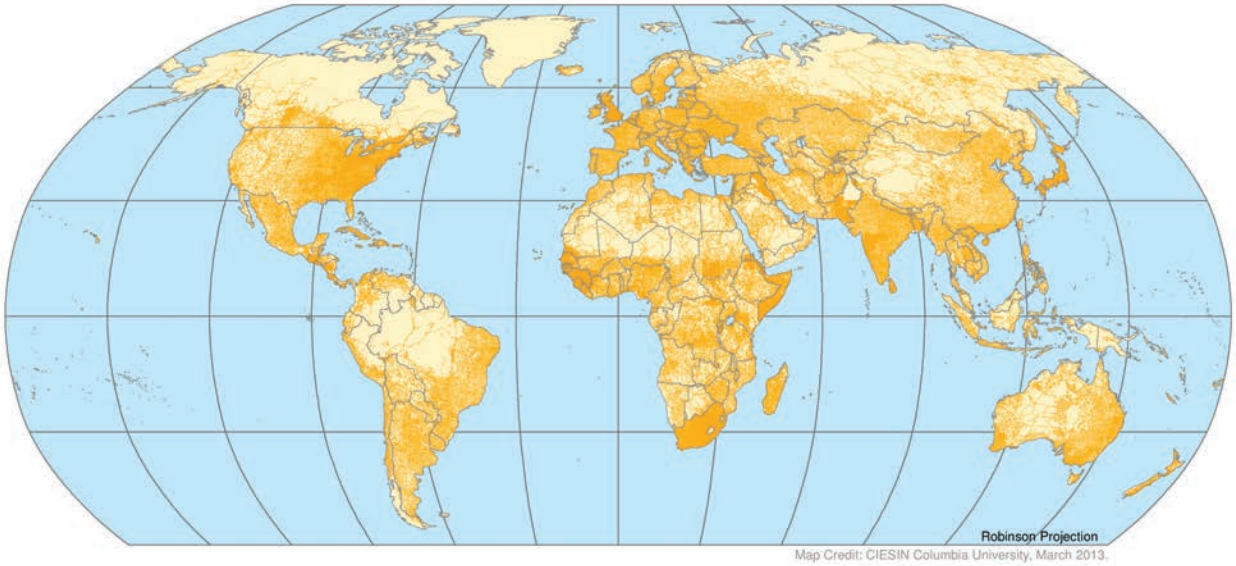

Figure 4.6 Visualisation of the Global Roads Open Access Data Set Version 1 (SEDAC, 2016).

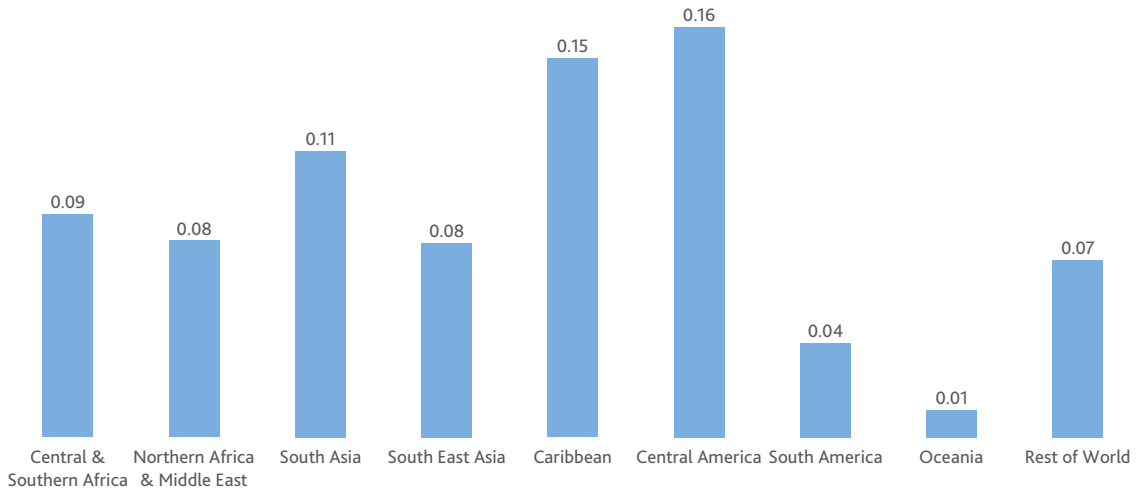

Figure 4.7 Road density (km of road per km^2) by region based on latest available data (SEDAC, 2016)

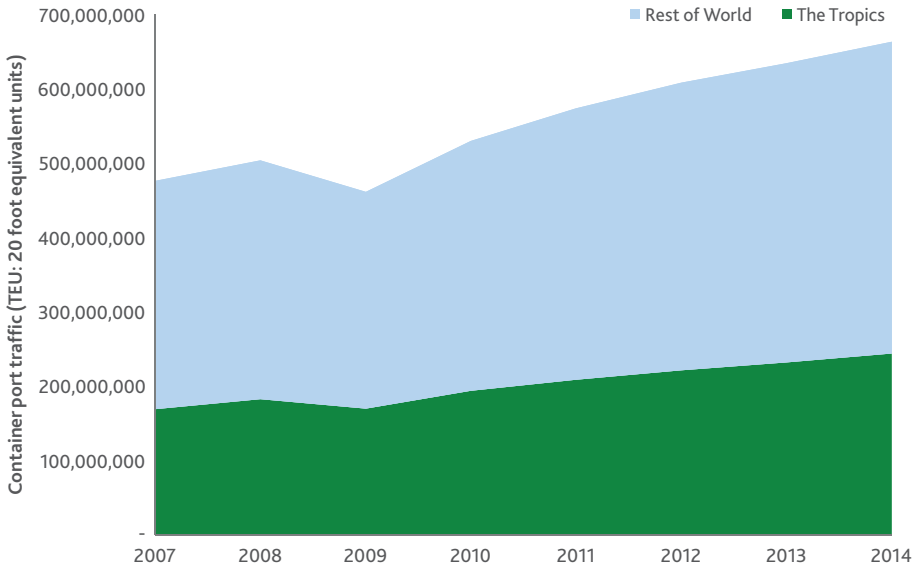

Figure 4.8 Container port traffic, Tropics and the Rest of the World (World Bank, 2016b, Ports Australia, 2016, AAPA, 2016, Kingdom of Saudi Arabia Ports Authority, 2014, IPA, 2015, Pan et al., 2014).

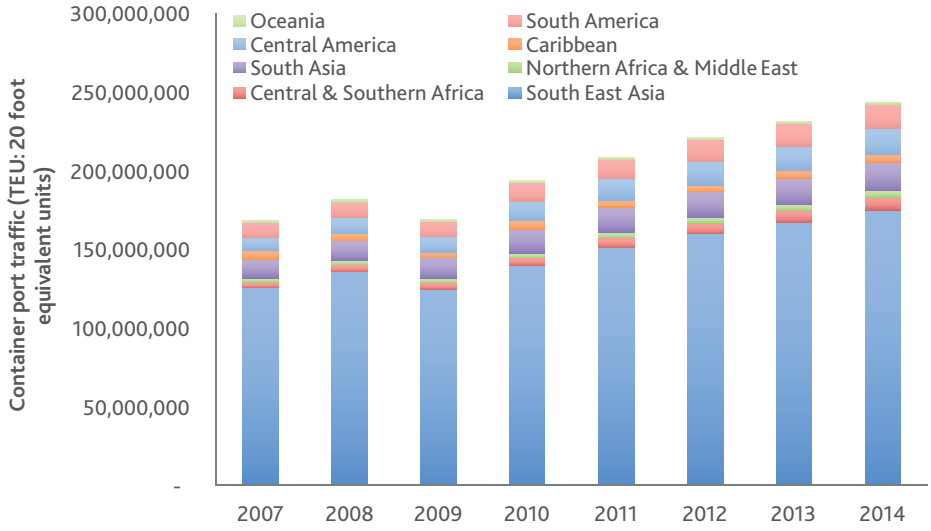

Figure 4.9 Container port traffic, Regions of the Tropics (World Bank, 2016b, Ports Australia, 2016, AAPA, 2016, Kingdom of Saudi Arabia Ports Authority, 2014, IPA, 2015, Pan et al., 2014).

Port capacity

Since the 1950's, world trade has grown substantially faster than estimated world gross production (Levinson 2006). It is believed that alongside international trade liberalisation policies, improvements in shipping technology and infrastructure have driven this growth, particularly the rise of container based shipping (Kaukiainen, 2014). It is estimated that around 90% of world trade by volume is now carried by ships. Ports, and particularly those capable of handling large volumes of containers, are a means of integration into a global economic system and very important in many tropical nations. This indicator measures through volume – the total number of containers both arriving and departing port.

Comprehensive data on the volume of containers are only available from 2007, however since then, the volume of container traffic has increased 5% globally per annum (Figure 4.8). Growth in tropical regions is a little higher at almost 6% per annum. Most tropical regions have shown comparable growth since 2007; however there have been larger increases percentage wise in Central and Southern Africa and Central America. Increases in Central and Southern Africa (15% per annum) are driven by Angola, Nigeria and Kenya, which have all shown rapid growth. This growth has been facilitated by better port infrastructure alongside growing international demand for the continent's cheap natural resources including oil, petroleum and other

minerals. Increases in recent years in Central America are driven largely by through traffic in the Panama Canal. Traffic through the canal is expected to increase further with the opening of the third set of locks in 2016, allowing for more and larger capacity vessels to pass through the canal.

Container volume in the Tropics is dominated by South East Asia (Figure 4.9), reflecting high volumes of containers passing through Hong Kong and other ports associated with the Pearl River Delta in China such as Shenzhen and Guangzhou. The Pearl River Delta region covers nine cities in Guangong province and is the manufacturing hub of China (Liu et al., 2013). It houses thousands of manufacturing plants and generates tens of millions of containers every year (Liu et al., 2013).

In other regions of the Tropics, container traffic growth has been less than, or similar to global patterns. In Oceania in particular, there has been very little change. The lack of the necessary port infrastructure to handle large container ships and a small manufacturing industry might underestimate the importance of ports for other industries in this region. Many ports in Oceania transport livestock, agricultural products and other natural resources through other means than containers. For example, although tropical Australia accounts for 67% of national train freight (largely from mining and agriculture) (BITRE, 2015) it accounts for just over 1% of the country's container traffic (Ports Australia, 2016). It should also be noted that data from a number of ports, particularly in Fiji and Papua New Guinea is likely to be under reported or not available.

Role of the private sector

The private sector plays an increasingly important role in the development of transport infrastructure in the Tropics, particularly roads and seaports. Public-Private Partnerships are a key tool in the provision and management of transport infrastructure, providing poorer countries with access to finance that public institutions are unable to raise themselves.

Private investment in roads represents the largest investment in transport projects by both number and total investment in developing countries in the Tropics. Since 1990, public-private investments in South Asia have numbered in the several hundred, driven by significant investment in rural road programs in India and Bangladesh (Figure 4.10). The majority of transport investment in South East Asia, Central America and South America was also in roads as well.

Most investment in both Central and Southern African and Northern Africa and the Middle East was in new seaport infrastructure (Figure 4.10 &Figure 4.11).

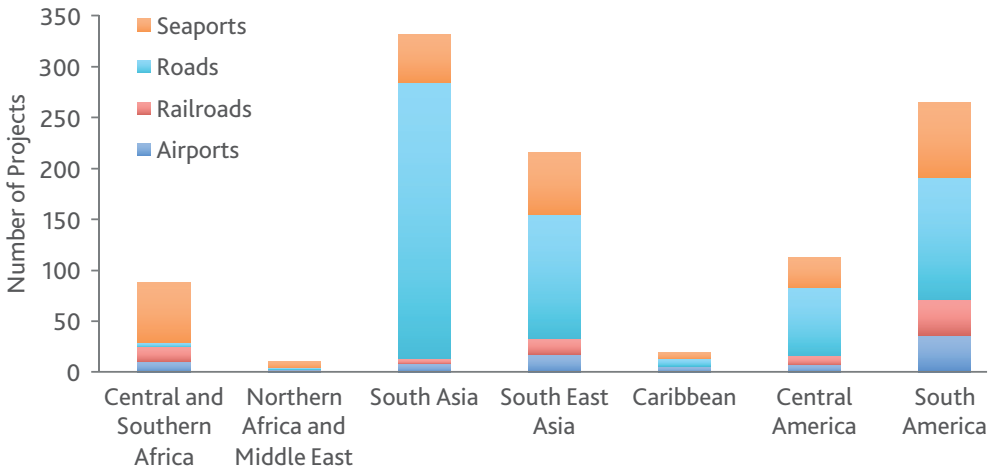

Figure 4.10 Total Number of transport projects with private investment in tropical developing nations since 1990 (World Bank, 2016a)

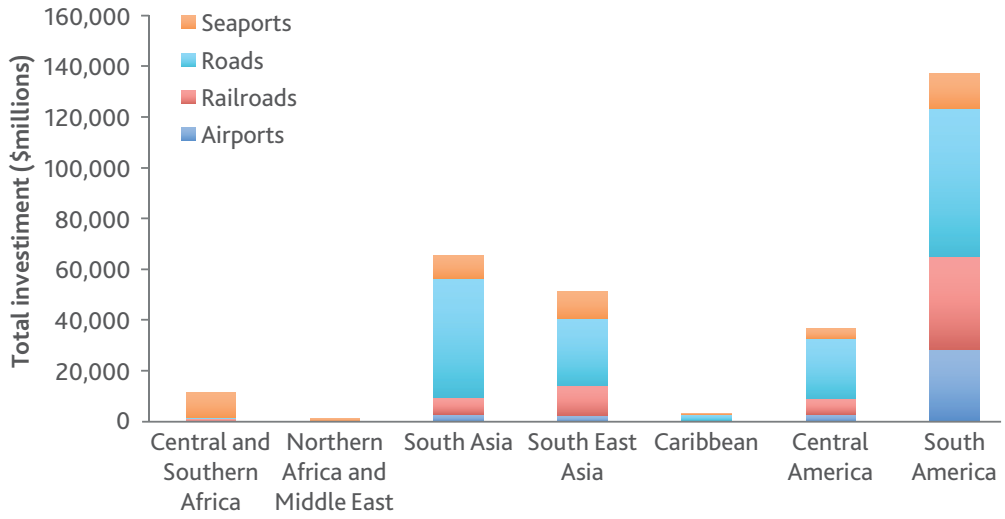

Figure 4.11 Total Investment (million $PPP) in transport projects with private investment in tropical developing nations since 1990 (World Bank, 2016a)

What is very clear from these data is that investment in roads, particularly profitable toll roads, is popular for private investors in the Tropics. Roads are considered to have a high return on investment and many nations have promoted private investment in transport infrastructure through various concessions. For example, due to a road concession program launched in 1995, Brazil now has one of the longest road networks under private concessions in the world (Rodrigues and Manuel, 2014). Some 7% of all paved roads in Brazil are toll roads, built with public private partnerships. Similar programs exist throughout Latin America where most land based transport including freight is heavily dependent on road vehicles.

Relationship with other sectors

Sustainable transport is an essential ingredient in sustainable development strategies. Transport infrastructure is generally long term: roads, railways, air and sea ports will last for decades, having long lasting impacts on people, urban development and the environment. It is a complex sector with implications for a wide range of other sectors and populations, economic actors and individuals (United Nations, 2016). Transport infrastructure in the Tropics is particularly exposed to the effects of weather, particularly in regions with high rainfall and extreme events such as tropical cyclones.

Health and wellbeing

The major role of transport infrastructure is to provide access for both people and freight; access to health services; access to markets; access to education. Through improving access, a weather proof road or reliable public transport route can play an important role in preventative health care in multiple ways (Banerjee and Sachdeva, 2015). Provision of roads especially reduces travel time and costs, improves healthcare supply, increases income, awareness, and social interactions, all of which contribute to improved preventative care outcomes (Banerjee and Sachdeva, 2015).

Transport also plays an important role in the health, wellbeing and mobility of older people. In tropical regions of Africa, especially in the era of HIV/AIDs, many family groups consist of grandparents supporting and caring for orphaned grandchildren (Porter et al., 2013). Other parts of the Tropics, particularly South East Asia and Latin America are facing a growing older population. Health concerns and poverty mean that continuing access to livelihoods is essential for the elderly to support themselves and others in their care. Research in a rural area in Tanzania, where road access and transport availability is difficult, particularly in the wet season, found that transport is a major hurdle for many older people not only for their daily domestic water and fuel needs but also for accessing health care and markets (Porter et al., 2013).

Conversely, transport infrastructure can also have a negative impact on health and wellbeing. Every year 1.24 million people die in road accidents and a further 3.5 million people die prematurely due to outdoor pollution contributed to in part by road vehicles, particularly in South Asia and South East Asia (United Nations, 2016). Based on estimates per capita, the Tropics has a much higher rate of road fatalities at 20 per 100,000 people compared with 15 per 100,000 in the rest of the world (World Bank, 2016b). According to available data, the Tropics accounts for around 50% of all road fatalities globally (World Bank, 2016b). Along with road and traffic conditions, this is also reflective of the quality of emergency health care available in many tropical countries.

Although airports are important centres of employment and help drive economic growth, they may also have negative effects on health and wellbeing, at least locally. Noise and air pollution and subsequent health impacts are factors, as are reduced property values (Cidell, 2015).

Another important aspect of transport infrastructure and health is its relationship with active mobility i.e. using more active modes of transport like walking and cycling. In tropical nations, walking and cycling rates remain high, often because there is no other option. Increasingly however, particularly in tropical cities, where traffic congestion, pollution and heat are increasing factors, active mobility becomes not only uncomfortable but aslo hazardous. Rapid urbanisation often means that road design favours cars over people. Improving active mobility options in the Tropics can have long term positive heath and environmental outcomes. This is explored in depth in Case Study 7 which looks at infrastructure initiatives to promote walking and cycling in the tropical city of Singapore.

Environment

The traditional approach to meeting demand to move freight and people globally has been to build more infrastructure: bigger ports, more roads, and longer railways. However, this approach has not been sustainable and has resulted in ongoing impacts, particularly on vulnerable and diverse tropical ecosystems. Transport infrastructure can be responsible for air, water, and noise pollution, habitat fragmentation and destruction as well as being a vector for invasive species and diseases (OECD, 1997).

Local impacts of large scale transport infrastructure include air, water, and noise pollution. Transport infrastructure can produce carbon monoxide, carbon dioxide, hydrocarbons, nitrogen oxides, particulates, soot, and ozone. All of these compounds can affect air and water and have environmental and health impacts and they can also combine to have additional impacts beyond the problems cause by each individually (e.g. photochemical haze in large cities). These chemicals also have implications beyond human health, with effects on ecosystems and the global climate (OECD, 1997).

Traffic in particular, is a major source of noise, particularly in urban areas. Noise pollution has well documented impacts on human health and wellbeing through health problems such as stress, disturbed sleep, cardiovascular disease and hearing loss (OECD, 1997). It has also been demonstrated to have an impact on the natural environment with a number of biological responses in wildlife such as changes in hearing thresholds, movement and foraging behaviours, predator/prey relationships and mating behaviours (Shannon et al., 2015). In a review exploring the impact of noise pollution globally only 11% of articles explored the impacts of noise pollution in a tropical region (Shannon et al., 2015).

As well as producing pollution, transport infrastructure has the potential to fragment unique and diverse tropical ecosystems. Roads and railways can have immediate and long term impacts on tropical environments (Laurance et al., 2014). The impact of new roads is of particular concern for pristine tropical forests; resulting in a collection of negative impacts such as land colonisation; habitat disruption and overexploitation of wildlife and natural resources (Laurance et al., 2014). Recent work on how best to build and maintain roads in order to environmental costs is explored further in Case Study 6.

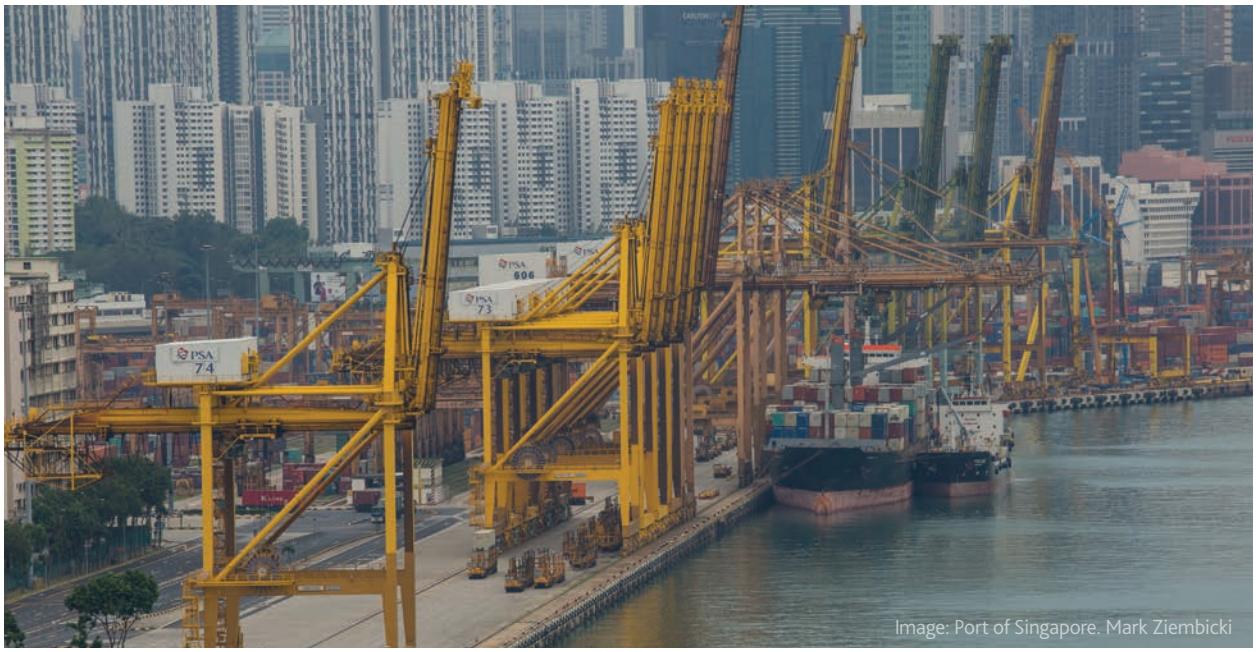

Image: Port of Singapore. Mark Ziembicki

Shipping is a major vector for alien species moving across oceans. Since vessels began crossing seas and sailing between regions, marine species have travelled with them; initially on wooden hulls and more recently in the ballast water of increasingly larger and faster merchant ships (Hutchings et al., 2002). Most of these aquatic travelers do not survive in their new environment and thus pose little risk. Some flourish however, and can crowd out other species or change the balance of existing ecosystems (OECD, 1997). There are a number of well-known examples from temperate regions (e.g. zebra mussels in the American Great Lakes) but there are few known from tropical ports (Hutchings et al., 2002). This may be because the risk of invasive species becoming established is actually much lower in well connected, high diversity, tropical marine ecosystems due to greater competition from native species. There is some evidence to suggest however that artificial, disturbed or polluted tropical habitats are much more susceptible to invasions from exotic species even in the Tropics (Hutchings et al., 2002). Therefore, maintaining diverse ecosystems and good water quality in coastal areas, even alongside complex coastal infrastructure can help lower the risk of infestation.

A changing tropical climate

Climate change will have significant impacts on transport infrastructure. Railway and road networks for example, are especially vulnerable to climate stressors such as higher temperatures, increased precipitation, and flooding. Such stressors are especially acute in the Tropics, and are set to increase (Sims et al., 2014b). Consequently, to ensure spending on such infrastructure is sustainable and delivers the best possible returns and lasting development benefits, it is critical that investments consider the consequences of a changing climate. High temperatures can result in softening or rutting of asphalt roads; and high rainfall can lead to reduced load carrying capacity and lifespan of roads and railways. Increased flooding frequency will overrun and erode roads, particularly unpaved roads (Cervigni et al., 2017). Additional to these maintenance and rehabilitation costs, climate related damage to transport infrastructure will cause more frequent disruptions to the movement of people and goods with direct consequences for economic productivity (Cervigni et al., 2017). Coastal infrastructure associated with ports and shipping is likely to be increasingly vulnerable to rising sea levels and extreme events such as tropical cyclones with both economic and environmental consequences.

Addtionally, higher temperatures and more extreme weather related to climate change is likely to affect those using active modes of transport such as walking and cycling in the Tropics. Flash flooding, heat and pollution increase risks for those without the protection of larger vehicles, potentially discouraging the use of less carbon intensive transport modes.

Image: China. Mark Ziembicki

Climate change mitigation

In 2010, greenhouse gas emissions from the transport sector had reached 7.0 gigatonnnes of CO_2 equivalent, effectively doubling since 1970 (Sims et al., 2014a). This is almost a third of total end use energy from all sectors; 80% of this increase has come from road vehicles. The transport sector is responsible for around 23% of total energy related CO_2 emissions and there is a very high risk that the continuing growth in passenger and freight activity could outweigh all mitigation measures (Sims et al., 2014a). Most is this increase has actually occurred outside of the Tropics; about 10% of the world's population account for 80% of total motorized passenger kilometres, mostly in the OECD

countries of Europe and North America (Sims et al., 2014a). Evidence suggests that although greenhouse gas from developing countries are increasing and are not likely to reach a peak in the foreseeable future, it is likely that activity levels from transport in particular will plateau at much lower levels than in developed regions (Sims et al., 2014a).

Looking forward

It is clear that access to transportation is essential for human development and wellbeing in the Tropics, however implementation of transport infrastructure requires a fully integrated environmental and social cost benefits approach. Improving and maintaining existing infrastructure and limiting new infrastructure expansion into intact ecosystems is likely to be the best example. However, this may impede development of currently underserved communities. Finding a balance between access to markets, education, health care, and the environmental impact of transport will be essential for transport development in the Tropics.

There are alternatives to the models of development that have defined transport infrastructure to date. Tropical nations have opportunities to leapfrog unsustainable transport systems (particularly a growing reliance on cars). A sustainable future for the Tropics both will require shifting some travel from cars and towards mass transit modes. However, existing trends show that this is not occurring –investments in road infrastructure are increasing throughout the Tropics along with a growing reliance on personal vehicles. The switch to more sustainable methods of transport has been slow even in highly developed nations such as Australia and USA.

The future of sustainable transport may also include other means for people to access the goods and services they require. Improvements in technology mean that telecommuting; remote education and health consultation; e-commerce and even 3D printing may provide alternatives. In addition, well planned cities and other communities can offer people the ability to access what they need without long trips in fossil fueled powered vehicles, using more active forms of transport comfortably and safely.

Image: Galapagos Islands. Mark Ziembicki

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GLOBAL 'ROADMAP' SHOWS WHERE TO PUT ROADS WITHOUT COSTING THE EARTH

Professor William Laurance, James Cook University

"The best thing you could do for the Amazon is to blow up all the roads." These might sound like the words of an eco-terrorist, but it's actually a direct quote from Professor Eneas Salati, a forest climatologist and one of Brazil's most respected scientists.

Many scientists share Salati's anxieties because we're living in the most explosive era of road expansion in human history. The International Energy Agency (IEA) predicts that by 2050 we will have 60% more roads than we did in 2010 (Dulac, 2013). That's about 25 million kilometres of new paved roads – enough to circle the Earth more than 600 times.

Our research team has developed a global "roadmap" of where to put those roads to avoid damaging the environment (Laurance et al., 2014) . These maps are also available to the public on a new website (Global Roadmap, 2014).

Roads today are proliferating virtually everywhere – for exploiting timber, minerals, oil and natural gas; for promoting regional trade and development; and for building burgeoning networks of energy infrastructure such as hydroelectric dams, power lines and gas lines.

Even national security and paranoia play a role. The first major roads built in the Brazilian Amazon were motivated by fears that Colombia or the US might try to annex the Amazon to utilise its valuable natural resources. Road building along India's northern frontier reflects concern about disputed territories and China's role in the region.

According to the IEA, around nine-tenths of new roads will be built in developing nations (Dulac, 2013), which sustain the most biologically important ecosystems on Earth, such as tropical and subtropical rainforests and wildlife-rich savanna-woodlands.

Crucially, such environments also store billions of tonnes of carbon, harbour hundreds of indigenous cultures, and have a major stabilizing influence on the global climate.

Killer roads

Why are roads regarded as disasters for nature?

Far too often, when a new road cuts into a forest or wilderness, illegal poachers, miners, loggers or land speculators quickly invade – unleashing a Pandora's box of environmental problems.

For instance, my colleagues and I recently found that 95% of all forest destruction in the Brazilian Amazon has occurred within 5 kilometres of roads (notably, we also found that many Amazonian roads are illegal; for every kilometre of legal road, there were three kilometres of illegal roads) (Barber et al., 2014).

Other research has shown that major forest fires spike sharply within a few dozen kilometres of Amazon roads (Adeney et al., 2009).

The Congo Basin is experiencing a rapid increase of forest-road building by industrial loggers, with over 50,000 kilometres of new roads bulldozed into the rainforest in recent years. This has opened up the forest to a tsunami of hunting. The toll on wildlife has been appalling; in the last decade, for instance, around two-thirds of all forest elephants have been slaughtered for their valuable ivory tusks .

In Peru, a new highway slicing across the western Amazon has led to a massive influx of illegal gold miners into formerly pristine rainforests, turning them into virtual moonscapes and polluting entire river systems with the toxic mercury they use to separate the gold from river sediments.

Avoid the first cut

Many road researchers believe the only safe way to protect a wilderness is by "avoiding the first cut" — keeping it road free (Centre for Tropical Environmental and Sustainability Science, 2017). This is because an initial road opens up a forest to deforestation, which then spreads rapidly. An initial road slicing into a wilderness typically spawns a network of secondary and tertiary roads, allowing deforestation to easily metastasise.

For instance, the first major highway in the Amazon – completed in the early 1970s to link the cities of Belém and Brasília – was initially just a razor-thin cut through the forest. Today, that narrow incision has grown into a 400-kilometre-wide slash of forest destruction across the entire eastern Amazon.

But we need roads

And yet, for all the environmental perils of roads, they are also an indispensable part of modern societies. Most economists love roads – seeing them as a cost-effective way to promote economic growth, encourage regional trade and provide access to natural resources and land suitable for agriculture.

How do we balance these two competing realities – between wealth and social development, and the potential catastrophic impacts on tropical forests?

This vexing question has been the focus of a group of researchers from Harvard, Cambridge, Melbourne, Minnesota, Sheffield and James Cook Universities and the Conservation Strategy Fund.

A global roadmap

This scheme has two components. The first is a map that attempts to illustrate the natural values of all ecosystems worldwide. We built this map by combining data on biodiversity, endangered species, rare habitats, critical wilderness areas, and vital ecosystem services across the Earth.

We added in parks and other protected areas, as these are also high priorities for nature conservation.

The second component is a road-benefits map. It shows where roads could have the greatest benefits for humankind, especially for increasing food production.

Focusing on food is vital because, with continuing rapid population growth and changing human diets, global food demand is expected to double by 2050.

Roads affect food because large expanses of the Tropics – especially in Sub-Saharan Africa and expanses of Asia and Latin America – are populated by small-scale farmers who produce much less food than they could if they had new or better roads. Such roads could give them ready access to fertilizers, modern farming methods and urban markets to sell their crops.

In these regions most of the native vegetation has already been cleared, so intensifying farming shouldn't have major environmental costs. In these contexts, new or better roads (along with other investments in modern farming methods) are a key way to help struggling farmers to boost their productivity.

A potential bonus of this strategy is that, as farming becomes more productive and rural livelihoods more prosperous, regions with better roads tend to act as "magnets" – attracting people from elsewhere, such as the margins of vulnerable forests.

In this way, investing in better roads in appropriate areas can help to focus and intensify farming, accelerating food production while hopefully helping to spare other lands for nature conservation.

Conflict zones, but reasons to hope

By intersecting our environmental-values and road-benefits maps, we have estimated the relative risks and rewards of road building for Earth's entire land surface – some 13.3 billion hectares in total.

In our map, green-toned areas are priorities for conservation where roads should be avoided if possible, and red-toned areas are priorities for agriculture (Figure CS6.1).

Dark-toned areas are "conflict zones" – where environmental and agricultural priorities are likely to clash (light-coloured areas are lower priorities for both environment and farming).

The good news is that there are substantial areas of the planet where agriculture can be improved with modest environmental costs.

But there are also massive conflict zones—in Sub-Saharan Africa, expanses of Central and South America, and much of the Asia-Pacific region, among others. These hotbeds of conflict often occur where human population growth is rapid and there are many locally endemic species — those with small geographic ranges that are especially vulnerable to intensive development. Our global roadmap is, admittedly, an exceedingly ambitious effort. Yet our hope is that our strategy can be incorporated with finer-scale local information to help inform and improve planning decisions at national and regional scales.

Our effort is a first step toward a vital goal: a global plan for road expansion. We're not so naïve as to believe everyone will immediately adopt it, but such efforts are unquestionably a crucial priority.

There is precious little time to lose if we don't want to see the world's last wild places overwhelmed by an onslaught of roads, destructive development and the roar of fast-moving vehicles.

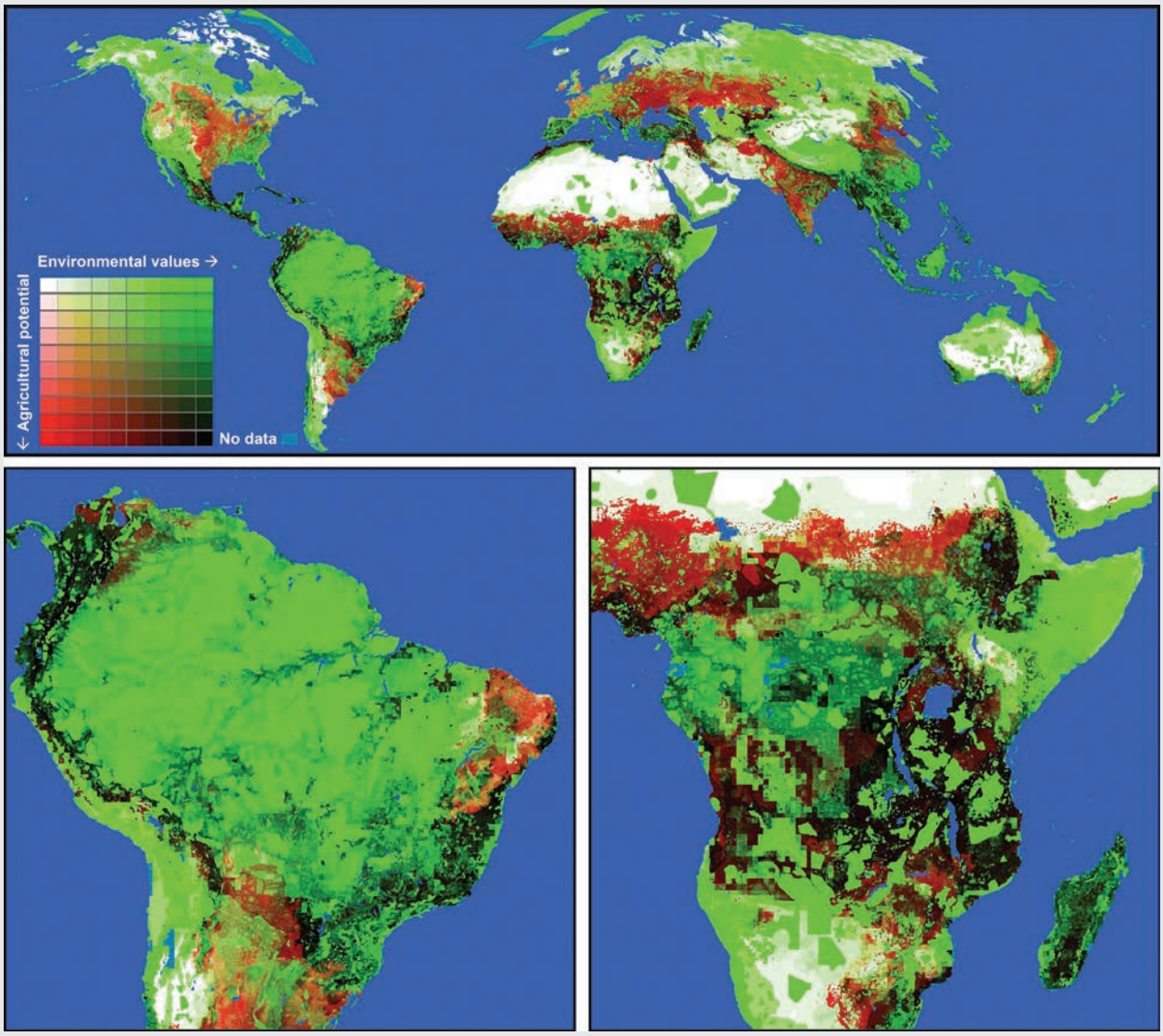

Figure CS6.1 A global roadmap, with parts of South America and Africa magnified (Laurance et al., 2014).

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WALKING AND CYCLING IN THE TROPICAL ISLAND OF SINGAPORE

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Key Messages

- Walking and cycling are green-space efficient and accessible modes of transport that have personal and social benefits.
- Planning for walking and cycling in tropical countries should take a multi-disciplinary approach, considering environmental factors and personal features of pedestrians and cyclists. A human-centric approach is important to establish quality needs of pedestrians and cyclists.
- Weather in the tropics is an important factor for trips on foot or by bicycle. Ample provision of shelters along the pathways is a key factor to encourage the use these transport modes.

Walking and cycling in tropical Singapore

Singapore is a dense 716km^2 island city-state with 5.54 million habitants (SINGSTATS 2015). Being a highly urbanised island nation, authorities in Singapore are applying concerted efforts to balance land use planning with inhabitants' needs and desire for a sustainable and liveable city (CLC and ULI 2015). Active mobility, i.e. walking and cycling, is being widely promoted, especially as the first/last mile (FLM) trip stage to public transport nodes and for short-range trips within townships.

Located close to the equator, Singapore has a tropical climate, with medium-high temperatures, elevated humidity, and year-round rainfall (Meng et al. 2016). Such climatic conditions reduce the attractiveness of active mobility. Elevated temperature and humidity often result in excessive perspiration, and frequent rainfall increases the risk of traffic accidents. Indeed, most leading walking- and cycling-centric cities today are in the temperate regions. Active mobility is nevertheless still attractive in tropical climates, and is highly feasible with appropriate infrastructure planning and design.

Walking and cycling improve health, encourage social interaction, are green-space efficient modes of transport, and contribute towards relief of traffic congestion and pollution. These multi-faceted value-add benefits are much appreciated in a nation with an aging population (SINGSTATS 2015), and where transport infrastructure takes up 12% of available land (LTA 2015a). The authorities in Singapore are focusing vigorously on improving capacity, safety, comfort and accessibility for active mobility users to encourage more walking and cycling trips.

State of developments of active mobility in Singapore

Provision for walking has been available and planned since early years of Singapore's national development (Koh, Wong, and Menon 2014). Attention on cycling infrastructure re-surfaced around a decade ago after a period of "non-popularity" (Koh and Wong 2012). Currently, the walking mode share is 22% and cycling share (as a main mode of transport) is of 1-2% (LTA 2015a). Recently, the interest, research, and provision for walking and cycling has been intensified with aims to further increase active-mode shares.

The high walking trip rate and burgeoning cycling trip rate (albeit from a low base) in Singapore is closely related to the well-maintained, accessible, and comprehensive public transport network (urban rails and buses). Locally, public transport planning is integrated with active mobility planning to ensure they complement each other (LTA 2015a). Presently, 65% of individual people journeys during peak hours are made on public transport. The authorities aim to further increase the public transport mode share to 75% by 2030 while also reducing the distance from home to the transit stations (MEWR and MND 2015). These developments shall likely result in continual increase in active FLM trips (see Figure CS7.1).

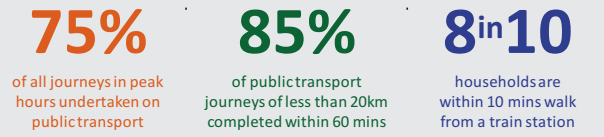

Figure CS7.1 Land transport master plan targets by 2030 (LTA 2015a).

Regarding walking infrastructure provision, accessible footpaths can be found alongside most roads. Signalised crossings and overhead bridges are widely available to facilitate movement of pedestrians and increase their safety. In addition, shelters connect key facilities and amenities, e.g. public transport stations, schools, and markets (Chin and Menon 2015; Koh, Wong, and Menon 2014). Local research has demonstrated that the most important determinant in promoting walking is 'weather-protection' (Koh and Wong 2013). This can be related to the tropical climate of the country, highlighting the importance of shelter provision to foster walking trips.

For cycling, infrastructure has initially focused on recreational trips however, infrastructure provision for cycling as a mode of

transport is receiving more attention in recent years. Designated bicycle-parking facilities are located at most train stations, the Park Connector Network (PCN)is now 300km in length (NParks 2016) and intra-town cycling paths (LTA 2015c) are available for off-road cycling. In addition, 11 towns in Singapore are being "transformed" into cycling towns where pedestrians and cyclists can share off-road pathways and crossings (Koh and Wong 2012). As of the end of 2016, cyclists are now allowed to ride on footpaths (previously only allowed in cycling towns) (Cheong 2016c, MOT Speeches 2016). Indeed, cyclists riding on footways is already quite prevalent island-wide (Koh and Wong 2013).

A series of actions have been recommended and are currently being developed in Singapore to "tackle" the tropical weather and develop walk-able and cycle-able environment (see Figure CS7.2). In addition, as active mobility users also consider scenery as an important mobility factor, provision of vertical greenery or the use of greenery as shelters are being considered in Singapore as part of the Sustainable-Singapore-Blueprint 2015 (MEWR and MND 2015).

CHECKLIST FOR TROPICAL CITIES – Factors that will enhance comfort of active travel in the tropics

MAKE IT CONVENIENT & EFFICIENT	MAINTAIN CONTINUITY OF MOVEMENT	MAKE IT COMFORTABLE & ATTRACTIVE	MIX THE USES	CLOSE THE LOOP W/ END-OF-TRIP AMENITIES
Integrate cycling and walking infrastructure w/ **public transport** **Bike share** systems for cities starting to promote cycling	**Cycling friendly junction designs** with gentle bends to facilitate continuous cycling **Continuous sidewalks** that require cars to stop to allow pedestrians and cyclists to continue through intersection without stopping	**Street planting** to provide shade and visual relief for all road users **Sheltered walkways for pedestrians** **Prioritize maintenance** for pedestrians and cycling infrastructure	**Mixed use developments** to make walking and cycling more convenient for daily commutes	**Adequate public bike parking** facilities at destinations **Showers and laundromats** at workplaces

Figure CS7.2 Developing walking and cycling environments (CLC and ULI 2014).

The first walking and cycling town in Singapore is being developed to further promote walking and cycling as transport modes for FLM trips and for short-range trips (Lim 2016). At this model town (Ang Mo Kio), dedicated walking and cycling paths, wider crossings and extensive provision of shelter and greenery for users' comfort are being implemented (see Figure CS7.3). Traffic calming devices are also being installed to reduce motorised vehicle travelling speed to enhance safety of active mobility users (Lim 2016). The town is being developed with joint collaboration of various authorities under the Sustainable Singapore Blueprint 2015, with aims to achieve "a more liveable and sustainable Singapore, to support the diverse needs and growing aspirations of Singaporeans" (MEWR and MND 2015). These developments are expected to be completed by 2019.

Figure CS7.3 Paths and crossings in Ang Mo Kio

A multi-disciplinary approach has been adopted in Singapore, using a combination of engineering and social studies techniques, towards the planning and implementation of state-of-the-art active mobility infrastructure. Active mobility schemes are being implemented from a human-centric perspective. Herein, quantitative and qualitative data gathering techniques are applied to establish quality needs of active mobility users. Perception-surveys, travel-surveys, unobtrusive observations, one-to-one interviews, telephone interviews, online surveys, and focus group sessions are applied, in order to gather data for projects on infrastructure development, as well as to develop enforcement for good and safe travel behaviour, especially at locations where spaces are shared among pedestrians and cyclists (Cheong 2016a, 2016b; Choi and Toh 2010; Khew 2015; LTA 2015b; URA 2011). Information is collected from different stakeholders and public at large.

Planning the land use and infrastructure development follows a scientific and rigorous framework (see Figure CS7.4). The 10-15 years Master Plan ensures that land use is maximised to meet target economic growth and population transport needs. Tropical weather conditions are considered at each stage of planning, ensuring that suitable alternatives and schemes are proposed and implemented.

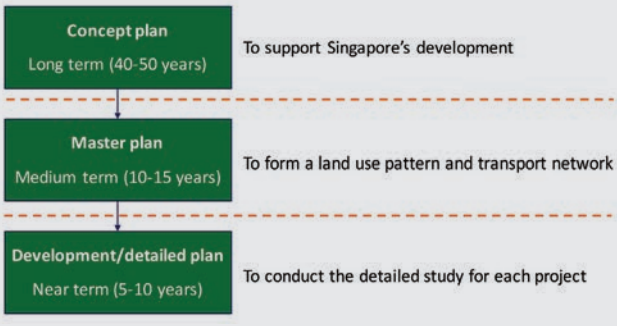

Figure CS7.4 Urban planning framework in Singapore (Zhang, Meng, and Wong 2015)

Singapore's experience

Examples of walking and cycling infrastructure in Singapore can be used as guidelines and/or examples for developing similar infrastructure in other tropical countries/cities, especially in economies that are urbanising rapidly and need to optimise land use.

Holistic data collection entailing a variety of techniques and multi-disciplinary analysis approach are employed in Singapore that are of aid to researchers and planners in different locations to develop transport-related projects accordingly. A lot of data are anchored on the quality needs of the users, as consistent with a human-centric design perspective. Local characteristics of the country/city itself as well as the inhabitants should be taken into consideration when planning and implementing the mobility infrastructure.

Public transport and active mobility need to be developed together and not as independent modes of transport. Singapore's planning framework provides useful examples that achieve high share of active mobility modes, substantially reducing traffic congestion and pollution. Flexibility is required in applying new transport schemes or green-field developments, as well as incorporating greenery-centric initiatives such as foliage-covered walkways and vertical greenery.

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8

THE CUT FLOWER INDUSTRIES OF THE TROPICS

Ann Penny, James Cook University

Key Messages

- The cut flower industries of the Tropics would not exist without transport infrastructure.
- Tropical nations have been able take advantage of improvements in both air and sea freight to access markets which would have otherwise been inaccessible
- The cut flower industry has the potential to be an ongoing source of income and sustainable use of resources for tropical countries.

Background

The custom of giving cut flowers, decorating with cut flowers, or using flowers to honour an event or loss is believed to have prehistoric origins. Today, the floriculture trade is now worth some USD 20 billion worldwide (van Rijswick, 2015).

It is also one of the most visible and rapidly growing agricultural export industries of the Tropics. High altitude climates near the equator provide ideal conditions for growing flowers popular in the cut flower markets in Europe and North America such as roses, carnations, and chrysanthemums. Longer, almost year round growing conditions due to small temperature fluctuations, secure water sources, and inexpensive labour contribute to thriving industries. The cut flower industry in higher latitudes either has a much shorter growing season or requires air tight greenhouses with heating, irrigation, and in some cases, artificial sunlight (Bofinger, 2009). With rising costs associated with energy, combined with lower costs of air freight and improvements in refrigerated shipping, tropical countries such as Colombia, Ecuador, Kenya and Malaysia can now compete with older, traditional markets for cut flowers.

The world cut flower market is dominated by the Netherlands, however between 2003 and 2013 it's market share declined from 58% to 52%. To understand this in more detail: In 2003, Japan imported 10% of its flowers from Malaysia; in 2013 it was 26%. During the same period its imports from the Netherlands declined from 8% to 2%. Similarly, Russia has increased imports from Ecuador and Kenya at the expense of cut flowers from or via the Netherlands. The United States imported about 65% of all cut flowers from Colombia in 2013, against 55% in 2003 (van Rijswick, 2015).

The role of transport infrastructure in Kenya and Colombia

The cut flower industries of the Tropics would not exist without transport infrastructure. Tropical nations have been able take advantage of improvements in both air and sea freight to access markets which would have otherwise been inaccessible to an industry where time and refrigeration is essential for the value of the product.

The Kenyan flower industry is centred around Lake Naivasha (100km from Nairobi) and employs around 500,000 people (Bofinger 2009). The key to the cut flower industry in Kenya is the transportation to final markets. Good road networks connecting growing centres with Nairobi's Jomo Kenyatta International Airport mean that flowers picked in the morning in Kenya reach markets in Amsterdam by evening (World Bank, 2009). Cut flower exports from Kenya to Europe grew rapidly from the 1960s when wide bodied jets began to transport tourists and offered cargo capacity to the industry (World Bank, 2009).

Colombia is the highest volume exporter of cut flowers to the United States. In 2005, Some 84% of the 247,421 tonnes of air cargo going to the United State from Colombia were cut flowers (Bofinger, 2009). Similar to Kenya, this industry grew rapidly due to greater availability of air transport and deregulation within Colombia. Most of the flowers are grown on the high altitude plateau around Bogota (Conlon, 2015).

More recently, alongside air freight, improvements in container shipping have also opened new markets for flower growers the Tropics. In 2013, Colombia shipped about 700 containers of chrysanthemums to the United Kingdom. Vietnam also uses containers to ship flowers to Japan. Expansion of container shipments of cut flowers is driven by various factors including cheaper rates than air freight, the ability to better control conditions within containers, better port facilities, improved knowledge around the best flowers to transport, and growing attention on sustainability issues (van Rijswick, 2015).

Success at a price? Sustainability and social issues

Throughout the Tropics, the cut flower industry has been praised for providing employment, income and infrastructure such as schools and hospitals. However, environmental issues such as

water overuse and unregulated chemical pesticide use alongside social issues such as poor working conditions and wages have affected the perception of floriculture as a sustainable industry. The industry is also considered carbon intensive, particularly due to the high emissions associated with air freight.

Water is essential for growing and keeping cut flowers fresh. Lake Navaisha in Kenya provides the primary source of water for a large proportion of that country's floriculture. In 2009, during a drought, the Lake dropped to its lowest levels in 60 years (WWF, 2015) and there have been ongoing water pollution problems. However, in recent years, a number of programs have been working to improve water management in the basin by encouraging water regulation and governance, sustainable land and natural resource use and sustainable development (WWF, 2015).

Chemical pollution is common in flower growing areas. Flowers are not edible crops so are exempt from regulations on pesticide residues – and in many cases use agrochemicals that are banned, or untested elsewhere. This has been an ongoing issue in Colombia, however market forces are starting to change behavior. The market in the USA is starting to demand a more natural, ethical product which has seen much of the industry shift away from strong pesticide use. This also has health implications for the workers when they are no longer exposed to harsh pesticides, believed to cause birth defects (Lesmes-Fabian and Binder, 2013).

Working conditions and wages have improved also. The Kenyan floriculture industry now accounts for 9% of Kenya's GDP. This means there has been a lot of focus on the industry from within Kenya and internationally. The growth of the fair trade market and increased scrutiny on ethical standards has improved working conditions and wages for Kenyan workers.

Contradictions exist across this industry in terms of carbon emissions as well. Some suggest that because flowers are sold so far from their point of origin, the industry must be very carbon intensive. However, per flower production is much less than in colder climates where energy is required, particularly for year round production. Advancements in shipping container technology will also that mean that more flowers can be transported by ship, which will result in much lower emissions per flower.

Conclusion

Due to improvements in transport infrastructure, the flower industries of the Tropics have transformed communities; providing growth in income and wellbeing. However, there are some environmental consequences of these intensive agricultural products. There is also risk associated with these industries – cut flowers are a luxury item and an economic downtown in the markets of North America and Europe may have an impact. For the time being however, these industries, if managed appropriately provide an opportunity for sustainable development for tropical nations.

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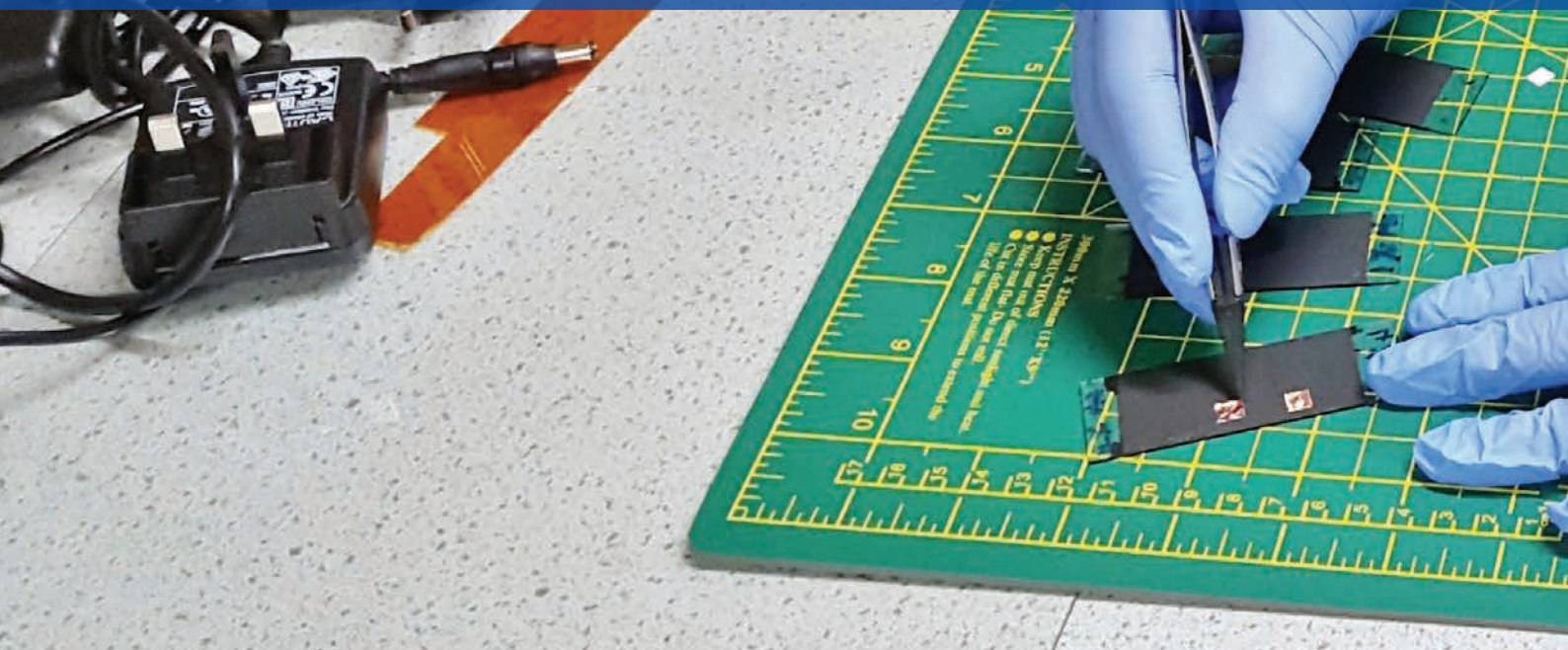
5

INFORMATION AND COMMUNICATION TECHNOLOGY

Image: Sally Kwong

SUMMARY

- Mobile phones remain the main source of connectivity in the tropics. Despite rapid growth since the turn of the century at 92 phones per capita the Tropics remains below the rest of the world (103).
- There is considerable variation across regions and subscriptions per capita in South America and South East Asia are greater than the global average.
- Large gaps in internet access remain in most parts of the Tropics despite a 10 percentage point improvement since 2010.
- High speed, fixed line internet access is very rare in the Tropics but there is increasing access to mobile and satellite broadband
- ICT is increasingly important in the Tropics and can contribute to financial inclusion, health and education outreach and improved productivity of primary industries.
- Of all infrastructure sectors in the Tropics, ICT infrastructure receives the most private investment.




PARTEC

5

People across the globe are more connected than ever. Digital technologies, mobile phones, the Internet and other forms of digital information exchange have changed the way we conduct business, education and share knowledge. Information and Communication Technologies (ICT) refers to any technology that enables the communication and electronic capture, processing and transmission of information. This includes older technologies such as radio, television and fixed line telephony as well as more recent innovations such as personal computers, mobile phones, broadband networks and the Internet. The potential of these new technologies lies in their capacity to instantaneously connect vast networks of individuals, organisations and governments, across all corners of the world. ICT can provide many opportunities for education, entrepreneurship, new modes of finance and banking, and play a role in reducing corruption.

Tropical nations have experienced rapid, but uneven growth in ICT access and use in recent decades. Although mobile phones have become commonplace throughout the Tropics, access to the Internet and high speed broadband particularly has had lower adoption rates in the region and has thus slowed the diffusion of ICT use in services, business and governments. Furthermore, just having nominal access to technology is often not enough. A lack of basic skills or 'digital literacy' limit realising the full potential of information and communication technologies. Furthermore, in many cases, poor access to other basic infrastructure and services is more important and overrides the benefits of ICT facilities. In many rural areas of the Tropics for example, accessing electricity to charge a mobile phone is often more difficult than purchasing the phone to begin with (World Bank, 2012).
Such reasons may, in part, explain why according to the 2016 World Development Report "the effect of technology on global productivity, expansion of opportunity for the poor and the middle class and the spread of accountable governance has been less than expected" (World Bank, 2016c).

International goals and agreements | **BOX 5.1**

Global Goals
The United Nations has recognised the great potential Information and Communication Technologies have for helping achieve the new Sustainable Development Goals and has included increasing access to ICT as a specific target in SDG 9.

SDG 9: ***Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.***
The target specific to ICT is:

- Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020

Connect 2020 Agenda
Through the Connect 2020 Agenda, member states of the International Telecommunications Union (ITU) committed to work towards the shared vision of "an information society, empowered by the interconnected world, where telecommunication/ICT enables and accelerates socially, economically and environmentally sustainable growth and development for everyone" (ITU, 2014).

The agenda includes four major goals:

- Goal 1: Growth – Enable and foster access to and increase use of telecommunication/ICT
- Goal 2: Inclusiveness – Bridge the digital divide and provide broadband for all
- Goal 3: Sustainability – Manage challenges resulting from telecommunication/ICT development
- Goal 4: Lead, improve and adapt to the changing telecommunication/ICT environment.

Indicators

Mobile phone subscriptions (per 100 people) – Mobile phone subscriptions per capita are an indicator of mobile phone diffusion within a nation. Mobile phones are often considered a gateway to ICT access in many developing nations allowing communities to overcome infrastructure barriers and deliver communication networks to previously unconnected populations. Subscription data tend to overestimate the absolute number of people using phones because they do not account for people who may have multiple subscriptions and because inactive subscriptions are often included in datasets.

Mobile broadband subscriptions (% of mobile phones) – Increasingly affordable smartphones and pre-paid data plans mean that people are increasingly accessing the Internet through mobile phones and mobile broadband networks. Subscription data tends to overestimate the number of people who use phones through a distortion by those who own multiple subscriptions and the inclusion of inactive subscriptions in the data.

Internet users (per 100 people) – The Internet, the global system of interconnected computer network is a mechanism for information dissemination and access and a medium for interaction between individuals, businesses and governments. Information and content availability over the Internet enables greater inclusion, empowerment and helps facilitate human development. Internet users are individuals who have used the Internet (from any location) in the last 12 months. The Internet can be used via a computer, mobile phone, personal digital assistant, games machine, digital TV etc.

Fixed broadband access (per 100 people) – Fixed broadband facilitates access to the highest quality Internet services via a variety of high-speed technologies including digital subscriber line (DSL), cable modems and fibre optic cable. High speeds and the ever present, always connected and secure nature of broadband allows access to a greater range of services and richer internet experience. Broadband services remain either unavailable or prohibitively expensive in many developing nations.

Trends

Mobile phone subscriptions

Since its public debut some 30 years ago the mobile phone has become the world's most widely used communications technology. While on the surface the number of mobile phone subscriptions appears to exceed the total number of people on the planet, a distortion in the data due to the consideration of multiple subscriptions per person and the inclusion of inactive accounts tends to overestimate the true number of people using mobile phones, requiring some caution in interpretation of this metric as an indicator. Nevertheless, subscription data allow

us to understand the growth of mobile phone connections and make relative comparisons between regions. Globally, it appears that mobile phone ownership is becoming close to universal. By comparison, the overall proportion in the Tropics lags the rest of the world at 90 mobile phone subscriptions for every 100 people (Figure 5.1). Growth rates in mobile phone access have actually slowed in recent years, indicating saturation in many nations.

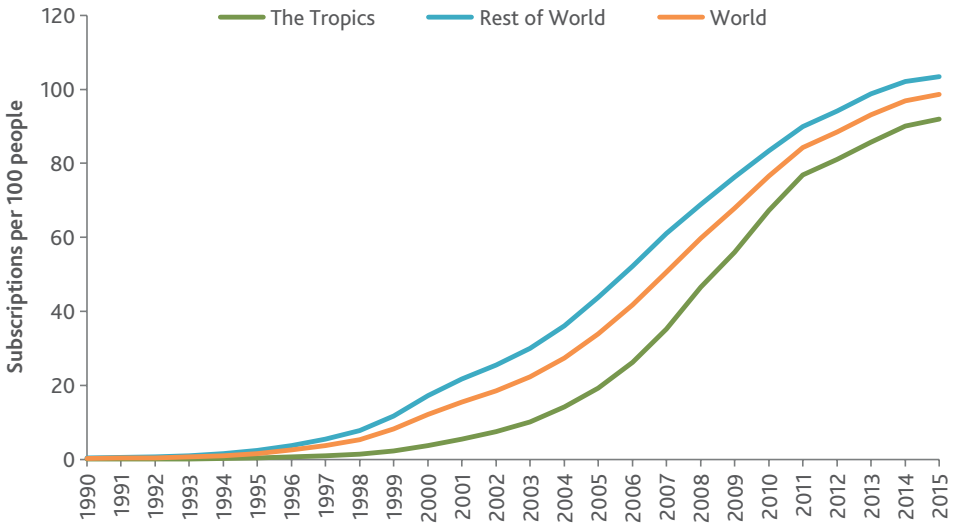


Figure 5.1 Number of mobile phone subscriptions in the Tropics and the Rest of the World (per 100 people) (World Bank, 2016b, ITU, 2016)

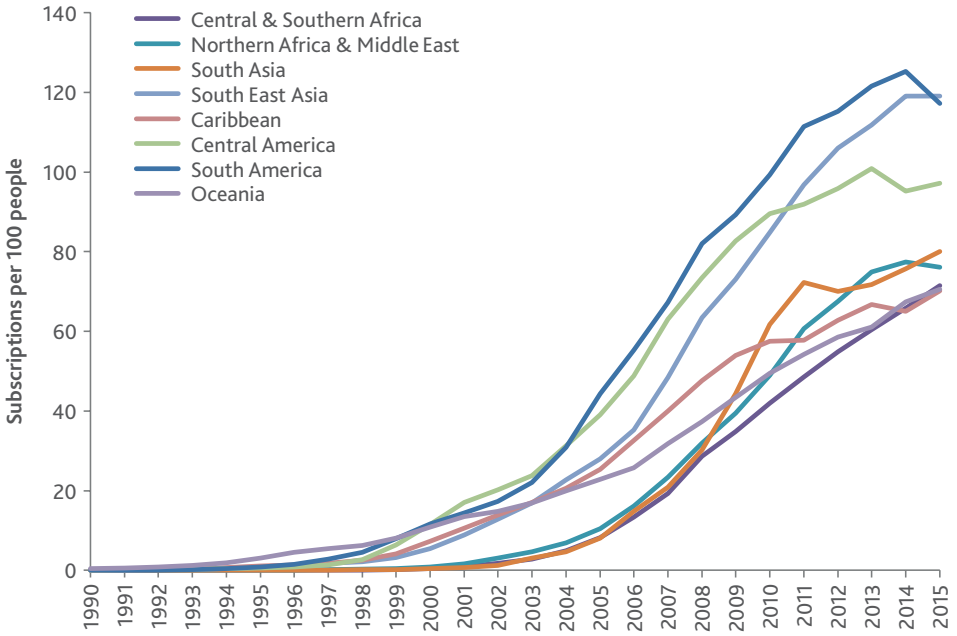


Figure 5.2 Mobile phone subscriptions (per 100 people) across tropical regions (ITU, 2016, World Bank, 2016b)

Although there is still considerable variation in access to mobile phones between regions in the Tropics, uptake has been significant and rapid in recent years. While coverage in Central and Southern Africa, Oceania, the Caribbean, South Asia and Northern Africa and the Middle East was below 80 mobile phone subscriptions per 100 people in 2015 the extraordinarily quick rate of mobile phone uptake will mean that these regions will soon catch up with the others. Furthermore, while in many regions mobile coverage is still often limited to urban areas this too is changing quickly with telecommunication companies building infrastructure in more rural and remote areas. Meanwhile, the prices of mobile phones (including of smart phones) are falling in developing countries, making them increasingly affordable. Apparent declines in mobile phone subscriptions in South Asia, Central America, and South America in recent years are largely due to corrections in the data associated with inactive subscriptions (GSMA, 2014).

Mobile broadband subscriptions

One of the most important and transformative technologies to arise in the past decade is the development of smart phones and mobile Internet access. Although using mobile phones for voice communication is still the main revenue generator for mobile phone companies (GSMA, 2014), smart phone technology and the rapid increase in third party software applications means that a mobile phone can be used for a wide variety of purposes. Lower prices for smartphones in many developing countries are driving a digital revolution with users and developers leveraging the potential and power of mobile networks to transform services across sectors including in agriculture, education, health, energy, and water and sanitation management. However, access to the Internet through mobile broadband remains low in many parts of the Tropics largely due to the lack of infrastructure and appropriate networks, or the high costs of accessing data. Although people may have access to a smart phone, they do not necessarily have access to the Internet and the full range of services provided by mobile broadband.

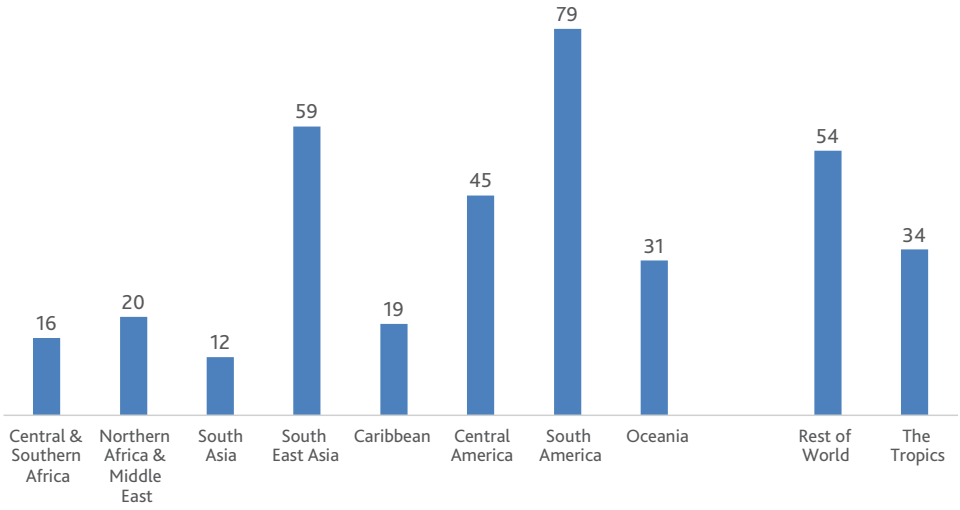


Figure 5.3 The number of mobile broadband subscriptions per 100 people across the Tropics and the Rest of the World in 2015 (GSMA Intelligence, 2016).

Although time series data are not available for mobile broadband subscriptions the latest available information from 2015 reported by the mobile broadband industry (GSMA Intelligence, 2016) provides a snapshot of the recent status of broadband access. Data available are number of broadband subscriptions per mobile phone subscriptions. Estimates here have been converted to the number per 100 people for regional comparisons (Figure 5.3).

Access to the Internet via a web browser on a mobile device varies across countries depending on costs, education, speeds and content (World Bank, 2012). These data estimate that in 2015 there were 34 mobile broadband subscriptions for every 100 people in the Tropics compared with 54 in the Rest of the World. Between tropical regions, there is wide variation in mobile broadband penetration with South America and South East Asia having higher uptake than global estimates. In both these regions, mobile broadband has tended to leapfrog traditional Internet access.

The lowest penetration rates occur in Central and Southern Africa, South Asia and the Caribbean. Low access rates in the Caribbean are driven largely by Cuba where government restrictions apply to mobile broadband access. Providing Internet access is much easier in urban areas, therefore countries, territories and regions with larger rural populations in Africa and South Asia have limited access to mobile broadband networks.

"Mobile phones and wireless internet end isolation, and will therefore prove to be the most transformative technology of economic development of our time."

Jeffrey Sachs, Columbia University, 2008

Image: Papua New Guinea. Mark Ziembicki

Internet Users

Household surveys are considered a more reliable means of measuring whether people are actually able to use the Internet in a meaningful way (ITU, 2016). The percentage of Internet users demonstrates that the number of people with real access to the Internet in the Tropics is much lower than the rest of the world. Although improving by 10 percentage points since 2010 to 27% in 2015, the gap between the Tropics and the rest of the world has remained wide (Figure 5.4).

The difference between the number of mobile broadband subscriptions and Internet users may be explained by the disparate sources of the data for each. Commercial suppliers provide mobile broadband data whereas the data on Internet users is estimated from household surveys. Both measures of access to mobile broadband and the Internet are not as high as they may appear because subscription data are somewhat misleading due to the inclusion of inactive subscriptions and because many people have multiple subscriptions. Consequently, the numbers may be inflated and do not accurately capture the large number of people without any access.

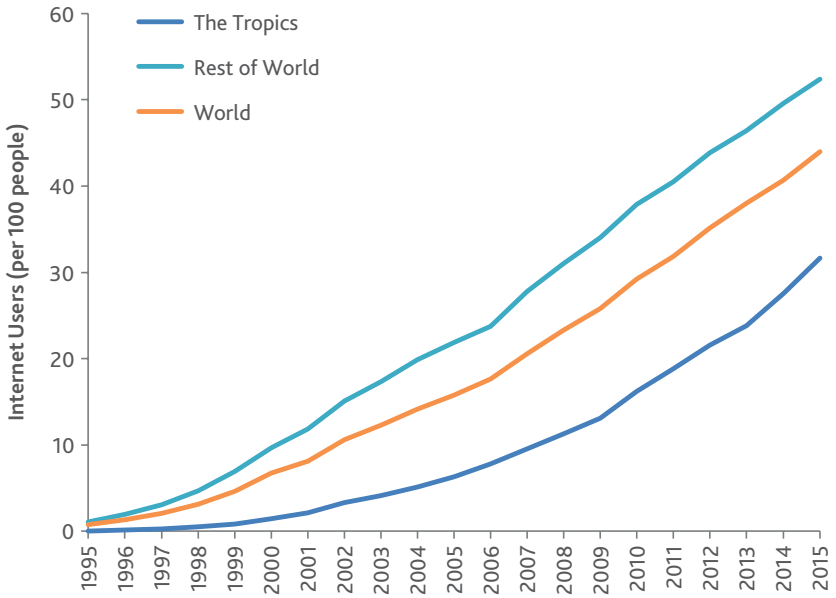


Figure 5.4 Internet Users (per 100 people) (ITU, 2016, World Bank, 2016b)

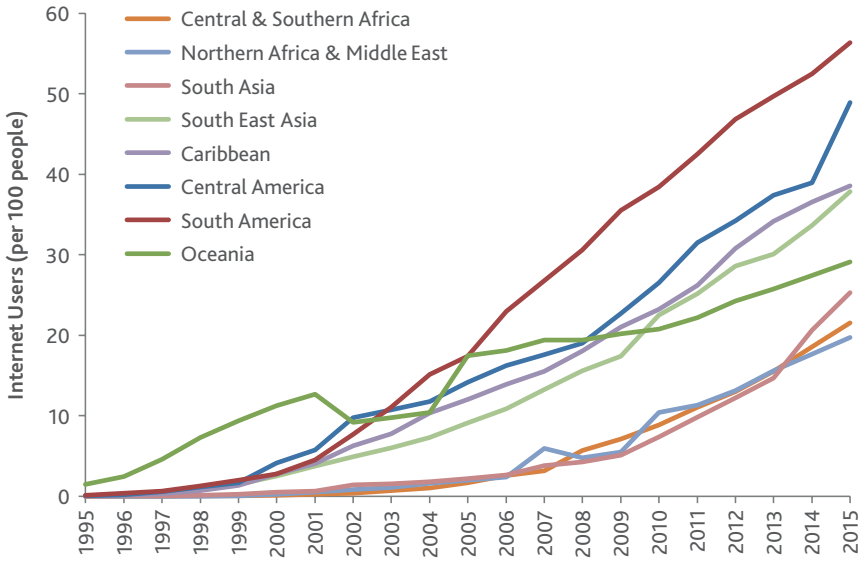


Figure 5.5 Internet Users (per 100 people) across the tropical regions (ITU, 2016, World Bank, 2016b)

Regionally within the tropics there are clear differences in how many people have access to and use the Internet (Figure 5.5). South America has the highest proportion of Internet users in the Tropics. This is largely driven by Brazil, which has relatively high rates of household Internet access alongside increasing access to mobile broadband. Although ICT infrastructure had been steadily improving in Brazil a major catalyst for recent improvements may have been due to its hosting of two major international events, including the 2014 FIFA World Cup football tournament and the 2016 Rio Olympics (Dutta and Mia, 2009). Even when including Australia and Hawaii in analyses, access in Oceania remained below 30% in 2015. Similarly, South Asia, and the tropical regions of Africa also remain very low. In most of these cases, these low rates of Internet use point not only to a lack of ICT infrastructure, but other compounding factors including unreliable energy sources and low rates of digital literacy.

Fixed broadband Internet access

Fixed line broadband internet access in the Tropics is much lower than any other form of Internet access (Figure 5.6). It generally requires more expensive and technical infrastructure but results in high speed access and the ability to send large amounts of data anywhere in the world. It is considered essential for business operations in many parts of the world, but access remains very low outside of major cities. In the Tropics, access to fixed line internet remains below 5%, three times lower than in the rest of the world. With just over 10% of the population with fixed line access South America has the highest rate in the Tropics although this is still notably lower than outside the region (Figure 5.7).

Given the rapid expansion of wireless technologies, fixed line solutions are likely to lag other forms of access to the Internet particularly in poorer nations of the Tropics. Although fixed line technologies do not have the flexibility of mobile technologies, they are more secure, more reliable and offer many more options for downloading or streaming. In wealthy nations such as the USA and Australia, mobile telephony has traditionally been seen as complementary to fixed line technologies. However, research has demonstrated that in nine African countries across all income groups, mobile telephony is seen as a substitute for fixed line broadband (Chabossou et al., 2008).

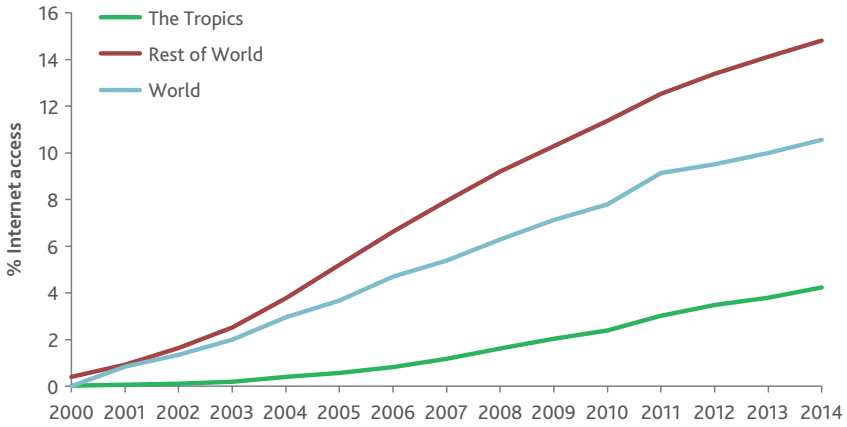


Figure 5.6 Fixed broadband Internet access (% of population) in the Tropics and the Rest of the World (ITU, 2016, World Bank, 2016b)

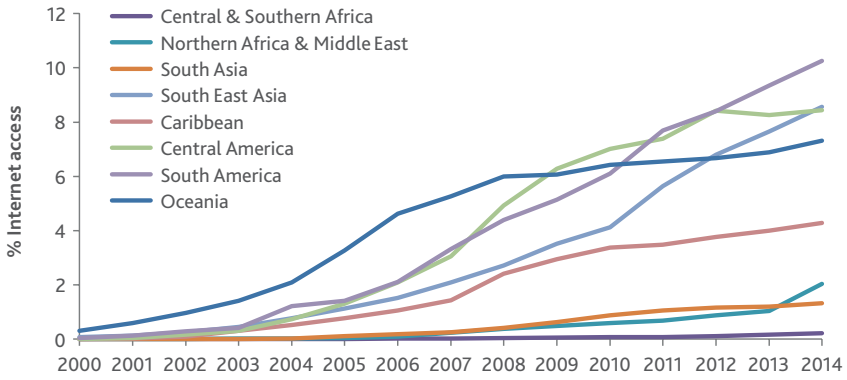


Figure 5.7 Fixed broadband internet access (% of population) across tropical regions (ITU, 2016, World Bank, 2016b)

The digital divide

Analyses presented here demonstrate that although many more people have access to the Internet than they did five years ago, access is far from universal or equitably distributed. According to the World Bank, the relative impacts of access to ICT infrastructure on global productivity, expansion of opportunity for the poor and the middle class, and the spread of accountable governance has been less than expected (World Bank, 2016c). The better educated, well connected and wealthier among us have received most of the benefits from the digital revolution. For example, 85% of the user generated content indexed by Google comes from North America and Europe, reflecting similar outputs to other knowledge producing platforms including the share of global scientific journals originating in those regions (World Bank, 2016c; State of the Tropics, 2014).

When access to the Internet data are disaggregated by income, age, gender and the urban/rural divide, the digital divide becomes even more apparent: the wealthy have more access than the poor; the young have more access than the old; men have more access than women and city dwellers have more access than people living in rural areas (World Bank, 2016c).

Barriers to Internet use and access

Distance, development and geography remain key barriers to ICT access in the Tropics. While the relative effect of geography has not yet been overcome, its influence has decreased as expensive and cumbersome infrastructure such as poles and wires are gradually replaced by mobile and satellite technology. However, in small island developing states especially, there are difficulties in extending connectivity to the outlying regions and islands (GSMA, 2015). It is often not profitable for private companies to increase their coverage and costs are too high for public investment.

While measures of ICT access are one thing the degree to which Information and Communications Technologies are actually used is another. Even when connected, the cost of accessing the technology can be prohibitive to poor communities. A significant barrier to Internet access in the Tropics is education. Many people do not access the Internet, even when it is available to them, due to a lack of technical skills and confidence. Limited digital literacy, and a lack of awareness of the potential usefulness of digital technologies remains an obstacle to adoption (World Bank, 2016c). There are also risks, both perceived and real, that technology replaces people in many industries. It is important to help people develop skills that technology complements, and not those technology replaces.

Role of the private sector

Private investment in infrastructure is an essential means for improving access to underserved populations. Until recently, the ICT sector was largely dominated by traditional land based infrastructure (poles and wires) and predominantly government owned and managed. The rise of mobile technologies has created a business environment which is now dominated by private sector ICT suppliers. Although this increases complexities relating to equity of access and governance issues, it provides opportunities for ICT firms and governments to work together to improve outcomes. In some cases communication infrastructure driven by private investment has had more success reaching underserved populations than those wholly funded by government (Kuppusamy et al., 2009, World Bank, 2016c). In those tropical nations such as Djibouti, Eritrea, and Ethiopia where the provision of mobile and Internet services remains entirely a government responsibility mobile phone penetration remains very low. In 2015, for example, Eritrea had the lowest mobile phone subscription rate in the world at 7% (World Bank, 2016c).

In rural and remote parts of the Tropics, or in small markets with limited existing infrastructure, it may not be profitable for ICT firms to invest. In many such regions, even where adequate infrastructure does exist, ICT access is simply too expensive for most people. In Chad, for example, the cost of 1 GB of data is equivalent to an average worker's monthly wage.

To promote equitable and affordable ICT access a combination of public and private investment is required. Across the tropics, on a per capita basis, the amount of private investment in ICT with a public component varies considerably with most investment occurring in South America (Figure 5.8) driven by investment in Brazil during the FIFA World Cup and Olympic games. Private investment is lowest in Oceania and Northern Africa and the Middle East. The very small market size in Oceania means that it is often not profitable for private companies to invest there even with public partnerships. In Northern Africa and Middle East much of the ICT infrastructure remains government owned and operated. Despite this, when all data around public private partnerships are examined for infrastructure development, ICT has the largest investment and number of projects in the Tropics (Figure 4.9).

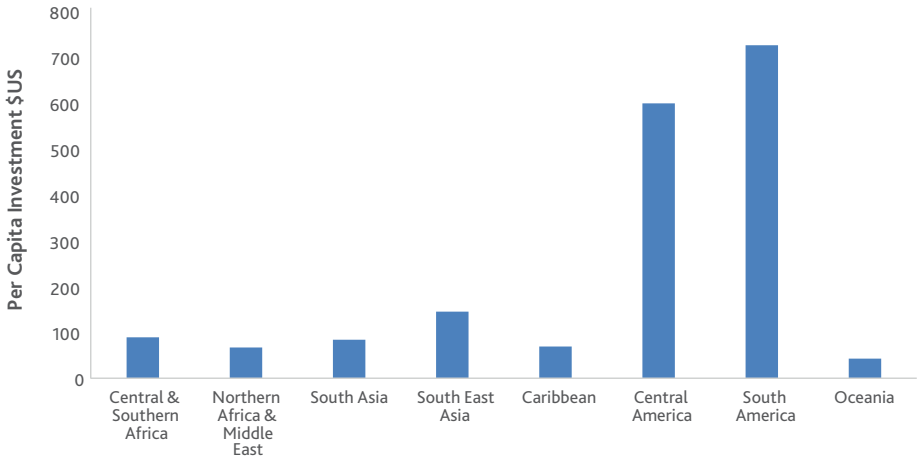


Figure 5.8 Total per capita investment ($US) in ICT projects with a public and private component between 1992-2014 according to tropical region based on 2014 population estimates (World Bank, 2016a, World Bank, 2016b)

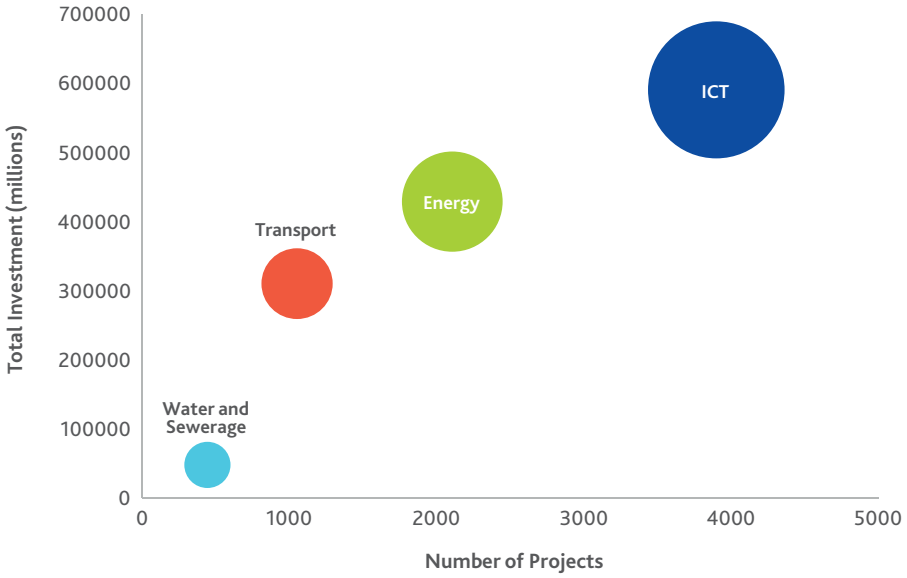


Figure 5.9 Total Investment and number of projects with both public and private investment across infrastructure sectors in the Tropics (1992 – 2014).

Relationship with other sectors

Information and communication technology has enormous potential for transforming the socio-economic condition of people and their communities, although it remains far from being realised in many regions of the tropics.

Health

Despite improvements, providing quality health care to rural and remote areas of many tropical countries and territories remains challenging. Improvements in communication infrastructure means health services can be expanded further, become more efficient, and lead to better patient outcomes. It means that many routine health services can be more efficiently delivered via mobile communication devices while also giving health professionals better access to information. Telemedicine and mobile health (m-health) can encompass: education and awareness; remote data collection; remote monitoring; communication and training; disease and epidemic outbreak tracking; and diagnostic and treatment support (Istepanaian and Zhang, 2012). In a study which surveyed mobile phone users in Africa, almost 50% of all respondents had some mobile contact with health care workers with rates as high as 83% in Rwanda and 79% in Ghana where m-health initiatives were actively promoted (James, 2014). According to the World Economic Forum, Rwanda places second out of 123 countries in how high ICT is prioritized by the government (James, 2014).

The use of such technologies for health care initiatives requires adequate training for health professionals and end users given the potential for misusing such technologies in unsafe or ineffective ways. Choosing, for example, between the many software applications developed for specific conditions such as diabetes, or other health and wellbeing applications, requires some knowledge of their relative strengths and weaknesses. Technology associated with m-health will not replace doctors and other medical professionals but if used effectively, it can complement and enhance the work they do, particularly in regions of the Tropics where travel is difficult or can be disrupted by weather or other events.

Education

ICT has the potential to transform education for children and adults across the Tropics by providing greater access to resources, and by increasing connectivity between teachers and students, and teachers and government agencies. It has the capacity to transform "Chalk and talk" pedagogies and leads to more options for post-secondary and higher education (World Bank, 2016c).

However, most products, services, usage models, expertise and research related to ICT come from high income, urban contexts in North America and Europe (World Bank, 2016c). There is evidence that solutions enabled by technology are imported and made to fit in environments that are often much more challenging. The idea that simply providing better technology in itself will improve education outcomes is considered largely false. Generally, technology is known to provide most benefit to those who have had prior exposure to it, and enjoy other privileges related to wealth and existing levels of education (World Bank, 2016c). In order for ICT to have an impact in areas of the Tropics where delivering quality education is challenging, understanding the local challenge and existing capacity in the system, as well as making sure teachers are adequately trained, much like medical staff, is important to make the most of the technology available to them.

Financial inclusion and digital currency

Not only does ICT connect people, it promotes financial inclusion particularly through mobile money. When people participate in a financial system, they are better able to start and expand businesses, invest in education, manage risk and absorb financial shocks (Cull et al., 2014). Mobile money is a service in which a mobile phone is used to access financial services. In 2014, there were an estimated 255 money services across 89 countries, including 60% of which were in developing markets (Shrier et al., 2016). It has been most successful in developing countries where few people have access to banking facilities due to high transaction costs and a lack of accessible bank branches. In tropical countries such as Cambodia, the Central African Republic and Niger, only 2-4 percent of all adults have an account at a formal financial institution (Cull et al., 2014).

A model example, M-PESA was launched just over ten years ago in Kenya (March 2007). The service allows users to deposit money into an account stored on their mobile phones using pin secured text messages. From there they can send money

Image: Quito, Ecuador. Mark Ziembicki

to friends and family, pay bills, or buy goods without having to carry cash. It does not require access to the Internet, just a basic mobile phone. Kenya now has over 18 million active subscribers and by the middle of 2016, some 7 million M-PESA accounts had also been opened in Tanzania. Although M-PESA is now one of many mobile money transfer systems operating throughout the Tropics, it is considered one of the most successful. Due to growing access to mobile phones, mobile money has effectively leapfrogged the provision of formal banking services.

Agriculture

Agriculture throughout the world is built on sharing knowledge: the best places to plant; the best seeds to use; the best market prices; local weather predictions. The agricultural sector in the Tropics is dominated by small holder farms with little access to physical infrastructure or market and extension information (State of the Tropics, 2014).

Evidence suggests that access to ICT leads to better market integration and leads to less price volatility in tropical countries (Nakasone et al., 2014). Mobile phones and Internet access can lead to greater awareness around market prices, allowing farmers to make more informed choices about when and where to sell their product. Digital technologies can also improve public extension programs, making tropical farmers more aware of ways to improve farm productivity, such as improved seed varieties, pest control and better nutrient management (World Bank, 2016c). Instead of having to visit a farmer directly, extension agents are able to use a combination of phone calls, text, videos and the Internet to reduce costs and have more frequent contact than they would otherwise have.

Looking forward

In order to reap the rewards of the digital revolution, tropical nations need to provide more than just the essential infrastructure for connection. Digital technologies have the capacity to transform business, work, education, health care and agriculture but they need the appropriate training and governance frameworks in place to ensure the best outcomes. Many tropical nations, communities and businesses are becoming more productive and better connected – even as many more still wait for the benefits of ICT to be realised.

Increasingly, largely due to its prevalence in North America and Europe, access to ICT is becoming recognized as a basic human right. In 2016, the Human Rights Council of the United Nations passed a resolution which condemns measures to intentionally prevent or disrupt access to or dissemination of information online and called on all States to refrain from and cease such measures (United Nations, 2016).

From a sustainability perspective, information and communication technology will allow people in rural and remote areas to access health care, education and other services without having to travel long distances. It also provides more options for teleworking, taking pressure off road and rail infrastructure in urban areas and reducing greenhouse gas emissions associated with travel. Although the digital revolution has not necessarily been completely realized in the Tropics, change has been rapid.– The fastest growing ICT markets are found in tropical nations (e.g. Sudan, Myanmar) while others still lag behind.

Image: Myanmar. KX Studio

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Image: Quito. Mark Ziembicki

6

HUMAN SETTLEMENTS, HEALTH AND EDUCATION

SUMMARY

- How infrastructure is planned and developed in cities will be both a central challenge and an enormous opportunity for tropical countries.
- In the Tropics, although more people still live in rural areas than in urban centres, tropical cities are growing at a faster rate. Between 1990 and 2014, the proportion of people living in a tropical city grew from 38% to 46%. By 2014, there were more than 1.4 billion people living in urban areas of the Tropics. The urban population has grown at an average of 2.3% per annum compared with 1.7% per annum globally since 1990.
- In the Tropics, more than one third of the urban population lives in a slum. The proportion of people who live in slum conditions declined slightly between 2009 and 2014 from 36% to 33% however, due to population growth in urban areas during that period, the number of people living in slum conditions in the Tropics increased from 387 million to 435 million.
- Providing secure tenure for slum dwellers is a key way tropical cities have improved conditions and driven transformation from informal to formal settlements.
- Health and education infrastructure in the Tropics lags the rest of the world
- In the Tropics there is only 1 hospital per 100,000 people compared with 1.5 in the rest of the world; fewer physicians per capita and fewer hospital beds.
- Only around half of all primary schools in the Tropics have access to electricity and it is as low as 15% in Central and Southern Africa.
- The future will be driven by cities, and tropical cities have the opportunity to be leaders in innovation and sustainability.

6

For most of human history, people have mostly lived in rural environments, however a transition to urban living has been underway since industrialisation commenced. The world's urban population exceeded the rural population for the first time in 2007 and cities are expected to absorb most global population growth between now and 2050 (Marchal et al., 2011). In the Tropics however, most of the population remains rural (State of the Tropics, 2014). Despite this, cities and conurbations in the Tropics are growing fast and face a number of challenges associated with planning, security, environment, pollution, and general wellbeing.

The development and growth of urban communities has also had adverse environmental social and health impacts – particularly when growth has not been adequately planned. For example, cities are responsible for natural habitat and biodiversity loss and the majority of global carbon emissions, while health risks in urban slums from sub-standard housing, and inadequate water and sanitation facilities are significant, and air pollution can be a major health issue.

Energy, communications, water and sanitation infrastructure as it relates to urban life have been explored in detail in previous chapters. This chapter explores the urban and human aspects of infrastructure development in the Tropics. It evaluates human settlements and communities and the capacity of those communities in terms of social infrastructure such as hospitals and schools.

International goals and agreements | **BOX 6.1**

Given the scope of this chapter: urban systems, health infrastructure and educational infrastructure,it cuts across many of the global goals for sustainable development as well as other international agreements such as the New Urban Agenda (2016). Sustainable cities and social infrastructure are essential ingredients to achieving the 2030 Agenda.

The sustainable development goals and relevant targets (United Nations, 2015) relating to this chapter include:

SDG 3: ***Ensure healthy lives and promote wellbeing for all at all ages***

- Achieve universal health coverage, including financial risk protection, access to quality health-care services and access to safe effective quality and affordable essential medicines and vaccines for all
- Support the research and development of vaccines and medicines for the communicable and non-communicable disease the primarily affect developing countries.
- Strengthen the capacity of all countries, for early warning, risk reduction and management of national and global health risks.

SDG 4: ***Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all***

- By 2030 ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes
- By 2030 ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university.
- By 2030 substantially increase the number of youth and adults who have relevant skillsm including technical and vocational skills, for employment, decent jobs and entrepreneurship
- Build and upgrade education facility that are child, disability and gender sensitive and provide safe, non-violent and effective learning environments for all.

SDG 11: ***Make cities and human settlements inclusive safe resilient and sustainable.***

- By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums.
- By 2030, provide universal access to safe, inclusive and accessible green and public spaces in particular for women and children, older persons and persons with disabilities.
- Support positive economic, social and environmental links between urban, peri-urban and rural areas for strengthening national, and regional development planning.
- Support least developed countries including through financial and technical assistance in building sustainable and resilient buildings utilizing local materials.

In 2016, world leaders officially adopted the New Urban Agenda, designed to set a new global standard on how urban centres and human communities are planned and managed.

Indicators

Urban population (% of total population) – the proportion of the population living in urban areas is often used as an indicator of how industrially advanced and prosperous a nation or region is. The process of urbanization has supported economic development in many regions of the world and estimates suggest that 80% of the world's gross domestic product is generated by urban areas. However, the development and growth of cities has also had adverse environmental, social, and health impacts – particularly when growth has not been adequately planned.

Slum population (% of urban population) – Slums are characterised by inadequate access to safe water, sanitation and other infrastructure, poor structure quality of housing, insecure residential status and overcrowding. Slums have a particular character in tropical cities and beyond the economic status of their residents, generally represent poor social and health outcomes, inequality of opportunity and lower levels of wellbeing.

Health Infrastructure (hospitals, beds, and doctors) – Health infrastructure including hospitals, hospital beds, clinics and doctors has a significant direct and positive contribution to the health outcomes of all countries. These are the building blocks

of health delivery including both the physical infrastructure (hospitals and beds) and the human capital (physicians).

Education Infrastructure (Schools with access to electricity) – As outlined in previous chapters, infrastructure such as electricity, all weather roads and access to communication technologies is important for good educational outcomes. Unfortunately, data coverage is not sufficient on the quality of school infrastructure so an indicator of access to electricity is used here. Primary schools are used here as the data has more coverage, however it is assumed that secondary schools would have an equal or higher rate of access as there are fewer secondary schools and they tend to be in larger settlements.

Trends

Urbanisation in the Tropics

In the years to 2050, the global urban population is expected to grow to 6.3 billion (United Nations, 2014). Almost 95% of this growth is expected to be in developing countries and some 60% of the increase in the Tropics (State of the Tropics, 2014). How infrastructure is planned and developed in high density human communities will be a central challenge for tropical countries, but also provides an enormous opportunity. Cities drive economic and social growth, can provide innovative ways to improve livelihoods and address health and environmental challenges.

Reported urbanisation rates – the proportion of the population living in urban areas – are often influenced by how a nation defines urban. The definition can vary significantly across nations although is usually based on factors such as population size and density, administrative boundaries or economic organisation. All nations regard settlements of 20,000 people or more as urban (consistent with the United Nations' interpretations) , though many nations classify settlements ranging in size from 500 to 20,000 as urban as well.

The world's urbanisation rate has grown rapidly since 1990, growing from 43% to 54% in 2014. During that period, the urban population grew from 2.2 billion to 3.8 billion. In the Tropics, although more people still live in rural areas than in urban centres, tropical cities are growing at a faster rate. Between 1990 and 2014, the proportion of people living in a tropical city grew from 38% to 46% (Figure 6.1). By 2014, there were more than 1.4 billion people living in urban areas of the Tropics. The urban population has grown at an average of 2.3% per annum compared with 1.7% per annum globally since 1990.

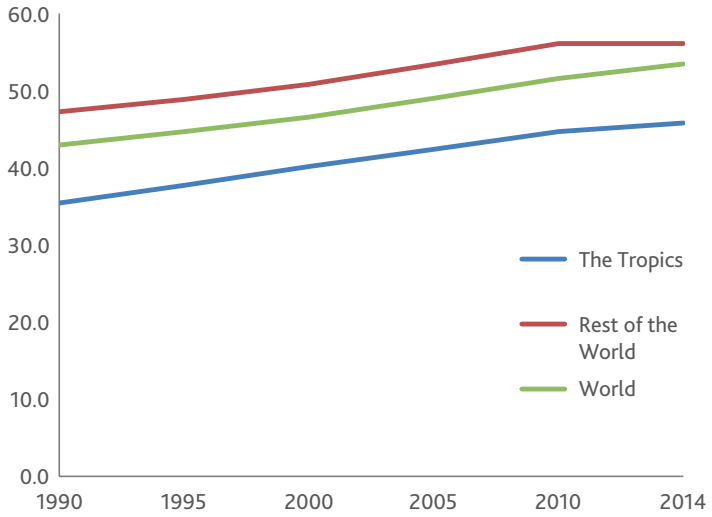

Figure 6.1 Proportion of people living in urban areas (United Nations, 2014)

In the Tropics, South America, Central America, and the Caribbean are highly urbanized with 79%, 68% and 63% of the population living in urban areas respectively in 2014. These regions consistently report urbanistion rates above global rates. There are a number of factors contributing to these high rates in Latin American and the Caribbean including consolidation of landholdings away from small holder farms, government policies favouring industrialization, and poor working conditions and wages in rural areas driving people to seek manufacturing related employment opportunities in urban areas.

Table 6.1 Urbanisation rates and urban population growth in the Tropics (United Nations, 2014)

	1990		2000		2010		2014		Av Annual Growth
	% pop	Millions	% pop	Millions	% pop	Millions	% pop	Millions	
Central and Southern Africa	20.1	101	25.1	154	29.0	239	31.4	285	**3.5%**
Northern Africa and Middle East	22.7	24	28.1	36	31.4	53	32.5	61	**3.1%**
South Asia	24.8	161	27.6	208	30.4	269	32.3	284	**1.9%**
South East Asia	24.4	177	31.7	271	40.3	364	43.9	396	**2.7%**
Caribbean	50.6	19	56.8	22	60.2	27	63.3	28	**1.4%**
Central America	57.9	60	62.2	77	65.9	93	67.7	99	**1.7%**
South America	66.0	161	72.4	205	77.9	243	79.4	255	**1.6%**
Oceania	36.3	3	34.9	3	33.7	4	33.5	4	**1.4%**

South East Asia accounted for the largest urban population growth in the Tropics. Between 1990 and 2014, urban areas grew by almost 220 million throughout tropical South East Asia. Indonesia was a major contributor to this growth with its urban population growing from around 55 million in 1990 to almost 135 million in 2014; an urbanisation rate that grew from 31% to 53%. After Brazil, Indonesia has the largest urban population in the Tropics. Most of this growth is due to rural to urban migration.

In contrast, all other regions of the Tropics remain mostly rural with an urbanisation rate of around 35%. Low rates of urbanisation are consistent with many nations having ongoing economic dependence on agriculture and other rural industries.

Slum population

Throughout the world, slums have long existed in urban settings and the basic features of slum life have changed very little since the 19th century. What has changed however is the scale of slum living and the extent of 'concentrated disadvantage' (Vlahov et al., 2007). In the 21st century, slums are no longer limited to a few thousand residents; globally more than 800 million people lived in slums in 2014, up from 650 million in 1990 (United Nations, 2014). Rapid urbanisation in developing countries (particularly tropical countries) has been a major contributor to the increase in the slum population.

Slums encompass a broad range of living situations and populations with correspondingly disparate origins and identities, making them difficult to define and survey. The available data focuses on the slum population of developing nations where most of the urban poor reside. In the Tropics, more than one third of the urban population lives in a slum. The proportion of people who live in slum conditions declined slightly between 2009 and 2014 from 36% to 33% (Figure 6.2). However due to population growth in urban areas during that period, the number of people living in slum conditions in the Tropics increased from 387 million to 435 million.

The proportion of the urban population living in slums declined across all tropical regions except for Northern Africa and Middle East, and the Caribbean. The increase in Northern Africa is driven by ongoing conflict in Sudan where more than 90% of urban dwellers continue to experience slum conditions. In the Caribbean, the catastrophic earthquake in Haiti in 2010 contributed to a rise in the proportion of people living in informal settlements. Improvement in other tropical regions has been small and in almost all regions, the actual number of people living in slums has increased. South America and Central America have been successful in reducing both the proportion and number of people living in slum conditions. Many cities in Latin America have worked on a continual program of slum upgrading which first provides security for slum dwellers and slowly improves infrastructure (sanitation, water etc.) transforming them from informal to formal settlements and suburbs.

Image: Yangon, Myanmar. Mark Ziembicki

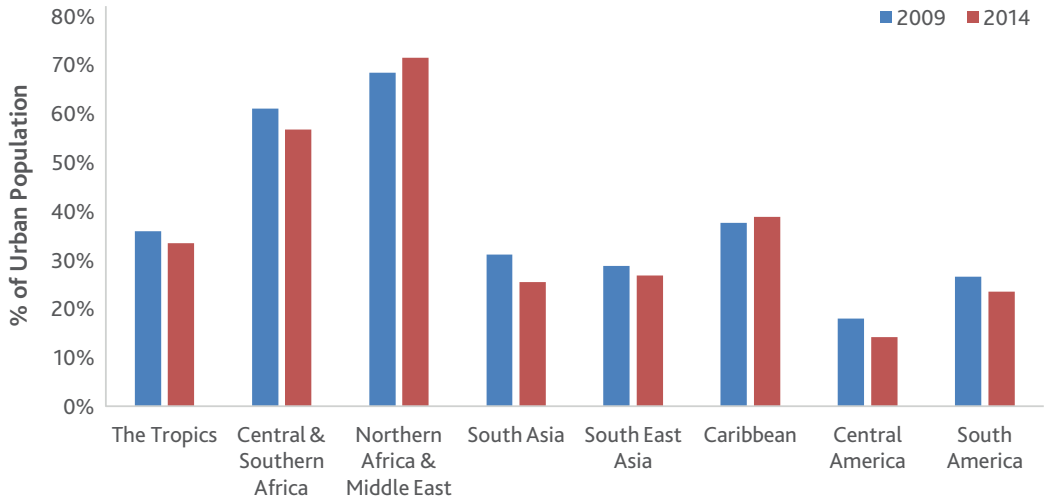

Figure 6.2 Proportion of tropical urban population living in slums 2009 and 2014 (World Bank, 2016)

Living in a slum is not necessarily always a negative or a permanent experience. Some evidence suggests that slums actually provide tremendous economic opportunities, particularly for the rural poor trying to escape subsistence-level rural poverty. Human networks and economies of scale offered by cities allow people to access more income thus improving their living conditions to either transform the slums into non-slum neighbourhoods or migrate to more formal settlements (Galiani et al., 2017).

However, slum neighbourhoods in tropical cities can be as diverse as the cities themselves. Residents of Nairobi's slum neighbourhoods are likely to be relatively well educated and employed and yet experience poorer living conditions in terms of access to infrastructure and services, quality of housing and crime rates than slum residents of Dakar who report much lower education and employment levels (Gulyani et al., 2014). One of the key differences between these two slum areas is one of tenure. In Dakar, there is a much higher level of owner-occupancy and stability, whereas in Nairobi there is high occupancy turnover (Gulyani et al., 2014). Evidence from South America suggests that providing slum dwellers with security of tenure is an important first step to transformation from an informal to a more formal settlement regardless of income (Galiani et al., 2017).

Health infrastructure

Access to health care, health care professionals and associated infrastructure will be essential for any form of sustainable development in the Tropics. Health facilities, especially hospitals, are critical assets for communities. They are important physical locations where people can get access to health professionals, medication and other health services.

Data on the number of hospitals are generally only presented for developing nations in this case, and represent only 46% of the tropical population as data are not reported for nations such as Nigeria, India, China and Brazil. Despite the data not including these large, populous tropical nations, they can still inform about the kind of health access smaller nations in the region have. Although data only covers developing countries, most of which are in the Tropics, there are more hospitals per 100,000 people in developing areas of the non-Tropics than there are in Tropics (Figure 6.3).

Across the tropical regions, Central America, driven by a high density in Mexico, has the most number of hospitals per capita. There is high demand for doctors and healthcare in Mexico given the large resident population and the fact that a significant proportion of the large Latin American population in the United States (particularly in the south) are likely to seek medical services in Mexico (De Jesus and Xiao, 2013). Lack of continuous health insurance coverage in the United States, perception of the quality of care and low English proficiency increased the likelihood of seeking health care in Mexico (De Jesus and Xiao, 2013).

Oceania appears to have quite high access, however a small population spread over a large area and many small islands means this is not neccesarily indicative of actual access to health care. For example, 2.4 hospitals per 100,000 people in Vanuatu actually means there are only 6 hospitals spread across 65 inhabited islands.

South Asia has the lowest number of hospitals per capita in the Tropics. Despite increased investment in health infrastructure in the region (particularly in India), improvement in health infrastructure outcomes have lagged other regions of the Tropics (State of the Tropics, 2014).

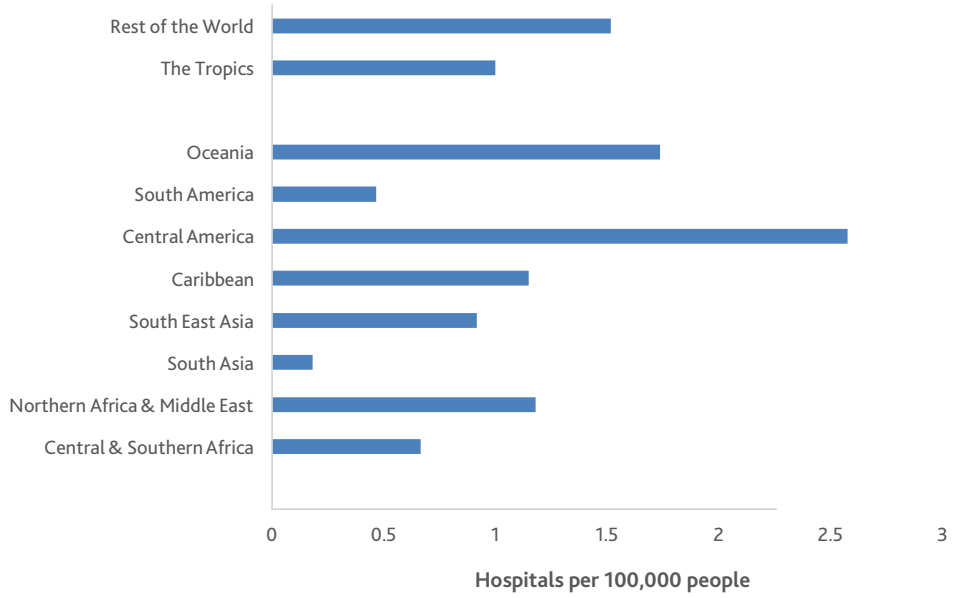

Figure 6.3 Number of hospitals per 100,000 people across the tropical regions (World Health Organisation, 2017)

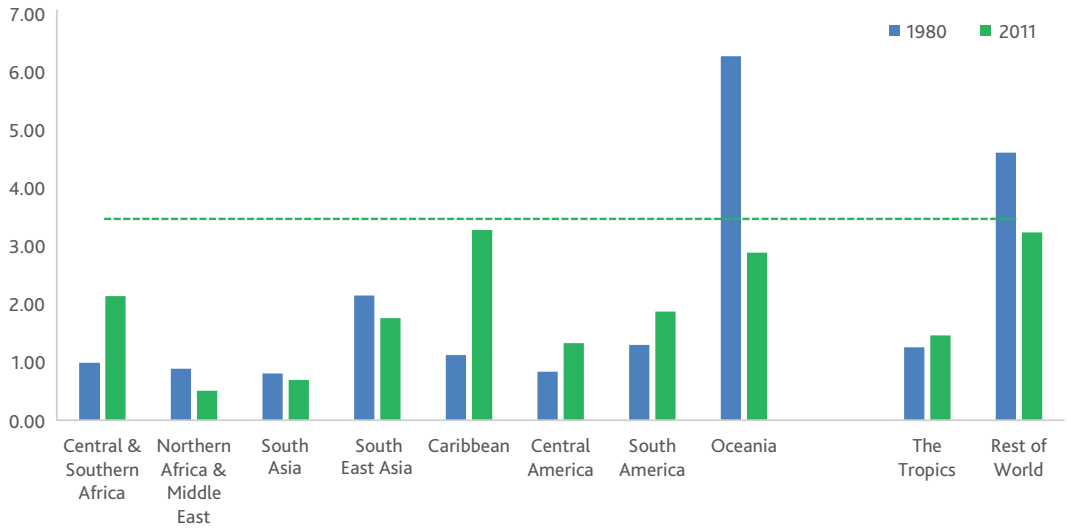

Figure 6.4 Number of hospital beds per 1000 people in the Tropics and the Rest of the World. (World Bank, 2016). The green line represents the minimum WHO recommendation (3.5 beds) for developing countries.

Perhaps a more universal indicator of accessible health infrastructure and the availability of inpatient services, is the number of hospital beds per 1000 people (Figure 6.4). Although there is no global norm for the suitable number of hospital beds per population, the World Health Organisation recommends between 3.5 and 5 beds per 1000 people. Interestingly not one tropical region reached this goal in 2011.

There is an added complicating factor in how this indicator should be interpreted however. The need for fewer hospital beds can be a reflection of an improved health care system. For example, in Australia, the number of beds per 1000 people declined from 11 in 1970 to less than 4 in 2011 – this does not reflect a lack of capacity in the health care system but an improvement in preventative health care where fewer beds are actually needed on a per capita basis. This decline in hospital beds in Australia accounted for the decline between 1980 and 2011 in Oceania.

The number of hospital beds per population also declined in Northern Africa and the Middle East, South Asia, and South East Asia; perhaps suggesting some growth in outpatient services in those regions but more likely suggest that health infrastructure development has not kept pace with population growth in those regions. The increase in Central and Southern Africa is somewhat

due to poorer data coverage in later years but is also driven by significant improvement in Ethiopia and Burundi. In South Asia the decline has been small and is inspite of a concerted effort by the Indian government to invest in heath infrastructure after the turn of the century (Gudwani et al., 2012). The large improvement in the Caribbean is driven by growth in Cuba and Barbados.

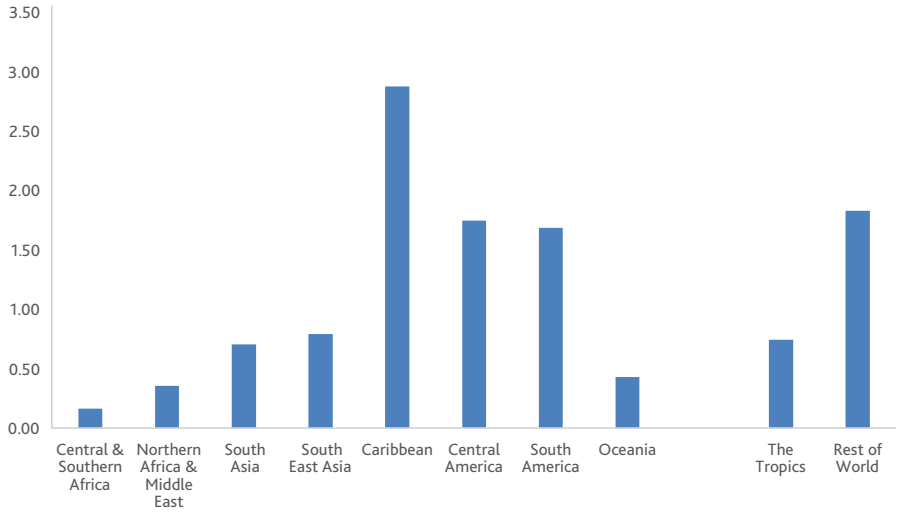

Figure 6.5 Number of physicians per 1000 people in the Tropics and the Rest of the world – latest available 2010-2014 (World Health Organisation, 2017).

The data presented here represent the latest available from the World Health Organisation ranging from 2010-2014. There are fewer physicians per population in the Tropics than the rest of the world, although there is variability between regions (Figure 6.5). Of note, Central and Southern Africa has the lowest density of doctors in the Tropics, despite experiencing the greatest health burden. The Caribbean has a very high proportion of physicians, driven by Cuba where significant investment in health care and training has been ongoing since the 1950s (Cooper et al., 2006).

Education Infrastructure

Education is the basis for successful human development. It underpins improved health outcomes and facilitates a greater range of options for employment, empowerment and freedom. Education has been a major focus globally and improvements in recent years have been rapid. Primary school education is moving closer to being universal and both youth and adult literacy have now exceeded 80% in most places. However, a number of tropical nations still lag global achievement levels. In South Asia, Central and South Africa, and Northern Africa and the Middle East adult literacy remains low at 65%; 63%, and 56% respectively (State of the Tropics, 2014).

Infrastructure in various forms provides access to education through provision of both goods and services. Indeed several studies demonstrate that enrolment increases when there is a reduction in the distance to the nearest school (Cuesta et al., 2016). However, even after that kind of access has been provided, there are other investments that could improve enrolment and the educational experience in general. In the Tropics, there is still a lack of basic infrastructure at a substantial number of schools. Many schools do not have access to electricity, or rely on unsustainable and unhealthy forms of energy such as diesel generators or firewood. Due poor data availability, the proportion of schools that have access to electricity is used here as a proxy for other important services provided by infrastructure such as water, sanitation, access to computers, and access to the Internet.

Data coverage for this indicator is poor and in some cases, probably an underestimate. These data are only available for developing countries, however it is safe to assume universal coverage for schools in wealthy countries in Europe and North America. It should be noted here these data omit large nations such as Nigeria, Kenya, Mexico, Vietnam, and China. However, according to UNDESA, some 188 million children attend schools that are not connected to any type of electricity supply (UNDESA, 2014).

When weighted by population, the available data clearly shows a deficit of electricity available to schools in the Tropics (Figure 6.6).

Image: Papua New Guinea. Mark Ziembicki.

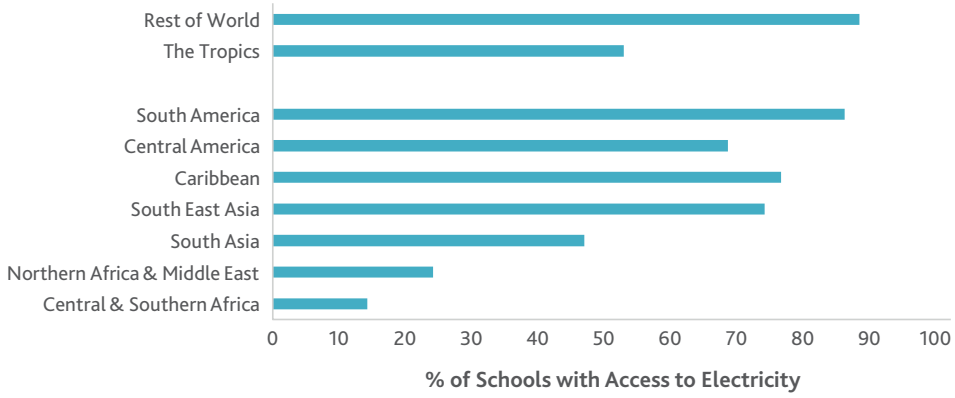

Figure 6.6 Percentage of schools from developing countries in the Tropics and the Rest of the World with access to electricity in 2012 (UNESCO, 2017). Data for Oceania are not available.

Central and Southern Africa has the lowest rates of access at less than 15% and includes nations where almost no schools have access to electricity such as Uganda (1.5%), Guinea (2.1%), and Niger (3.5%). The only countries in Central and Southern Africa with universal coverage are the island nations of Mauritius and Seychelles. In all other nations in the region where data is available, coverage is less than 50%. The situation is similar in Northern Africa and Middle East where the only nation with universal coverage is Saudi Arabia. Coverage is slightly higher in South Asia, Central America, Caribbean, South East Asia and South America but remains far from universal.

Electricity provides a number of benefits to the classroom. Lighting allows classes to be taught early in the morning and later at night; it facilitates use of a bundle of ICT technologies including telephones, televisions, computers, projectors, printers, copy machines and importantly, the Internet. There is evidence to suggest that access to electricity is correlated with improvements on both test scores and graduation rates (UNDESA, 2014).

Additionally, poor school infrastructure has an effect on teachers as well as students (Skelton, 2014). A school without electricity or sanitation for students will usually have no electricity or

sanitation for teachers either. If the roof leaks, everyone gets wet. There is evidence to suggest this has a substantial impact on teacher retention which is an ongoing challenge in areas where educational attainment is low (UNDESA, 2014).

Sustainable Cities and the New Urban Agenda in the Tropics

In 2016, world leaders adopted the New Urban Agenda (NUA) which sets a new global standard for sustainable urban development. The New Urban Agenda extensively commits to a range of initiatives to promote sustainable, equitable and transparent planning for human settlements globally (United Nations, 2016). In the NUA, leaders have committed to:

- Provide basic services for all citizens
- Ensure that all citizens have access to equal opportunity and face no discrimination
- Promote measures that support cleaner cities
- Strengthen resilience in cities to reduce the risk and the impact of disasters
- Take action to address climate change by reducing their greenhouse gas emissions
- Fully respect the rights of refugees, migrants and internally displaced persons regardless of their migration status
- Improve connectivity and support innovative and green initiatives
- Promote safe, accessible and green public spaces

This Agenda aims to promote safer, greener and more inclusive cities while maintaining cities as global drivers of economic growth. This Agenda is ambitious and will be a challenge for many tropical cities where basic services such as electricity, water, sanitation and waste management are far from universal.

Green space in tropical cities

Urban landscapes are complex, consisting of buildings, residential areas, streets, and business districts. In many cases these physical structures are interspersed with the open space of parks, playgrounds and sportsfields. These "green spaces" (see also Box 1.2) are considered vital aspects of urban living, promoting physical activity, psychological wellbeing, and general public health (Wolch et al., 2014).

Urban green spaces can also be a cost effective tool in climate change adaptation (Govindarajulu, 2014). Importantly from a tropical perspective, green spaces help reduce heat island effects, can act as buffers in case of extreme events such as floods and can act as natural storm water drains. There has been very little research on urban green spaces in tropical cities despite the valuable role it can play. Global data are not available to provide an in depth assessment the current status of green spaces in tropical cities, however it is likely to vary considerably. For example in Singapore, it is estimated that 47% of area is devoted to parks and gardens (BOP Consulting, 2017), whereas in India it ranges from almost none in Kolkata and Mumbai up to almost 50% in the planned city of Chandigarh (Govindarajulu, 2014). In the Tropics however, these green spaces are not always organized parks and gardens but in some cases can be complex jungle ecosystems within city borders not necessarily always publically owned (Yusof, 2013).

When nations and city develop rapidly, the role of green space is often undervalued – trees are removed to make way for highways and building; biodiverse wetlands are redeveloped; and parks are paved to create parking space. An additional challenge for tropical cities is that growing use of indoor climate control promotes a more internal lifestyle and green spaces are valued less, when in fact, a city with more green spaces requires less air conditioning (Saw et al., 2015).

Looking forward

Although existing and future megacities will be vital in ensuring a sustainable future for the Tropics, some of the best opportunities for future sustainable urban development are to be found in small to medium sized cities. Although they are transforming fast, their growth patterns can still be influenced (UN Habitat, 2015). Secondary cities are particularly important in the Tropics as they provide services to agricultural hubs, and act as centres for trade and education.

Given one third of all urban dwellers in the Tropics live in slum conditions, to date attention has focused on the immediate problems arising from rapid urbanisation such as how to accommodate the poor and generate employment. A key challenge for the future and to ensure these settlements have a sustainable future is to provide more security, particularly in terms of tenure and ownership. Additionally, planning will require input from other disciplines including agencies responsible for environmental, transport, energy, and economic and social development policy.

The manner in which tropical cities are managed in the coming decades will influence patterns of economic growth, settlement and the social and political stability of the Tropics. How cities grow will also influence the extent of environmental impacts and health outcomes for urban residents.

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9

HOUSING THE INFORMAL ECONOMY IN TANZANIA

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Key Messages

- Economic development is often riddled with problems, especially when stakeholders share different objectives initially. Tanzania is a developing country in the Tropics with 75-85 per cent of its population involved in the informal economy – an economic system based mostly on casual employment, kinship and social relations rather than contractual arrangements.
- Tanzania certainly has its share of physical infrastructure development challenges for this informal sector. Using the Managerial Flow Model in three market infrastructure projects, we reveal apparent gaps at the start of the policy implementation: planning, governance, selection, coordination & integration, and finally knowledge & communication.
- The managerial flow model is a useful consideration for any programme and policy implementation. We discover that managerial gaps can be closed at the beginning of the policy intervention or after implementation through an iterative revision process. However, if the managerial gaps are not closed at the onset of the project(s), poorer assets may be created, which may delay a successful implementation.

Tropical Context

Since the informal economy rose to prominence in the 1970s, its role in Africa's economic development has been much debated. The informal sector consists of 'units engaged in the production of goods and services with the primary objective of generating employment and incomes to the persons involved and which operate at a low level of organization, with little or no division between labour and capital as factors of production and on a small scale; labor relations – where they exist – are based mostly on casual employment, kinship or personal and social relations rather than contractual arrangements with formal guarantees'(Marquez, 1990). The significance of the informal economy is more pronounced in quite pronounced in tropical countries. For example, the non-agricultural employment share of the informal workforce is 78% in Africa, 57% in Latin America and Caribbean and 45-85% in different parts of Asia (Becker, 2004).

The Tanzanian economy largely depends on agriculture, where agriculture makes up a quarter of its GDP. It is estimated that the size of the Tanzanian informal sector is significantly large. Thirty-four percent of the people for whom informal sector work is a main activity are in rural areas. The main activity in rural areas is agriculture, thus rather than trying to "merely "formalise" the informal sector, one needs to realize that the most significant obstacle to growth in informal sector is the lack of access to the formal economy.

The 2006 Integrated Labour Force Survey (Tanzania National Bureau of Statistics, 2006) earlier suggested that of those employed in the wholesale and retail trade in Tanzania, 57.5 per cent were operating in the informal sector. About 21.6 percent of the informal sector operators were in manufacturing. The latest report, in 2014, suggested that three-quarters of paid and self-employed employees in non-agriculture sectors have informal employment (75.9 percent) (Tanzania National Bureau of Statistics, 2014). Hence, the informal economy changed little in the decade to 2014 in Tanzania.

Sustained economic growth and employment are critical for development and poverty alleviation (Mijiyawa, 2008). The role of Tanzania's informal economy in this regard is significant: it creates incomes and employment (Becker, 2004). Given the significance of informal sector in Tanzania as an employment generator, the public sector must assist the informal sector. In the last two decades, a number of municipal governments in Tanzania have invested in the construction of market infrastructures to house these informal business activities in the city of Dar es Salaam. This is an attempt to enhance economic growth to alleviate poverty and achieve decent work conditions.

Earlier research by (Melyoki, 2012) was conducted on three interesting physical infrastructures to house the informal economy: the Makumbusho and Urafiki market facilities in the Kinondoni Municipality and Temeke Sterio Market in the Temeke Municipality.

The Temeke Stereo Market, located in Temeke Municipality, was completed in 1999. The municipal authority forced wholesalers of agricultural produce from a nearby informal market setting to shift their activities to this facility and discouraged road-side hawking. The market facility became fully used by about 1,000 hawkers and kiosk operators.

On the other hand, the Urafiki Market located in Kinondoni Municipal (completed in 2004) lured only about 600 hawkers who had been operating along one of the roads leading into the City. The Urafiki facility was active before 2011 but started to decline. The Municipal Council finally demolished the facility in March 2011. The site had been given back to central government but its hawkers' fate remained unclear as TShs 400 milion (approx US$ 250,000) worth of goods had been lost by these hawkers.

Another project, the Makumbusho Market infrastructure located in Kinondoni Municipal was launched in 1997, with similar objectives as Temeke. However, the hawkers had not been consulted during construction of phase nor had a situation analysis been undertaken to identify their needs. Upon completion, rent was higher than originally set, and allocation of space went to people not originally intended. The irony was hawkers who had previously operated near that site were not allocated space. This caused these hawkers to resort to trading by the roadsides and in their homes.

These attempts to support the informal sector and sustain economic development in Tanzania with new physical infrastructure had mixed results. A number of gaps were observed in the project implementation at the local level, but the seriousness of the gaps varied. The cases highlighted that managerial gaps were responsible for the policy failure.

Background to the project

Brought together through the Academy of Management Public and Nonprofit Division's Professional Development Workshops for two consecutive years (in 2010 and 2011), several contributors have developed a model to analyze efforts to foster economic development. The managerial flow model that was developed identified fives issues that might surface during the implementation of public programs: (i) planning; (ii) governance; (iii) selection; (iv) coordination and integration; and (v) communication and knowledge (See Box CS 8.1).

Managerial Gaps	Box CS9.1

Planning Gaps emerge when public programs are defined on the basis of short-term expectations (Malecki, 1984, Rubin and Zorn, 1985), current fashions (Hospers et al., 2009), "announcement effects" or solely to allocate financial resources that otherwise could be diverted towards other policies or programs. Consequently they lack a meaningful definition of performance indicators.

Governance Gaps refer to problems when multiple public agencies and stakeholders work together, with different mandates and without a common goal; thus bringing overlapping initiatives and confusion over roles, responsibility and accountability (Ansell, 2000, Ansell and Gash, 2008).

Selection Gaps emerge when resources and efforts, scarcer that ever, are allocated without appropriateness under the fairness illusion. The gap also emerges from the difficulties in designing coherent projects to be supported or funded and monitored. This is particularly true with reference to entrepreneurship programs(Malecki, 1984, Rubin and Zorn, 1985).

Coordination & Integration Gaps arise due to a lack of leadership, reciprocity, legitimacy and trust in the interorganizational activities reduce the integration of public and private financial and human resources(Ansell, 2000, O'Toole Jr, 1997).

Communication & Knowledge Gaps arise due to asymmetric information flow and reciprocal knowledge gaps that push players to operate on different wavelengths, focusing only on their own silos (O'Toole Jr, 1995).

We argue that the managerial flow is a process where key actions can generate assets that could be considered an enabler aimed at achieving results. When carried out by different local actors and using context and stakeholder analyses, managerial actions, carried out by different local actors, could be represented by careful context and stakeholder analyses, and the execution of actions that are useful to reach a win-win situation. Managerial assets can be regarded as the awareness and useful knowledge generated about the problems and then possible solutions to make credible and convincing decisions.

Figure CS9.1 Managerial Feedback Mechanism (Kuah, 2012)

Kuah (2012) demonstrated the relationship between managerial actions and assets forming a virtual cycle. This is because well-considered managerial actions can create endowment or assets. Having strong assets can enhance and support further managerial initiatives, interventions and actions. Local public authorities can therefore adopt a robust process to create milestones or enablers aimed at achieving superior results using this model. More broadly, public managers must first be able to identify what assets exist and what actions will be necessary in building further assets. This is tantamount to the managerial feedback mechanism supporting managerial flows shown in Figure CS9.1.

Successes/failures

Four apparent gaps were observed at the start of the policy implementation in the Temeke Stereo Market: planning; governance; coordination; and communications and knowledge. When the Temeke Municipal Council realised that the facility was not being fully utiliwed, it held consultations with hawkers to discuss the root-cause; a process that closed up of gaps of communication and knowledge. The planning gap was gradually reduced through a revision of the market facility design as a result of feedbacks and improved knowledge. The governance gap was closed when both the Municipal and the hawkers began to work together towards a common goal in revitalizing the market facility. The different roles of the stakeholders became clearer as coordination increased. The Temeke case revealed that policy implementation may be a continuous process with different rounds or cycles based on outcomes obtained in each round. However, this process depends on the continuous communication between the key stakeholders involved, their readiness to learn, and undertake additional managerial actions.

The gaps for Makumbusho and Urafiki markets were also very similar. The lack of managerial actions led to absence of managerial assets, causing non-closure of some gaps in turn. For instance, there had not been any clear context analysis by stakeholders in both cases to identify the needs of hawkers in terms of what the facility should look like (in Makumbusho) or to identify the appropriate strategy to deal with the fact that the construction of the facility was being done on a land that had already been allocated for other public uses (in Urafiki). Consequently, the managerial gaps of planning, governance, coordination, and communication and knowledge were not addressed. The result was that the facilities developed in both cases could not achieve their intended results. Although the possibility in closing the gaps might be possible like in the Temeke case, the clear lack of communication, readiness to learn and commitment to undertake additional managerial actions prevented the closing of the managerial gaps in Makumbusho and Urafiki.

Lessons learned

A number of gaps were observed in the physical infrastructure projects implemented at the local level, but the seriousness of the gaps varied. We found evidence that managerial gaps can be closed at the beginning of the policy intervention or after implementation through a revision process(Kuah and Vecchi, 2012). There were identifiable managerial gaps in all five areas of the managerial flow, as seen in Table CS9.1. During the early stages of the project implementation, poor managerial actions result in poor assets created.

Table CS8.1 reveals managerial gaps could easily be avoided or minimised with consideration of the managerial flow model: in planning, governance, selection, coordination & integration, and finally knowledge & communication. If the managerial gaps are not closed at the onset of the project(s), poor assets may be created from the concomitant managerial actions; policy intervention is doomed to fail. Closing of the managerial gaps may therefore happen at the beginning of intervention or at later stage after the intervention has been implemented, as seen from the three cases.

With more physical infrastructure projects being implemented by Tanzania and other developing countries, it is imperative that public programmes do bear in mind stakeholders engagement and proper context analysis. We argue that the managerial flow process supports gap identification; appropriate managerial actions do generate managerial assets – an enabler at achieving results. However, the model cannot give an indication on the maximum number of gaps that can exist without affecting the success of a policy intervention.

Table CS9.1: Managerial Feedback Mechanism

		Planning	Governance	Selection	Coordination & Integration	Knowledge & Communication
Tanzanian Local Government Authorities	**Gaps**	Absence of shared vision, knowledge of issues and concerns of hawkers. Lack of consultation and consensus on the means to address the issue. Short-termism and without long-term plans/ vision	The Municipal Council(s) and hawkers' leadership were not established. Hawkers seen as a menace by the city rather than entrepreneurs needing support	Selection criteria not properly defined or considered. Allocation of stalls within the constructed facilities went to the wrong people in Makumbusho.	Absence of clear arrangements among the stakeholders & on the roles played by actors in realizing the project outcomes Led to accusations and counter accusations in Urafiki.	Absence of communications by local authorities and feedback from key constituencies i.e. Hawkers
	Actions	**Poor:** Immediate actions to construct physical infrastructure & allocate stalls within the facilities.	Discouraged hawking activities in the neighborhood of the constructed facilities.	**Poor:** Allocation of stalls to hawkers through an opaque and non-transparent arrangements not understood by stakeholders	**Poor:** Designed the facilities (stalls) without soliciting views of the hawkers who were the beneficiaries	**Poor:** Absence of timely & clear response from authorities to address the concerns of the hawkers
	Assets	**Poor:** Decisions were based on generalized popular opinions of policy makers & bureaucrats	**Poor:** Violent instruments deployed to force hawkers to shift from one place to another & to discourage hawkers from operating in unofficial places.	Learned that initial allocation of stalls was improper & revised the process (by involving stakeholders – hawkers) leading to better allocation	Learned that the initial design did not meet the needs of hawkers and hence modified it to incorporate hawkers inputs	Learned that the issues of developing infrastructure to support informal economy was complex and needed higher level government involvement

Source: Adapted from (Martin et al., 2012)

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Image: Singapore Skyline at night. Mark Ziembicki.

10

HOUSING A NATION: SINGAPORE'S HOUSING AND DEVELOPMENT BOARD

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Key Messages

- Singapore's public housing program can be described as one of the pillars of the nation's economic success story. Through long term planning and commitments by politicians/bureaucrats, the majority of Singaporeans now live in high quality public housing.
- The public residential suburbs concept of Singapore highlights a successful whole government approach to executing an urban development Concept Plan that optimises the use of limited land in a tiny country with limited natural resources.
- Although such an achievement may not be easily replicated in other developing tropical cities, it can nonetheless provide the following lessons on how to:
  - implement sustainable housing development & urban planning policies;
  - create a social cohesion policy where different ethnic groups are integrated through a public housing program; and
  - enhance social mobility through home ownership.

Tropical Context

The rapid pace of urbanisation in developing nations, including the ones that lie in the tropics, is staggering. According to a United Nations, Department of Economic Social Affairs report (2014), by 2050 2.5 billion people will be added to the world's urban population due to continuing population growth and urbanization with nearly 90 percent of this increase taking place in Asia and Africa.

As a result of rapid urbanization, a greater proportion of the world's urban population are living in urban tropical agglomerations[1] (Norris, 2014). Of the 1.5 billion people residing in locations with at least one million people, 35 percent are in tropical agglomerations such as Mexico City, Mumbai, Kolkata, Rio de Janeiro, Manila, Lagos, Guangzhou, Kinshasa, Shenzhen, Jakarta and Lima.

It takes effective policies and funding to properly house these growing urban cities. Attempts have been made by many governments to provide housing for its rising urban population but due to factors like corrupt administrations, poor planning and lack of political will; many attempts have not achieved its full potential.

Like most post-World War 2 decolonised nations in the tropical world, in the middle of last century, Singapore was lacking in every aspect of socio-economic development. However, Singapore's highly successful public housing policy has managed to provide almost every eligible person in the country with a roof over their head. This was done through the implementation of a robust land acquisition policy, detailed urban development Concept Plan[2], land reclamation projects (to acquire land from the country's shoreline) and smart home ownership policy that allows home buyers to access their social security/pension fund to cover the monthly mortgage.

Although Singapore's public housing success may never be successfully replicated in other parts of the tropical world, the 50 years of experience amassed by the Housing and Development Board (HDB) to provide universal public housing in Singapore provides a strong case study for the world to learn from.

Background

Before the Housing and Development Board (HDB) was established in 1960, the majority of the population had resided in overcrowded shophouses and urban ghettos with poor sanitation systems and inadequate fresh water supply. Such squalid living conditions, coupled with an inadequate provision of primary healthcare, triggered frequent epidemics (Tong & Narayan, 2015). Singapore's first generation leaders recognised the need to address this severe public health issue by tackling it, in tandem, with the country's public housing and environmental health concerns.

Armed with powers to acquire land for the building of public housing projects under the 1967 Land Acquisition Act, the HDB became arguably the most powerful property developer in Singapore over the years (Yuen, 2002). The HDB has the mission

1. According to Norris (2014), the United Nations define urban agglomeration as "large cities that do not necessarily conform to city boundaries". A single large urban agglomeration may comprise several cities or towns and their sub-urban fringes.

2. The Singapore urban redevelopment Concept Plan is a strategic land use and transportation plan that guides Singapore's development over the next 40-50 years. The plan is reviewed every ten years to ensure that land in tiny Singapore is well managed to meet long-term population and economic growth needs while providing a good quality living environment for its populace. The very first Concept Plan was developed in 1971 with the aid of experts from the United Nations Development Programme.

Figure CS10.1 Traditional housing styles, Singapore. Graeme Churchard.

Figure CS10.2 Toa Payoh, 1976. Housing Development Board

to build as many low-cost housing units as possible, meant initially for rental bythe low-income groups, but today's HDB lends itself to build high quality, affordable, high-rise homes. It has also implemented a home ownership scheme that which has improved the social capital and economic standing of Singaporeans (Wong & Yap, 2003).

Between 1960 and 1965, HDB's built 53,777 housing units mainly for rental (Teo & Huang, 1996). By 1969, HDB completed the construction of its first 100,000 flats[3]. Housing designs were initially kept simple and functional, comprising slab blocks comprising of 1 to 3 bedroom flats which were provided with rudimentary amenities such as piped water and electricity. Ancillary services such as wet markets, shops, recreation facilities (eg. cinemas and playgrounds), bus interchanges (bus ports) and schools were embedded in every housing estate.

When the country's public housing crisis was surmounted in the 1970s, the HDB began to move away from the "Fordist mass production system" (Wong & Yap, 2003 pp. 368) to build homes with quality finish and enhanced fittings (e.g. building bigger flats with more bedrooms andadding attached bathroomand additional bathroomsinmaster bedroom). HDB also began to work earnestly with other government agencies and private sector organisations to include sports facilities (eg. football stadiums and swimming pools), rail network and stations, green spaces and landscape parks, and, shopping malls. In the 1980s, about 85 percent of the population were living in HDB homes.

In keeping with its developed nation status, the 1990s saw the HDB designing homes to meet the aspirations of a more affluent and better-educated generation of home owners. Not only are HDB flats built higher (as high as 50 floors) with eye catching architecture, home buyers are now allowed to pick the design and colour of their floor tiles, doors and other common fittings. Integrated structures combining community, commercial and sporting facilities are being built to provide a hub for residents to shop, play and do essential transactions.

Figure CS10.3 Modern high rise living by HDB

As it moves into the 21st century, HDB began to pilot initiatives such as Smart HDB Town Framework[4] to leverage information and communication technology, and the HDB Greenprint to create a sustainable living environment[5]. Better lifestyle facilities

3. All statistics relating to HDB in this paper was extracted from A Chance of a Lifetime: Lee Kuan Yew and the Physical Transformation of Singapore (2016), published by Centre for Liveable Cities and Lee Kuan Yew Centre for Innovative Cities.

4. As part of HDB's "Smart HDB Town Framework" which was announced in 2014, new HDB towns will be designed using computer simulation and data analytics, complex systems modelling tools will be used to better integrate the use of new technologies (eg. solar energy, LED lighting, rainwater harvesting, pneumatic waste collection and vertical greenery). Smart technology will also be adopted to better manage energy usage in every home, develop elderly alert system to ensure of safety elderly relatives at home and install sensor activated lighting system in common areas.

5. The HDB Greenprint projects aims to introduce energy-efficient, water management, and waste management features into HDB housing estates. HDB towns will have enhanced greenery through the provision of green roofs and vertical greenery so as to lower down the surface temperature of residential buildings. An "eco-living" concept is also being promoted by setting aside more cycling tracks and installing bicycle parking racks to promote green commuting and encourage residents to interact in green spaces.

will be introduced through such smart and eco-towns programs where natural features such as waterways and greeneries greenery are integrated in the design of new housing estates to create luxurious waterfront and resort living environments.

Older HDB housing estates have not been neglected tooeither. Residents of HDB neighbourhoods that were built between the 1960s and 1980s are regularly consulted for ideas to rejuvenate their residential areas under the Estate Renewal Strategy[6]. Through such upgrading programs, older residential neighbourhoods have been transformed with modern facilities and amenities akin to the ones that are being constructed in new housing estates.

Successes/failures

With detailed planning and concerted effort on the part of the government, Singapore had managed to solve its critical urban housing woes in a few decades. There is now no evidence of any squatter informal settlements in Singaporenow as people were resettled by 1985 (Liu and Chua, 2016). Now more than 86 percent of the population lives in HDB flats[7] and the home ownership rate of HDB residents is 93 percent.

In the last 10 years, HDB has won several notable international awards[8] for its success in providing homes for the masses universal home access. In a 2014 survey conducted by the Institute of Public Studies to study the perception of Singapore's history, the formation of HDB was ranked as one of the 10 in the top ten of events most important to Singaporeans[9].
Singapore's public housing policy is also a study of social cohesion in multi-ethnic and multi-religious Singapore. Where in theIn colonial days, the various ethnic groups were living within distinct ethnic enclaves, however the policy of public home ownership dictates that every HDB housing estates must have a balanced mix of Singapore's major ethnic groups. This Ethnic Integration Policy has been successful in promoting a harmonious society where the various ethnic groups in Singapore learn to forge an even greater socio-economic outcome for this small island nation.

At 7,829 per square kilometer of land area[10], Singapore is one of the most densely populated nations in the world. However largely through the government's integrated housing policy, effective community policing strategy adopted by the Singapore Police Force, and community activity programs organised by the People's Association[11], Singapore's public housing estates are notcrime infested and racially divided urbanghettoshave low crime rates with no racial divides.

Lessons learned

It takes political will, resolute leadership and more than one government agency to execute an effective public housing policy. For a successful public housing project to take shape, various branches of the public service must work together to ensure a fruitful outcome. In the case of Singapore, HDB does the planning and builds the homes. However, in providing various other physical amenities such as roads, train networks, schools, parks, neighbourhood police posts and community centres, the HBD HDB has toworks closely with itspull in its counterparts from other agencies to build the relevant infrastructure and to deliver services.

This whole of government approach has been the hallmark of the Singapore public housing program and something which has to

6. Among others, the HDB Estate Renewal Strategy involves the retrofitting of flats, modernise town centres, installing lifts that stop of all floors, upgrading communal facilities, and enhancing road and transportation networks in the older housing estates.
7. The rest of the population lived in private developments and landed properties

8. Notable recent international awards include (source: HDB website www.hdb.gov.sg/cs/infoweb/about-us/achievements-and-accolades/achievements/past-achievements):

The Pinnacle@Duxton was bestowed as one of the "Best Tall Buildings" for 2010 by the Council on Tall Buildings and Urban Habitat (CTBUH). This award recognises noteworthy projects across four geographical regions (Americas, Asia & Australasia, Europe, and Middle East & Africa) that have outstanding design with technical innovations, exhibit sustainable attributes, and provide enhancement to both the cities and the lives of their inhabitants.

Awarded the UN-Habitat Scroll of Honour in 2010 "for providing one of Asia's and the world's greenest, cleanest and most socially conscious housing programmes".

Awarded the United Nations Public Service Award (UNSPA) for its Home Ownership Programme in June 2008. "The UNPSA is one of the most prestigious international awards for excellence in public service, and HDB is the only winner in the Asian region among 12 worldwide".

9. In this IPS study, "respondents were taken through a list of 50 historical events – from the founding of modern Singapore in 1819 to the last general election in 2011 – and asked if they were aware of the event". Source: http://lkyspp.nus.edu.sg/ips/news/ips-study-on-perceptions-of-singapores-history and http://lkyspp.nus.edu.sg/ips/wp-content/uploads/sites/2/2013/04/CNA_Pioneers-lauded-ahead-of-HDBs-55th-birthday_310115.pdf.

10. Source World Bank – http://data.worldbank.org/indicator/EN.POP.DNST

11. People's Association (PA) is a government statutory board that promotes racial harmony and social cohesion in Singapore. It organizes various programs and activities catering to Singaporeans from all walks of life with the purpose of connecting people to people, and people and government. PA operates over 100 Community Clubs and five Community Development Councils all located within HDB housing estates.

be looked intocan provide learnings forby any city administrator who is eager to learn from the Singapore experience.

Urban planning is not just about providing a roof over someone's headshelter for all. It entails proper allocation of industrial

and business precincts too. With proper execution of an urban development plan, local and foreign investors will be encouraged to sink their investmentsinvest in a location that can sustain a high level of physical and social infrastructure development. Continued improvement in Singapore's urban planning has not only provided better access to jobs, but also improved the property price of their HDB homes. This has helped to enhance social mobility of people living in this tiny island nation.

The government has used home ownership as one of the main agenda to pursuethe centre of its nation building objectives (Tan & Naidu, 2014). By effectively solving the housing crisis and

allowing its populace to own homes, the people believe that they have a stake in the country's developmentand are willing to defend the country. In the process, they endear themselves to the government and help to ensure the political survival of the ruling party. This encourages support for the government.

This whole of government approach to developing a sound public housing policy may prove to be a sustainable system to tackling a major issue relating to rapid urbanization. By working with a cohesive group of public administrators as opposed to a disjointed one, funding agencies like the World Bank may find it less cumbersome to provide policy advice and other forms of technical assistance surrounding public housing matters.

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Image: Cambodia. Mark Ziembicki

11

FOOD LADDER – FEEDING FOOD SECURITY

Kelly McJannett, Food Ladder

"You can't build a peaceful world on empty stomachs and human misery."

Norman Ernest Borlaug Nobel Laureate.

We are currently at 7.2 billion people on Earth, 1 billion of whom are hungry and undernourished, with severe food insecurity. The global food system is already fragile and failing, crop yields are stagnating, within 6 of the last 11 years we consumed more food globally than we produced. By 2050 the world population will reach 9 billion and we will need to increase food production by 60% to meet this increased need, under conditions much more challenging than those we are already experiencing.

We have the technology to make vast improvements to this situation already and we need to deploy these now, widely and with great urgency and commitment, particularly in light of rising fuel and energy prices, increases in severe weather events caused by climate change leading to further food shortages, and the rising population.

Food insecurity impacts on all facets of social order and life quality, without focusing on and correcting this inequality billions of dollars more will be spent on correcting the flow on impacts of extreme poverty and hunger. Aside from the more obvious mortality, health and education impacts, civic unrest and conflicts also arise from hunger. The French revolution was ignited from rises in the cost of bread and more recently the Arab Spring was sparked by people hungry in the streets.

Food Ladder has committed all our efforts entirely to focus on improving the Food crisis, we recognize and understand that to secure food impacts positively on a vast array of other social goals both in the short and long term. Consistent ongoing access to nutritious food is sustainability at it's very core. Food is a foundation for life.

Food Ladder is an award winning not-for-profit organisation that creates social enterprises to address food security in disadvantaged communities internationally and in remote communities in Australia. For the past 5 years Food Ladder has been usingi ts model of social business to create economic development and health outcomes concurrently with its custom designed hydroponic systems that grow commercial quantities of vegetables in places where itis impossible to grow food or there is limited access to food.

Food Ladder is a highly replicable model which has had a steep trajectory of both growth and impact.

Food Ladder has implemented its food security systems on the rooftops of village schools across India that are today feeding over 4,000 impoverished children who would otherwise have no access to nutritious vegetables. In remote tropical Australia, Food Ladder has also implemented its food security solution in Katherine in the Northern Territory and Ramingining in Arnhem Land, ensuring secure access to local, delicious produce for the communities. All Food Ladder systems are operated as viable and sustainable social enterprises. Finally, since its inception, Food Ladder has collectively employed over 600 disadvantaged people.

From the Australian perspective, Food Ladder has created a proven model to address food security in remote Indigenous communities which is securing fresh, locally grown produce for the first time in decades, engaging individuals in the growing of produce using sustainable technologies and educating children on the long-term health benefits of nutrition. The unquantifiable benefits also include the community's pride and sense of achievement through the projects which are proving to change attitudes around healthy eating as well.

Because Food Ladder works on a model of collaboration with in-community partners, Food Ladder also creates off take agreements with the local stores in communities, buying directly from the Food Ladder social enterprises to reduce freight costs and creating micro economic development, mitigating the issues of 'food miles' and ensure a fresher product for sale to community.

From enhancing school nutrition programs to providing meaningful work for Community Development Program (CDP) participants, Food Ladder creates a symbiotic relationship with important existing initiatives already operating in remote communities.

Food Ladder is a proven model to address food security in remote communities which is providing fresh, locally grown produce for the first time in decades, engaging individuals in the growing of produce using sustainable technologies and educating children on the long-term health benefits of nutrition. The benefits also include the community's pride and sense of achievement through the projects which are proving to change attitudes around healthy eating.

Food Ladder and ALPA in Ramingining

Arnhem Land was once a net exporter into Darwin of locally grown produce and locally caught fish, and many Yolngu people today remember farming and there is a deep desire to return to this and harvest their own produce and be self-sustaining in this area once again. This project has helped the community to overcome a variety of barriers such as zoning and water restrictions, enabling them to begin rebuilding one of their historical primary industries and creating new employment and educational opportunities in an innovative and efficient manner.

Many market garden projects modelling on the style of farming previously practiced in Arnhem Land have launched and failed. The Arnhem Land Progress Aboriginal Corporation (ALPA) had analysed and addressed the reasons for these previous failures early in the project development phase. ALPA chose the proven Food Ladder system because it operates in some of the worlds harshest climates, can overcome labour and water inefficiencies and has robust governance structures as an organisation.

By selecting the Food Ladder system ALPA has reduced costs associated with procuring food for the community and ensured local access to fresh produce. Food Ladder has eradicated massive water inefficiencies in the traditional market garden model thanks to its closed loop hydroponic system. This system is the only one of its kind operating successfully in remote Indigenous Australian communities.

- Seed funding was provided to build a 18m x 4.5m Food Ladder commercial hydroponic system in Ramingining to grow fresh produce for sale locally
- This is the same award winning system which have been built in Katherine and across India where it has proven to be 5 times more efficient than traditional agriculture.
- The greenhouse took a year to plan, 4 weeks to build and was completed August 29th 2016 with the first harvest occurring just 5 weeks later in early November 2016.
- The Ramingining greenhouse is 100% Indigenous owned and is governed by a triumvirate of three Indigenous businesses, Dinybulu Regional Services pty Ltd, Rulku Enterprises pty Ltd and ALPA.
- This Indigenous owned social enterprise is building the local economy through the introduction of a primary industry venture and creating sustainable Indigenous employment. This horizontal integration is further building in more sustainable local Indigenous jobs into the ALPA supply chain.
- The Greenhouse provides employment on a casual basis, with harvest and planting crews of up to 7 depending on harvest size, coming from a pool of 17 trained workers, this allows Yolngu to engage in meaningful work while allowing the labour pool to self- organise and flex to fit with times of cultural obligations and responsibilities for different members of the group. This a culturally conscious and respectful employment model.
- A hosting arrangement with CDP also allows the space to be used for training, Charles Darwin University (CDU) will be delivering a certificate 11 in rural operations with the

greenhouse as a practical teaching example, beginning next February and delivering to 15 CDP participants who will then be able to seek work in the greenhouse in Ramingining or elsewhere if they choose.

- Central to the success of the business is the sale of fresh produce in community, ALPA has embedded health education and healthy produce promotion deeply in the project to grow market demand in this socially responsible business model. There is much research showing that when children are involved in growing produce that they are more likely to eat it. The local school children have planted the first seeds, returned to inspect the germination process and participated in the first harvest.
- ALPA is aligning health and nutrition training through our full-time nutritionist, providing recipes with harvest to assist local Indigenous people to explore new vegetables and gain nutritional knowledge to support their own health and that of their families
- This initial greenhouse is a proof of concept to successfully trial, refine and perfect the organisation of harvests, staffing and delivery of produce into the store in a timely manner. ALPA will continue to investigate opportunities to replicate this model for locally producing food on a larger commercial scale across the other 25 ALPA sites to further ensure food security for remote Indigenous communities.

Nutritionists in Ramingining have recorded a 5% increase in the sale and consumption of fruit and vegetables since the Food Ladder system has been implemented. This is the only increase of note, and of such scale, in living memory. It is quantifiable evidence that Food Ladder is changing behavioural patterns in remote Indigenous communities among a demographic whom, with a limited amount of funds available to them each week to buy food, are choosing fresh and nutritious produce over other options.

Image: Myanmar. Mark Ziembicki

APPENDIX

Appendix 1: Regions and nations of the tropics

The geographic area that is the Tropics is clearly defined as the region between the Tropics of Cancer and Capricorn. However, national borders do not neatly align with these lines and there are a number of nations and territories which straddle the zone.

To determine which nations and territories to include in this analysis used the same two processes developed for the State of the Tropics 2014 Report. The first uses a population-based decision tool to assess whether nations partially in the Tropics be included in the Report, and the second reviews data availability to assess whether sufficient data are available to warrant a nation's inclusion in the Report. Excluded nations account for 0.1% of the tropical population.

Tropical nations to be included in the analysis, arranged by region and population estimated in 2015
**tropical population only*

REGION/Nation	Population (000s)
CENTRAL AND SOUTHERN AFRICA	**803,294**
Angola	25 022
Benin	10 880
Botswana	2 262
Burkina Faso	18 106
Burundi	11 179
Cameroon	23 344
Cape Verde	521
Central African Republic	4 900
Comoros	788
Democratic Republic of the Congo	77 267
Congo	4 620
Cote d'Ivoire	22 702
Equatorial Guinea	845
Ethiopia	99 391
Gabon	1 725
Gambia	1 991
Ghana	27 410
Guinea	12 609
Guinea-Bissau	1 844
Kenya	46 050
Liberia	4 503
Madagascar	24 235
Malawi	17 215
Mauritius	1 273
Mozambique	27 978
Namibia	2 459
Nigeria	182 202
Rwanda	11 610
Sao Tome and Principe	190
Seychelles	96
Sierra Leone	6 453
Tanzania	53 470
Togo	7 305
Uganda	39 032
Zambia	16 212
Zimbabwe	15 603
NORTHERN AFRICAL AND MIDDLE EAST	**179,982**
Djibouti	888
Chad	14 037
Eritrea	5 228
Mali	17 600
Mauritania	4 068
Niger	19 899
Saudi Arabia*	12 940
Senegal	15 129
Somalia	10 787
South Sudan	12 340
Sudan	40 235
Yemen	26 832
SOUTH ASIA	**832,332**
Bangladesh*	58 829
India*	752 424
Maldives	364
Sri Lanka	20 715
SOUTH EAST ASIA	**803,435**
Brunei Darussalam	423
Cambodia	15 578
China*	162 069
China, Hong Kong SAR	7 288
China, Macao SAR	588
Indonesia	257 564
Lao People's Democratic Republic	6 802
Malaysia	30 331
Myanmar	53 897
Philippines	100 699
Singapore	5 604
Thailand	67 959
Timor-Leste	1 185
Vietnam	93 448

REGION/Nation	Population (000s)
CARRIBBEAN	**41,264**
Antigua and Barbuda	92
Barbados	284
Cuba	11 390
Dominica	73
Dominican Republic	10 528
Haiti	10 711
Jamaica	2 793
Puerto Rico	3 683
Saint Kitts and Nevis	56
Saint Lucia	185
Saint Vincent and the Grenadines	109
Trinidad and Tobago	1 360
CENTRAL AMERICA	**144,625**
Belize	359
Costa Rica	4 808
El Salvador	6 127
Guatemala	16 343
Honduras	8 075
Mexico*	98 903
Nicaragua	6 082
Panama	3 929
SOUTH AMERICA	**316,808**
Bolivia	10 725
Brazil*	177 916
Colombia	48 229
Ecuador	16 144
Guyana	767
Peru	31 377
Suriname	543
Venezuela	31 108
OCEANIA	**13,275**
Australia*	1 354
Fiji	892
French Polynesia	283
Kiribati	112
Marshall Islands	53
Micronesia (Fed. States of)	104
New Caledonia	263
Palau	21
Papua New Guinea	7 619
Samoa	193
Solomon Islands	584
Tonga	106
Tuvalu	10
United States of America*	1 414
Vanuatu	265

For large straddling nations, subnational regions to be included in the analysis

AUSTRALIA		
Queensland	Western Australia	Northern Territory
Central West	Kimberley	
Far North	Pilbara	
Fitzroy		
Mackay		
Northern		
North West		
BANGLADESH		
Barisal	Chittagong	Kulna
BRAZIL		
Acre	Goias	Pernambuco
Alagoas	Maranhoa	Rio de Janeiro
Amapa	Mato Grosso	Rio Grande di Norte
Amazonas	Mato Grosso do Sul	Rondonia
Bahia	Minas Gerais	Roraima
Ceara	Para	Sao Paulo
Distrito Federal	Paraiba	Sergipe
Espirito Santo	Piaui	Tocantins
CHINA		
Guangdong	Guangxi	Hainan
INDIA		
Andaman & Nicobar Islands	Gujarat	Mizoram
Andhra Pradesh	Jharkhand	Orrisa
Chhattisgarh	Karnataka	Pondicherry
Dadra & Nagar Haveli	Kerala	Tamil Nadu
Damon	Lakshadweep	West Bengal
Dui	Madhya Pradesh	
Goa	Maharashtra	
MEXICO		
Aguascalientes	Jalisco	Quintana Roo
Campeche	Mexico	San Luis Potosi
Chiapas	Michoacan	Tabasco
Colima	Morelos	Tlazcala
Federal District	Nayarit	Veracruz
Guanajuato	Oaxaca	Yucatan
Guerrero (Warrior)	Puebla	Zacatecas
Hidalgo (Noble)	Queretaro	
SAUDI ARABIA		
Asir	Jizan	Najran
Baha	Makkah	
UNITED STATES		
Hawaii		

Acronyms

AAI	Airport Authority of India
AAPA	American Association of Port Authorities
ADB	Asian Development Bank
APEC	Asia Pacific Economic Cooperation
ATA	Alternative Technology Association
AU-NEPAD	African Union – New Partnership for Africa's Development
BITRE	Bureau of Infrastructure, Transport and Regional Economics (Australia)
CAAC	China Civil Aviation
CBD	Convention on Biological Diversity
CDC	Center for Disease Control and Prevention
CFS	Committee on World Food Security
CIA	Central Intelligence Agency (USA)
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
DFAT	Department of Foreign Affairs and Trade (Australia)
ECOSOC	United Nations Economic and Social Council
EIA	Energy Information Administration (USA)
EPA	Environmental Protection Authority (USA)
FAA	Federal Aviation Administration
FAO	Food and Agricultural Organisations of the United Nations
FIVAS	Association for International Water Studies (Norway)
GACA	General Authority of Civil Aviation (Saudi Arabia)
GBRMPA	Great Barrier Reef Marine Park Authority (Australia)
GSMA	Global System for Mobile Communications
HEI	Hedley Environmental Index
HK EPD	Hong Kong Environmental Protection Department
IAACA	International Association of Anti-Corruption Authorities
IAEA	International Atomic Energy Agency
IBGE	Instituto Brasileiro de Geografia e Estatística
IBRD	International Bank for Reconstruction and Development
ICAO	International Civil Aviation Organization
IEA	International Energy Agency
IFAD	International Fund for Agricultural Emergency
IFPRI	International Food Policy Research Institute
IHC	International Housing Commission
IIDEA	International Institute for Democracy and Electoral Assistances
ILO	International Labour Organisation
IMF	International Monetary Fund
INEGI	Instituto Nacional de Estadística y Geografía (Mexico)
IPA	Indian Port Authority
IPCC	Intergovernmental Panel on Climate Change
IPU	Inter-Parliamentary Union
ITC	International Trade Centre
ITIF	Information Technology and Innovation Foundation
ITU	International Telecommunication Union
IUCN	International Union for the Conservation of Nature
MDG	Millennium Development Goals
MEA	Millennium Ecosystem Assessment
NASA	National Aeronautics and Space Administration (USA)
NHMRC	National Health and Medical Research Council (Australia)
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
OECD	Organisation for Economic Co-operation and Development
OTA	Office of Technology Assessment, United States Congress
SDG	Sustainable Development Goals
SPC	Secretariat of the Pacific Community
UN	United Nations
UN AIDS	Joint United Nations Programme of HIV/AIDS
UN CCD	United Nations Convention to Combat Desertification
UN DESA	United Nations Department of Economic and Social Affairs
UN ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UN HABITAT	United Nations Human Settlements Programme
UN REDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation
UN WTO	United Nations World Tourism Organisation
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Scientific, Educational and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
UNGEI	United Nations Girls Education Initiative
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children's Fund
UNIFEM	United Nations Development Fund for Women

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